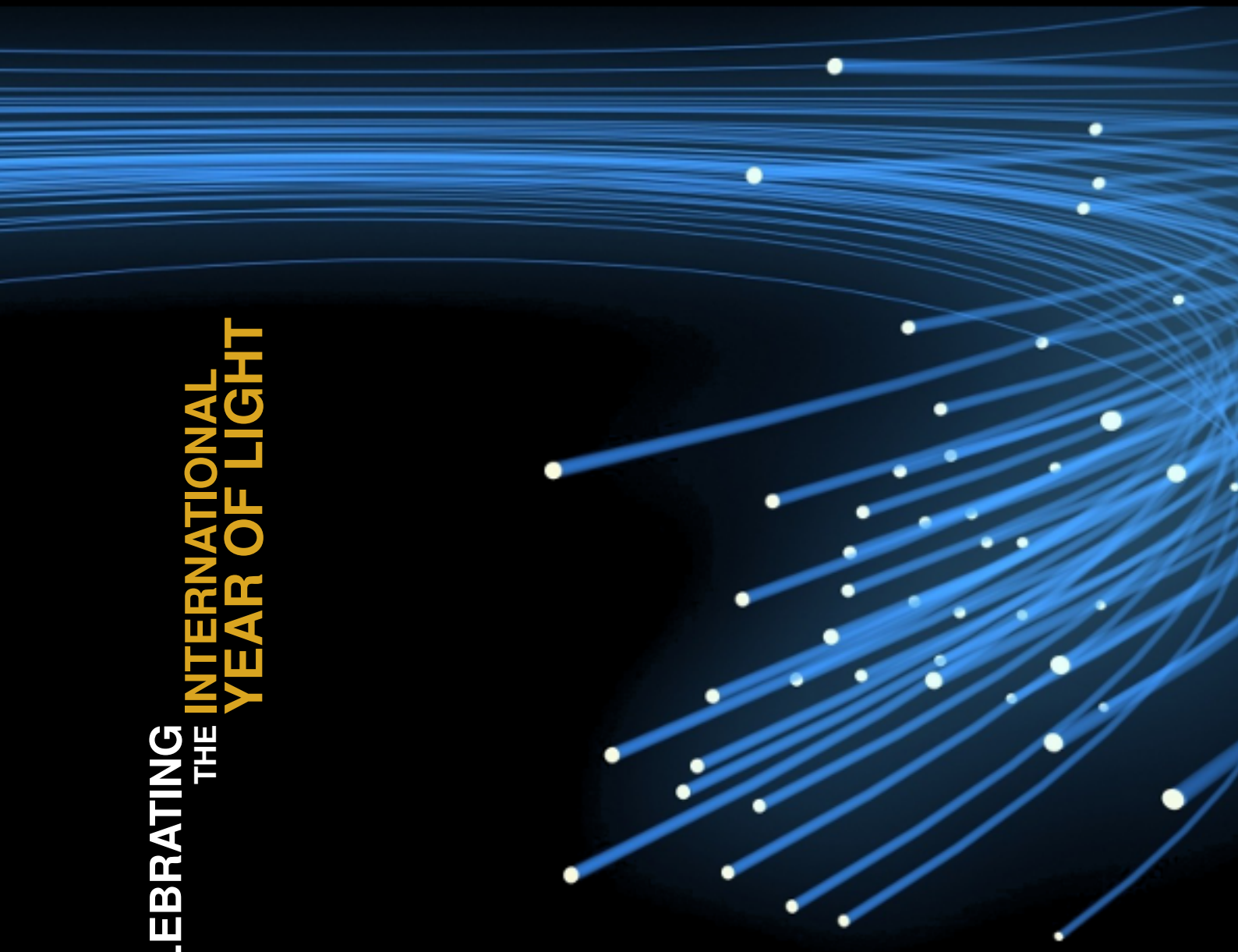
META'15 New York - USA

The 6th International Conference on Metamaterials, Photonic Crystals and Plasmonics



CELEBRATING THE INTERNATIONAL YEAR OF LIGHT

Program

August 4 – 7, 2015
New York, USA

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The 6th International Conference on Metamaterials, Photonic Crystals and Plasmonics

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Edited by

Said Zouhdi | Paris-Sud University, France
Vinod M. Menon | City College of New York, USA

CONTENTS

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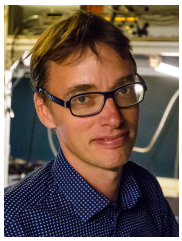

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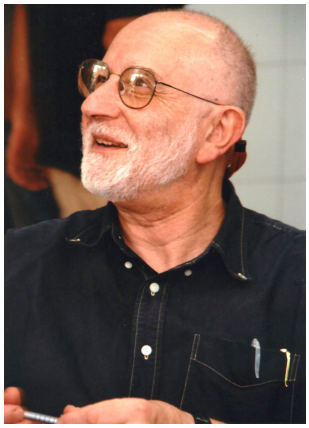


Sir Michael Berry

University of Bristol, UK

The singularities of light : intensity, phase, polarization

Sir Michael Berry, is a world-renowned physicist famous for the discovery of geometric phase called the Berry's effects in quantum mechanics ; He specializes in semiclassical physics (asymptotic physics, quantum chaos) applied to wave phenomena in quantum mechanics and other areas such as optics. He received his Ph.D. degree in theoretical physics from St. Andrews in 1965. Since 1967, he has been at the University of Bristol, first as a postdoctoral fellow, then Lecturer and then Reader before becoming Professor in 1979.
Among his many honors, Professor Berry became a member of the Royal Society of London in 1982, a Fellow of Royal Society of Arts in 1983, and a Fellow of the Royal Institution in 1986. He also became a member of the Royal Society of Sciences in Uppsala, Sweden in 1986 as well as a member of the European Academy in 1989. In 1990, he received the Julius Edgar Lilienfeld prize from the American Physical Society and the Paul Dirac medal and prize from the Institute of Physics. He then won the Naylor Prize from the London Mathematical Society in 1993. In 1995, he became a Foreign Member of the National Academy of Sciences in the United States. In 1996, he became a Knight Bachelor. Professor Berry won the Kapitsa Medal from the Russian Academy of Sciences in 1997 and the Wolf Prize in Physics in 1998. In 2000, he became a member of the Royal Netherlands Academy of Arts and Sciences. Also in 2000, Michael shared the Ig Nobel Prize in Physics with Andre Geim for their work on "The Physics of Flying Frogs". In 2005, he became a Fellow of the Royal Society of Edinburgh and, also in 2005, he won the Polya Prize from the London Mathematical Society.

Federico Capasso

Harvard University, USA

From Achromatic Flat Optics to Disordered Metasurfaces with Functional Connectivity

Federico Capasso, is the Robert Wallace Professor of Applied Physics at Harvard University, which he joined in 2003 after 27 years at Bell Labs where he was Member of Technical Staff, Department Head and Vice President for Physical Research. He is visiting professor at NTU with both the School of Physical and Mathematical Sciences and Electrical and Electronic Engineering. His research has focused on nanoscale science and technology encompassing a broad range of topics. He pioneered band-structure engineering of semiconductor nanostructures and devices, invented and first demonstrated the quantum cascade laser and investigated QED forces including the first measurement of a repulsive Casimir force. His most recent contributions are new plasmonic devices and flat optics based on metasurfaces. He is a member of the National Academy of Sciences, the National Academy of Engineering, the American Academy of Arts and Sciences. His awards include the King Faisal Prize, the IEEE Edison Medal, the SPIE Gold Medal, the American Physical Society Arthur Schawlow Prize in Laser Science, the Jan Czochralski Award for lifetime achievements in Materials Science, the IEEE Sarnoff Award in Electronics, the Materials Research Society Medal, the Wetherill Medal of the Franklin Institute, the Rank Prize in Optoelectronics, the Optical Society Wood Prize, the Berthold Leibinger Future Prize, the Julius Springer Prize in Applied Physics, the European Physical Society Quantum Electronics Prize.

Nader Engheta

University of Pennsylvania, USA

Metaplatforms

Nader Engheta, is the H. Nedwill Ramsey Professor at the University of Pennsylvania in Philadelphia, with affiliations in the Departments of Electrical and Systems Engineering, Bioengineering, Physics and Astronomy, and Materials Science and Engineering. He received his B.S. degree from the University of Tehran, and his M.S and Ph.D. degrees from Caltech. Selected as one of the Scientific American Magazine 50 Leaders in Science and Technology in 2006 for developing the concept of optical lumped nano-circuits, he is a Guggenheim Fellow, an IEEE Third Millennium Medalist, a Fellow of IEEE, American Physical Society (APS), Optical Society of America (OSA), American Association for the Advancement of Science (AAAS), and SPIE-The International Society for Optical Engineering, and the recipient of numerous awards for his research including 2014 Balthasar van der Pol Gold Medal from the International Union of Radio Science (URSI), 2013 Benjamin Franklin Key Award, 2013 Inaugural SINA Award in Engineering, 2012 IEEE Electromagnetics Award, 2008 George H. Heilmeier Award for Excellence in Research, the Fulbright Naples Chair Award, NSF Presidential Young Investigator award, the UPS Foundation Distinguished Educator term Chair, and several teaching awards including the Christian F. and Mary R. Lindback Foundation Award, S. Reid Warren, Jr. Award and W. M. Keck Foundation Award. His current research activities span a broad range of areas including nanophotonics, metamaterials, nano-scale optics, graphene optics, imaging and sensing inspired by eyes of animal species, optical nanoengineering, microwave and optical antennas, and engineering and physics of fields and waves. He has co-edited (with R. W. Ziolkowski) the book entitled "Metamaterials : Physics and Engineering Explorations" by Wiley-IEEE Press, 2006. He was the Chair of the Gordon Research Conference on Plasmonics in June 2012.

Claire Gmachl

Princeton University, USA

Quantum Cascade lasers and applications in mid-infrared photonics

Claire F. Gmachl, is the Eugene Higgins Professor of Electrical Engineering at Princeton University. She is best known for her work in the development of quantum cascade lasers. earned her M.Sc. in Physics from the University of Innsbruck in 1991. She went on to receive her Ph.D. in Electrical Engineering from the Technical University of Vienna in 1995, graduating sub auspiciis Praesidentis (with special honors by the president of the Austrian republic). Her studies focused on integrated optical modulators and tunable surface-emitting lasers in the near infrared. From 1996 to 1998, she was a Post-Doctoral Member of Technical Staff at Bell Laboratories. In 1998, she became a formal Member of Technical Staff at Bell Labs and in 2002 she was named a Distinguished Member of Technical Staff, in part due to her work on the development of the quantum cascade laser. In 2003, she left Bell Labs and took a position as Associate Professor in the Department of Electrical Engineering at Princeton University, where she is currently working as a full Professor since 2007. In 2004, Popular Science named Gmachl in its "Class of 2004 - Brilliant 10," its list of the 10 most promising scientists under 40. She went on, in September 2005, to win the MacArthur Foundation's "genius grant." Recently, she was named the director of the new Mid-InfraRed Technologies for Health and the Environment (MIRTHE) Center, funded by the National Science Foundation. Although Gmachl originally intended to study theoretical applied mathematics, her interest soon turned to theoretical applied physics, and, with the encouragement of an advisor, experimental sciences. As such, she works in the fields of optics and semiconductor laser technology. Gmachl has conceived several novel designs for solid-state lasers and her work has led to advances in the development of quantum cascade lasers.

Atac Imamoglu

Swiss Federal Institute of Technology in Zurich (ETHZ), Switzerland

Spin-photon quantum interface

Atac Imamoglu, is a graduate of Middle East Technical University, Turkey, in electrical engineering. He got his Ph.D. in electrical engineering from Stanford. He did post-doctoral work on atomic and molecular physics at Harvard. In 1993, he joined the Electrical and Computer Engineering Department of University of California, Santa Barbara. In 1999, he became a professor of electrical engineering and physics. In 2001 he moved to the University of Stuttgart in Germany. Since 2002, he has been working at ETHZ (Swiss Federal Institute of Technology), Switzerland, where he is heading the research group on Quantum Photonics. His group at ETHZ investigates quantum optics of solid-state zero-dimensional emitters, such as quantum dots or defects, embedded in photonic nano-structures. He received the Charles Townes Award of the Optical Society of America in 2010, Quantum Electronics Award of IEEE in 2009, the Muhammed Dahleh Award of UCSB in 2006, the Wolfgang Paul Award of the Humboldt Foundation in 2002, the TUBITAK prize for physics in 2001, David and Lucile Packard Fellowship in 1996, and NSF Career Award in 1995. He is a member of the Scientific Advisory Committee at the IMDEA Nanoscience Institute. He is a fellow of the American Physical Society, of the Optical Society of America and the Turkish National Academy of Sciences.

Mikhail D. Lukin

Harvard University, USA

New Interface Between Quantum Optics and Nanoscience

Mikhail Lukin received the Ph.D. degree from Texas AM University in 1998. He was a post-doctoral fellow at the Institute for Theoretical Atomic and Molecular Physics at Harvard University from 1998-2001. He joined the faculty of Harvard Physics Department as an Assistant Professor in 2001 and has been a Professor of Physics at Harvard since 2004. He is a fellow of the Optical Society of America. His research interests include quantum optics, quantum control of atomic and nanoscale solid-state systems, quantum dynamics of many-body systems and quantum information science. He has co-authored over 150 technical papers and has received a number of awards, including Alfred P. Sloan Fellowship, David and Lucile Packard Fellowship for Science and Engineering, NSF Career Award, Adolph Lomb Medal of the Optical Society of America (2000) and AAAS Newcomb Cleveland Prize.

Vladimir Shalaev

Purdue University, USA

New material platform for plasmonics

Vladimir (Vlad) M. Shalaev, Scientific Director for Nanophotonics in Birck Nanotechnology Center and Distinguished Professor of Electrical and Computer Engineering at Purdue University, specializes in nanophotonics, plasmonics, and optical metamaterials. Vlad Shalaev received several awards for his research in the field of nanophotonics and metamaterials, including the Max Born Award of the Optical Society of America for his pioneering contributions to the field of optical metamaterials, the Willis E. Lamb Award for Laser Science and Quantum Optics, the UNESCO Medal for the development of nanosciences and nanotechnologies, and the OSA and SPIE Joseph W. Goodman Book Writing Award. He is a Fellow of the IEEE, APS, SPIE, and OSA. Prof. Shalaev authored three books, twenty-six invited book chapters and over 400 research publications.

Nikolay Zheludev

Southampton University, UK & NTU, Singapore

Using metamaterials for optical switching

Nikolay Zheludev, directs the Centre for Photonics Metamaterials at Southampton University, UK and the Centre for Disruptive Photonic Technologies at Nanyang Technological University, Singapore. His personal awards include Senior Professorships of the Engineering and Physical Sciences Research Council (UK), the Leverhulme Trust Seniors Fellowship and the Royal Society Wolfson Research Fellowship. He was awarded MSc, PhD and DSc from Moscow State University.

KEYNOTE SPEAKERS

Girish S Agarwal

Oklahoma State University, USA

Single Photons and Atoms at Meta Surfaces

Harry Atwater

California Institute of Technology, USA

Electronically Tunable Metamaterials

Carl Bender

Washington University, USA

PT symmetry and the taming of instabilities

Alexandra Boltasseva

Purdue University, USA

Transparent conducting oxides and hard plasmonic ceramics for next-generation nanophotonics

Jacob Khurgin

Johns Hopkins University, USA

How to deal with the loss in Plasmonics and Metamaterials

Evgenii Narimanov

Purdue University, USA

Photonic Hypercrystals

Jeremy O'Brien

University of Bristol, UK

Quantum Photonic Computing

Mordechai (Moti) Segev

Technion, Israel

Photonic Topological Anderson Insulators

META'15 VENUE

META'15 will be held at both the **North Academic Center (NAC)** and the **Advanced Science Research Center (ASRC)** of **The City College of New York (CCNY)** from 4 to 7 August 2015.

GETTING TO CCNY

ADDRESS

160 Convent Ave, New York, NY 10031.

NOTE : Getting to CCNY by public transportation from any of the three major airports takes about 90 minutes. The cost is $2.25-$17.25. (Taxis take a bit less time, but not much less, and cost $35-$50.).

BY PUBLIC TRANSPORTATION

Get to the Broadway–7th Avenue subway line and take the #1 train toward upper Manhattan and the Bronx. Get off at the 137th Street Station. When you go up the stairs, you're at the south end of a small triangular park. Walk to the northeast corner (138th Street, away from Broadway). Make a right and walk one long block to Amsterdam Avenue. City College is on the other side of Amsterdam Avenue.

The North Academic Center is on your right. To enter it, cross Amsterdam Avenue and go right, with the building on your left. You will find two entrances (the building forms a bridge between them). If they are both closed, go to the main entrance all the way down the stairs near either entrance, and then between the stairs.

The Towers dormitory is near the south end of the campus, about 1/2 mile away, and the Harlem YMCA is about 1/2 mile east, across St. Nicholas Park. All the other hotels and hostels we recommended are near stations of the #1 subway train.

BY CAR

DON'T drive to CCNY, unless you already have plans for parking.

Get to Manhattan's West Side Highway (US Route 9A) either from the Lincoln Tunnel (follow signs after exit in Manhattan to West Side Highway N), or via I95. (If you are on I95 South, just after the intersection with I-87 the road splits ; take the right half, to the "last exit in NYC", and follow signs to the West Side Highway South. If you are on I-95 North, cross the George Washington Bridge ; toward its end look for and follow signs to the West Side Highway South, 9A.).

Take the 125th Street exit from 9A, and turn away from the river at 132nd Street. At Broadway, make a left, and then the next right at 133rd Street. This street ends in the CCNY parking lot.

After parking, walk back to the entrance, and then make a right turn on foot, and go north on Convent Avenue about 1/4 mile. After crossing 135th Street, you eventually pass the tall, relatively new Science

Building on your right.

To get to the main entrance of NAC, make a left at the end of the Science Building.

From Kennedy Airport

Take Airport free shuttle to the Subway (and Parking lots). There, take "A" train to 59th Street (Manhattan), and transfer there to the Broadway line, #1 train north. Time : about 90 minutes ; cost, about $10.00.

From LaGuardia Airport

Take the Q33 bus to Roosevelt Av. or 74th Street. Take the #7 train to its Manhattan terminal, Times Square. There transfer to the Broadway line, #1 train north. Time : about 90 minutes ; cost, $2.25-$5.00.

From Newark Airport

Take the Olympia Airport shuttle to the Port Authority Bus Terminal. Follow directions below from there. Time : about 75 minutes ; cost, $17.25.

From Pennsylvania Station or Port Authority Bus Terminal

The Broadway-7th Avenue subway line is in the station ; follow signs. Time : about 30 minutes ; cost, $2.25.

From Grand Central Station

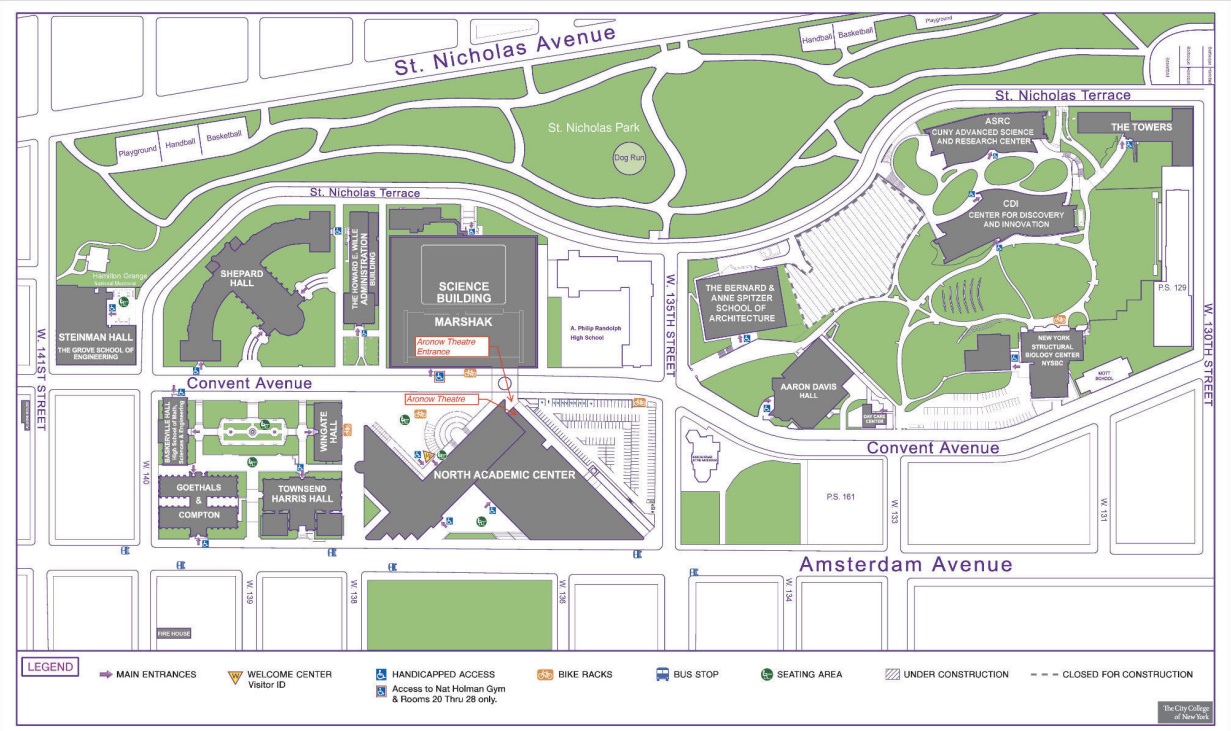
Take either the 42nd Street Shuttle or the #7 train (both accessible from inside the station) to Times Square ; there follow the signs to the #1 local uptown. Then transfer to the Broadway line, #1 train north. Time : about 40 minutes ; cost, $2.25.

From George Washington Bridge Bus Terminal

The Broadway-7th Avenue subway line is in the station ; follow signs. Take the #1 train SOUTH and cross Broadway before following the directions to CCNY given above. Time : about 20 minutes ; cost, $2.25.

CCNY CAMPUS MAP

The main campus of The City College of New York is comprised of 36 tree-lined acres running from 133rd Street to 140th Street in Harlem, bounded by St. Nicholas Terrace and St. Nicholas Park on the east and Amsterdam Avenue on the west.



GUIDELINES FOR PRESENTERS

ORAL PRESENTATIONS

Each session room is equipped with a stationary computer connected to a LCD projector. Presenters must load their presentation files in advance onto the session computer. Technician personnel will be available to assist you.

Scheduled time slots for presentation are 15 mn for regular, 20 mn for invited presentations, 30 mn for keynote talks and 40 mn plenary talks, including questions and discussions. Presenters are required to report to their session room and to their session Chair at least 15 minutes prior to the start of their session.

The session chair must be present in the session room at least 15 minutes before the start of the session and must strictly observe the starting time and time limit of each paper.

POSTER PRESENTATIONS

Presenters are requested to stand by their posters during their session. One panel, A0 size (118.9 x 84.1 cm), in vertical orientation, will be available for each poster (there are no specific templates for posters). Pins or thumbtacks are provided to mount your posters on the board. All presenters are required to mount their papers one hour before the session and remove them at the end of their sessions.

GENERAL INFORMATION

Venue

THE CITY COLLEGE OF NEW YORK
North Academic Center (NAC) & the Advanced Science Research Center (ASRC)
160 Convent Ave, New York, NY 10031, USA

Registration Desk

Monday 3 August (15 :00 – 18 :30) : Lobby of the Aronow Theater
Tuesday 4 August (08 :00 – 10 :00) : Lobby of the Aronow Theater
Tuesday 4 August (10 :00) – Friday 7 August : Poster/Exhbition area

Conference Group Photo

Date : Tuesday, 4 August
Time : 12 :45 – 12 :55

Conference Cocktail

Date : Thursday, 6 August
Time : 17 :30 – 19 :30
Venue : The Historic Great Hall (located in Shepard Hall)

Best Poster Awards Ceremony

Date : Thursday, 6 August
Time : 18 :30 – 19 :00
Venue : The Historic Great Hall (located in Shepard Hall)

TECHNICAL PROGRAM

Monday 3rd August, 2015

Registration

Aronow Lobby

15:00 - 18:30

Tuesday 4th August, 2015

Registration

Aronow Lobby

08:00 - 17:30

Opening ceremony

Aronow Theater

Inaugural address: Tony Liss (Dean of Science) and Gillian Small (Vice Chancellor for Research)

08:45 - 09:00

09:00 - 10:20 — Aronow Theater

Session 1A1

Plenary Session I

Chaired by: Nader Engheta

09:00 : Plenary talk
Quantum Cascade lasers and applications in mid-infrared photonics
Claire Gmachl
Princeton University (USA)

09:40 : Plenary talk
New material platform for plasmonics
Vladimir M. Shalaev
Purdue University (USA)

We outline the recent progress in developing new plasmonic materials that will form the basis for future low-loss, CMOS-compatible devices that could enable full-scale development of the metamaterial and nanophotonic technologies.

Coffee Break and Exhibit Inspection

Session 1P1

Poster session I

10:20 - 11:00

P1: Design, Fabrication and Characterization of Terahertz Reflectarrays Based on a Silicon Substrate
H. Hasani[1], **M. Tamagnone**[1], **S. Capdevila**[1], **C. Moldovan**[1], **A. M. Ionescu**[1], **C. Peixeiro**[2], **J. R. Mosig**[1], **A. Skrivervik**[1]
[1] *Ecole polytechnique federale de Lausanne (EPFL) (Switzerland),* [2] *University of Lisbon (Portugal)*

We present the design, fabrication and measurement of terahertz reflectarray surfaces realized by metallic patterns fabricated on a back-metallized thin silicon substrate. The device is designed to steer an incident beam towards a predefined direction. An excellent agreement is found between measurements and expected performances.

P2: Stretchable and Transparent THz Reflectarrays Based on PDMS

P. Romano, M. Tamagnone, S. Capdevila, S. Rosset, H. Shea, J. R. Mosig
Ecole polytechnique federale de Lausanne (EPFL) (Switzerland)

We present the design, implementation and preliminary characterization of terahertz reflectarrays based on polydimethylsiloxane (PDMS). The metal patterns are created with e-beam metal evaporation using a shadow mask while the ground plane is implemented using ion implantation on the opposite side of the thin PDMS membrane. Measurements demonstrate good performance in terms of losses and beam deflection, in agreement with numerical simulations.

P3: Giant magnetodielectric metamaterial
Ji Zhou, Ke Bi, Xiaoming Liu
Tsinghua University (China)

We demonstrate a giant magnetodielectric effect at GHz region in a metamaterial based on ferrite unit cells. The effect is derived from a couple of ferromagnetic resonance and Mie resonance in ferrite unit cells. Experimental results show that the effective permittivity of the metamaterial can be tuned by the applied magnetic field, and a giant magnetodielectric effect at microwave range, has been obtained.

P4: Antenna Array Bandwidth Enchancement using Polymeric Nanocomposite Substrate
Wan Asilah W. Muhamad[1], Razali Ngah[1], Mohd Faizal Jamlos[2], Ping Jack Soh[2]
[1] *Universiti Teknologi Malaysia (Malaysia),* [2] *Universiti Malaysia Perlis (Malaysia)*

A new antenna substrate made from Polydimethylsiloxane (PDMS) and magneto-dielectric (PDMS-Fe3O4) polymeric nanocomposite is presented. This substrate enhances antenna performance in terms of lower reflection coefficient, wider bandwidth and size compactness. The 4x2 antenna array operating at 2.6 GHz is water resistant as the radiating structure is fully embedded inside the substrate. Simulated and measured S11 and radiation pattern agrees well, while a bandwidth increment of 242.25 percent is observed relative to a similar FR4 antenna.

P5: Polymer (PDMS-Fe3O4) Magneto-Dielectric Substrate for a MIMO Antenna Array
Abdulrahman S. M. Alqadami, Mohd Faizal Jamlos, Ping Jack Soh
Universiti Malaysia Perlis - UniMAP (Malaysia)

This paper presents the design of a 2 x 4 multiple input multiple output antenna array fabricated on a nanocomposite polymer substrate. Iron oxide (Fe3O4) nanoparticles and polydimethylsiloxane (PDMS) are used to form this polymer magneto-dielectric substrate layer. The results of the proposed antennas showed up to 41 percent enhancement in terms of bandwidth, 9.95 dB gain and 57 percent efficiency which indicating its suitability for RF/microwave applications

P6: Terahertz magnetic response of rare earth orthoferrites
Xiaojian Fu, Tie Jun Cui
Southeast University (China)

For most materials, the magnetism rapidly declines above microwave frequencies, and the magnetic permeability is usually taken as unit in the optical regime. The so-called metamaterials can achieve high frequency magnetic response by employing the artificially designed magnetic resonance. However, the working frequencies of metamaterials depend on the periodic structure and may not be easy to tune. In this study, we investigate the intrinsic magnetic properties of rare earth orthoferrites, which may have potential application in tunable terahertz metamaterials.

P7: Negative Refraction and Spatial Dispersion in Metamaterials
John S. Derov, Daniel Jackson
Air Force Research Laboratory (USA)

Both negative refraction and spatial dispersion has been observed in metamaterials. A combination of simulated and measured data is used to show the relationship between the negative refraction and spatial dispersion in a split-ring/wire-post Metamaterial. When the spatial modes are excited, three waves propagate through the metamaterial, incident, longitudinal, and transverse waves. The relationship between spatial dispersion and negative refraction along with excitation and control of the spatial modes in a metamaterial will be presented and discussed.

P8: Slowing microwaves with deeply subwavelength 3D printed metamaterial waveguides
Nadege Kaina[1], Alexandre Causier[2], Mathias Fink[1], Thomas Berthelot[2], Geoffroy Lerosey[1]

[1] *ESPCI ParisTech (France),* [2] *CEA Saclay (France)*

We study resonant wire media scaled at very subwavelength scales. We show that introducing local defects permits to guide the waves with a transverse confinement of the order of one period in any direction, independently of the medium's spatial organization. We prove that the propagation within these waveguides exhibit very low group velocities that can be tuned by modifying the geometrical parameters of the neighboring wires. We present simulation and experimental results of 3D printed polymer copper coated waveguides.

P9: Engineering of dark modes through symmetry matching
S. N. Burokur, Anatole Lupu, Andre de Lustrac
Paris Sud University (France)

The aim of the present contribution is to show that in contrast to the classical indirect excitation through hybridization mechanism leading to EIT phenomenon and maximum in transmission, our proposed direct dark mode excitation manifests as a sharp maximum in reflection and minimum in transmission. We discuss the advantages related to this operation mode and detail the essential of the underlying excitation mechanism which is not based on modes hybridization.

P10: Phase demodulation based on zero-index metamaterials
Yue Qin, Yongxin Wang, Ping Xu
Soochow University (China)

We theoretically demonstrate that zero-index metamaterials (ZIM) junction with three ports can realize the function of optical interferometer in optical phase demodulation. When the junction is made up of epsilon-near-zero (ENZ) material, performance of the proposed structure becomes deteriorated because of impedance mismatch, which results in distortion and intensity decrease of final demodulated wave. To improve performances, three approaches including narrowing the area of ENZ junction, adding proper defect and using anisotropy ENZ junction are presented.

P11: Collecting and guiding electromagnetic waves via one-dimensional gradient-index structures in silicon photonics
HongChen Chu, Jie Luo, Yun Lai
Soochow University (China)

We propose to collect and guide electromagnetic waves in the vertical direction of incidence by using the 1D counterpart of meta-surfaces: one-dimensional gradient-index structures. For guided modes confined in a silicon plate, we find it possible to draw wave energy into the vertical direction with nearly 100 percent efficiency. Through theoretical analysis and numerical simulations, we designed the gradient structure and proved the function. Our work demonstrates an example of controlling electromagnetic waves in the sub-wavelength scale with one-dimensional gradient-index structures.

P12: Zero-n Bandgap with Photonic Crystal Superlattices Both For Negative and Positive Refraction
Serdar Kocaman, Ekin Karaca
Middle East Technical University (Turkey)

We demonstrate numerically that superlattices with photonic crystals for both negative and positive refraction sections can be designed in order to get zeroth order bandgap in the near infrared region and fine tuning can be obtained with the coupling radius between the layers.

P13: Reconfigurable Metamaterial Microwave Filters using Moire Interference
Jae-Hyung Han, Inbo Kim, Jung-Wan Ryu, Muhan Choi
Kyungpook National University (Korea)

We report the numerical and experimental results of transmission property of electromagnetic waves (EM waves) incident to a reconfigurable metamaterial based on Moire interference. The Moire pattern is created by superimposing two transparent layers each of which has a periodic metallic pattern. The numerical and experimental results show that the transmission of electromagnetic wave is modulated up to about 90 percent at 11 Gigahertz.

P14: Noble metal nanoparticles coated with novel aminothioalkil ligands for synthesis of covalently bonded polymer-nanoparticles composites.
Michalina Iwan, Tomasz Andryszewski, Marcin Fialkowski
Polish Academy of Sciences (Poland)

We present a facile and potentially general approach to the synthesis of nanocomposite in which noble metal nanoparticles (NP) are covalently bonded to a polymer matrix. In this approach, the NPs are functionalized with novel aminothioalkil ligands that are capable to bind chemically to a wide range of polymers possessing carbonyl groups or hydroxyl groups that can be oxidized into carbonyl groups.

P15: Real-time continuous-wave amplitude terahertz modulation system based on active metamaterials

Saroj Rout, Sameer Sonkusale
Tufts University (USA)

We demonstrate a real-time terahertz modulation system at 448 GHz using a metamaterial terahertz modulator and a continuous-wave terahertz source based on photo-mixing of two tunable distributed feedback lasers. Another photo-mixer followed by a lock-in I/Q detection of the cw spectrometer serves as a complex receiver of amplitude modulation used to determine the spectral transmitivity of the modulator.

P16: One-dimensional metamaterial photonic crystal with defects, a study of the surfaces modes

Jaime Perez-Rodriguez, Martha Palomino-Ovando, Gregorio H. Cocoletzi
Benemerita Universidad Autonoma de Puebla FCFM (Mexico)

We explore the coupling of the surface plasmons with modes associated to the defect in one-dimensional photonic crystals which are composed by alternating layers of a left hand material and a dielectric. This photonic crystal has a defect in the middle of its structure which is obtained by varying the dielectric layer thickness. The presence of the defect generates an electric field amplification in the left hand material which improves the conditions for propagation of surface modes.

P17: Specific Absorption Rate Reduction of Multi-standard Mobile Antenna with Double-Negative Metamaterial

Touhidul Alam, M. R. I. Faruque, M. T. Islam
Universiti Kebangsaan Malaysia (Malaysia)

This paper presents a printed multi-standard mobile wireless antenna loaded with double-negative metamaterial that covers the operating frequency of 1.66 GHz to3.95 GHz and 4.45 GHz to 5.73 GHz. The antenna is assimilated with a semicircular shape radiating patch, metamaterial loaded ground plane and microstrip feed line. The perceptible novelties exhibited in this proposed antenna is reduction of specific absorption rate (SAR) with metamaterial loaded ground plane.

P18: Design and Implementation of Waveguide Bandpass Filter Using Complementary Metaresonator

Tanveer Ul Haq[1]**, Muhammad Faisal Khan**[1]**, Omar Siddiqui**[2]
[1] *Ghulam Ishaq Khan Institute (Pakistan),* [2] *Taibah University (Saudi Arabia)*

Passband filter for rectangular waveguide is designed using complementary symmetric split ring resonator (CSSRR). By varying different geometrical parameters of CSSRR, the passband frequency and bandwidth can be varied. Effect of design parameter on quality factor of filter is also calculated. By appropriate choice of CSSRR geometrical parameters, a filter is proposed which gives passband of 2 GHz in ku band.

P19: High-Contrast Nanoparticle Sensing using a Hyperbolic Metamaterial

Wenqi Zhu, Ting Xu, Amit Agrawal, Henri Lezec
University of Maryland (USA)

Using planar hyperbolic metamaterials composed of alternating layers of metal (Ag) and dielectric (SiO2), we demonstrate a transmission device for nanoparticle sensing that exhibits extremely high optical contrast. Due to its high sensitivity to nanoparticles in deep-subwavelength proximity to a surface, achieved without the use of cumbersome dark-field optics, this HMM-based device hints at promising applications in bio-chemical sensing, particle tracking and contamination analysis.

P20: Metasurface based micro-plasma device

Shiva Piltan, Ebrahim Forati, Dan Sievenpiper
University of California San Diego (USA)

A metasurface based micro-plasma device is proposed taking advantage of the inherent resonance of the surface. The structure combines the DC and laser induced discharges and reduces both the required DC voltage and laser power to ignite the plasma.

P21: A Wideband Double-Negative Metamaterial Based on Framed Crosses
Anatolii Konovalenko[1], Jorge Reyes-Avendano[2], Felipe Perez-Rodriguez[1]
[1] *Benemerita Universidad Autonoma de Puebla (Mexico),* [2] *Escuela de Ingenieria y Tecnologias de Informacion (Mexico)*

A new type of negative index metamaterial composed of metal framed crosses is proposed. The new metamaterial design leads to a relatively-wide band of simultaneously negative permittivity and permeability within the microwave range.

P22: Dual Resonant Polarization-Independent and Wide Angle Metamaterial Absorber in X-Band Frequency
Osman Ayop, M. K. A. Rahim, N. Murad, N. Samsuri
Universiti Teknologi Malaysia (Malaysia)

This paper presents the dual resonant polarization-independent metamaterial absorber with wide operating angle in X-band frequency. The resonating elements are designed using the two circular rings structure with different radius. The resonating elements are printed on the top and bottom surface of FR4 substrate, while at the middle layer, a full copper layer is placed. The proposed structure achieves high absorbance, which is 96.41 percent and 93.61 percent at resonances for normal incident angle. The operating angle is nearly 70o.

P23: VCO based on Composite Right/Left-Handed Metamaterial Transmission Lines loaded with RTD
H. J. El-Khozondar[1], M. Abu-Marasa[1], R. J. El-Khozondar[2], M. Elbahri[3], S. Zouhdi[4]
[1] *Islamic University of Gaza (Palestine),* [2] *Al-Aqsa University (Palestine),* [3] *University of Kiel (Germany),* [4] *Paris Sud University (France)*

This paper proposes a voltage control oscillator (VCO) at high frequency consists of nonlinear composite right/left-handed transmission line (CRLH-TL) loaded with Resonant Tunneling Diode (RTD). The system has equals input and output resistance. In this work, we used OrCAD and ADS software to analyze the proposed circuit. The VCO capable of generating oscillation at frequency equals 14.4 GHz.

P24: Metamaterials lens design for microwave
Tamelia Ali[1], Igor Bendoym[2], Steve Kacenjar[3], Andrii Golovin[1], David Crouse[1]
[1] *City College of New York (USA),* [2] *Pheobus Optoelectronics (USA),* [3] *Lockheed Martin Corp. (USA)*

The development of flat, low profile, and light weight metamaterial lens for microwave allows for small phase error, wide frequency band, wide angle scanning, and true-time delay beam forming. This lens design is promising for applications in remote sensing, THz imaging, and adaptive antennas in microwave regime. In this work, the comparison between the beam shaping of metamaterial lenses and the diffraction limited optical systems in extended bandwidth is provided both analytically and numerically.

P25: Mie-resonance-mediated light trapping in Si nanocone arrays
Eunah Kim[1], Yunae Cho[1], Dong-Wook Kim[1], Kwang-Tae Park[2], Jun-Hyuk Choi[2], Seung-Hyuk Lim[3], Yong-Hoon Cho[3], Yoon-Ho Nam[4], Jung-Ho Lee[4]
[1] *Ewha Womans University (Korea),* [2] *Korea Institute of Machinery and Materials (Korea),* [3] *KAIST (Korea),* [4] *Hanyang University (Korea)*

We investigated optical characteristics of Si nanocone (NC) arrays, of which optical reflectance was less than 10 percent in the visible wavelength range. Comparison of the experimental and simulated optical reflectance spectra clearly suggested the Mie resonance played a key role in the remarkable AR effects. The photoluminescence intensity of the NC arrays was an order of magnitude larger than that of a planar wafer, also supporting the Mie-resonance-mediated strongly concentrated light at the surface.

P26: Efficient collection of incoming photons and photo-generated carriers in Si nanostructure array solar cells
Yunae Cho[1], Eunah Kim[1], Dong-Wook Kim[1], Joondong Kim[2]
[1] *Ewha Womans University (Korea),* [2] *Incheon National University (Korea)*

Si nanostructure array enables much improved broadband and omnidirectional optical absorption, compared with conventional light trapping strategies. We achieved a very high photocurrent density of 36.94 mAcm-2 from our nanoconical frustum array crystalline Si (c-Si) solar cells. Optical simulation studies showed that the expected photocurrent nanostructured cells could slightly exceed the Lambertian limit with the help of remarkable antireflection (AR) effects and efficient carrier collection capability.

P27: Acoustic Metasurface
Hussein Esfahlani, Sami Karkar, Herve Lissek
Ecole Polytechnique Federale de Lausanne (Switzerland)

Metasurfaces have gained fame for their ability to control the transmitted and reflected phase front of waves. Here, we introduce a reflector-type acoustic metasurface designed in such a way to control the phase front of reflected sound waves. The proposed structure can be considered an acoustic counterpart of the electromagnetic reflectarray antenna. This structure is very thin, and possesses sub-wavelength unit-cells.

P28: Design of a flat metamaterial lens operating at 60 GHz
Jason Pereira[1], Shimul Saha[2], Helena Cano-Garcia[3], Efthymios Kallos[4]
[1]*Metamaterial Technologies Inc. (Canada),* [2]*Metamaterial Technologies Inc. (United Kingdom),* [3]*Medical Wireless Sensing Limited (United Kingdom),* [4]*Medical Wireless Sensing Limited (Canada)*

This paper presents the design and simulation results of a flat, focusing lens consisting of three metamaterial layers and operating in the V-band at 60 GHz. It is approximately a twelfth of the thickness of conventional dielectric hyperbolic lenses. Its simulated focusing performance was compared to a conventional dielectric lens and it was found to perform similarly.

P29: Broadband perfect absorption of elastic waves by ultra-thin films composed of damping elastic metamaterials
Yuetao Duan[1], Jie Luo[1], Guanghao Wang[1], Zhihong Hang[1], Bo Hou[1], Ping Sheng[2], Jensen Li[3], Yun Lai[1]
[1]*Soochow University (China),* [2]*Hong Kong University of Science and Technology (Hong Kong),* [3]*University of Birmingham (United Kingdom)*

We find that when the film is of a large value of almost pure imaginary mass density and a free space boundary, or of a small value of almost pure imaginary modulus and a hard wall boundary, perfect absorption can be achieved. We design elastic metamaterials with large damping so as to achieve such effective media and therefore provide a practical method to realize broadband perfect absorption of elastic waves in ultra-thin films.

P30: Ultra-transparent 1D Photonic Crystals
Zhong Q. Yao, Jie Luo, Yun Lai
Soochow University (China)

We propose to realize ultra-transparent 1D photonic crystals. Here, by ultra-transparency we mean that the transmission through the photonic crystals is unity, i.e. transparent, for a large range of incident angles. We provide theory as well as numerical verifications. Such a class of 1D photonic mediaopens up many new possibilities such as cloaking.

P31: Wavefront Modulation with Transmissive and Reflective Acoustic Metasurfaces
Wenqi Wang, Yangbo Xie, Adam Konneker, Bogdan-Ioan Popa, Steven Cummer
Duke University (USA)

Acoustic metasurfaces are devices that exhibit exotic wave manipulating properties with thin planar profiles. Building on our previous works of transmissive acoustic lenses and metasurfaces, we present here several reflective metasurfaces based on an expanded library of labyrinthine acoustic metamaterials. We demonstrate that by engineering the surface acoustic impedances, the reflected acoustic wavefront can be tailored with extended degree of freedom.

P32: Phase and Group Velocities in Metamaterials
Omar Siddiqui
Taibah University (Saudi Arabia)

The electromagnetic properties are usually studied by constructing dispersion surfaces and Brillioun diagrams. Although these are useful tools, the time-domain picture is needed to complete the understanding of the dispersion behavior. In this paper, the electromagnetic behavior of different metamaterials is explained by means of phase and velocity surfaces and time domain wave propagation simulations. The dispersion behavior can also be understood by looking at the relation between the phase and group velocities

P33: Reflectance spectra comparisons of different multilayered plasmonic nanoantenna arrays
Semih Korkmaz, Ekin Aslan, Sabri Kaya, Mustafa Turkmen

Erciyes University (Turkey)

Metal - dielectric - metal (MDM) based plasmonic nanostructures simultaneously minimizing the reflectance with perfect impedance matching and eliminating the transmittance by maximizing material losses typically consist of three functional layers that comprise a dielectric layer sandwiched between two metal layers. In this study, we proposed different plasmonic nanostructures operating in mid infrared regime. We investigated the spectral response of these plasmonic nanostructures by using finite difference time domain (FDTD) method.

P34: One-Way Dirac Cones and Edge States in 2D Photonic Crystals with Broken Parity and Time-Reversal Symmetries

Xiang Ni[1], Steven Munoz[2], Alexander A. Lisyansky[1], Alexander B. Khanikaev[1]
[1] *Queens College-The City University of New York (USA),* [2] *The Graduate Center -The City University of New York (USA)*

Bulk spectrum and edge modes of a magnetic photonic crystal with broken TR and PS are studied. It is shown that for specific values of parameters defining the strength of the symmetry reduction the bulk modes exhibit a peculiar one-way Dirac-like dispersion. The domain wall formed by two crystals with reversed symmetry reduction parameters supports an edge mode which coexists with the one-way bulk Dirac regime.

P35: Enhanced Sound Pressure Level by High Effective Index of Refraction and Impedance in an Acoustic Metamaterial Cavity

Kyungjun Song[1], Jedo Kim[2]
[1] *Korea Institute of Machinery and Materials (Korea),* [2] *Pukyong National University (Korea)*

We design and experimentally demonstrate an acoustic metamaterial localization cavity which is used for sound pressure level (SPL) gain using double coiled up space like structures. This unique behavior occurs within a subwavelength cavity that is 1/10th of the wavelength of the incident acoustic wave, which provides up to a 13 dB SPL gain. We show that the amplification results from the Fabry-Perot resonance of the cavity exhibiting simultaneously high effective refractive index and effective impedance.

P36: Millimeter-sized ultrasmooth single-crystalline gold flakes for large-area plasmonics

You-Xin Huang, Kel-Meng See, Jer-Shing Huang
National Tsing Hua University (Taiwan)

In this work, we present a new synthesizing method of ultra-large millimeter-sized single-crystalline gold flakes for large-area plasmonics.

P37: Thermo-optical properties of polydimethylsiloxane (PDMS) doped with metallic nanoparticles

J. F. Algorri[1], B. Garcia-Camara[1], D. Podereux[2], R. Vergaz[1], V. Urruchi[1], J. M. Sanchez-Pena[1]
[1] *Carlos III University of Madrid (Spain),* [2] *Universidad Politecnica de Madrid (Spain)*

The thermo-optical response of polydimethylsiloxane (PDMS) doped with metallic nanoparticles is theoretically studied. The temperature dependence of the effective refractive index of the mixture has been analyzed through the spectral evolution of the output power ratio of a beam crossing a sample. Both the nanoparticle size and the concentration effects have been analyzed to design a potential temperature sensor.

P38: Room Temperature Ferromagnetism in Antiferromagnetic Cobalt Oxide Nanoctahedra

Nerio Fontaina-Troitino[1], Benito Rodriguez-Gonzalez[1], Michael Farle[2], Veronica Salgueirino[1]
[1] *Universidade de Vigo (Spain),* [2] *Universitat Duisburg-Essen (Germany)*

Cobalt oxide octahedra were synthesized by thermal decomposition. Each octahedron-shaped nanoparticle consists of an antiferromagnetic CoO core enclosed by eight 111 facets interfaced to a thin surface layer of strained Co3O4. The nearly perfectly octahedral shaped particles with 20, 40 and 85 nm edge length show a weak room temperature ferromagnetism which can be attributed to ferromagnetic correlations appearing due to strained lattice configurations at the CoO/Co3O4 interface.

P39: Landau damping of electromagnetic transport via dielectric-metal superlattices

Alejandro Paredes-Juarez, Denis Iakushev, Benito Flores-Desirena, Nykolay Makarov, Felipe Perez-Rodriguez
Benemerita Universidad Autonoma de Puebla (Mexico)

We discuss the propagation of plane electromagnetic waves through a one-dimensional periodic array of bilayers with metal inclusions. We show that the nonlocality of metal conductivity gives rise to the emergence of the collisionless Landau damping, which considerably alters the photonic band structure of the array and

its transmission within the THz and near-infrared frequency range.

P40: Effect of the material thicknesses on the optical properties of fractal perfect absorber
Ekin Aslan, Sabri Kaya, Mustafa Turkmen
Erciyes University (Turkey)

The effects of material thicknesses on the spectral responses of plasmonic absorber nanoantenna arrays based square fractal nanoholes are analyzed. Quality factor of the structure is also calculated. Absorbance spectra of the structure are presented versus different thicknesses for patterned layer and dielectric spacer. Due to its tunable resonance in mid-infrared regime to maintain large amplitudes and high Q factor features the proposed structure can be a good candidate for biosensing applications with the use of infrared spectroscopy techniques.

11:00 - 12:40 — Aronow Theater

Session 1A2

Symposium 1: Functional Metastructures and Nanomaterials: Properties, Fabrication and Modeling I

Organized by: Alexander Govorov and Hilmi Volkan Demir

Chaired by: Na Liu and Fiorenzo Vetrone

11:00 : Invited talk
Thermoplasmonic assisted hydrodynamics. From microbubble formation to fluid convection
Guillaume Baffou
Institut Fresnel (France)

This presentation focuses on the physics of microscale thermo-induced processes in liquids assisted by plasmonic heating. In particular, focus will be put on recent results regarding bubble formation, fluid superheating and strong fluid convection induced by gold nanoparticles under cw illumination.

11:20 : Invited talk
Thermoplasmonic control of chemical reactions and cell function at the nanoscale
Theobald Lohmuller
LMU Munich, Department of Physics (Germany)

Plasmonic nanoparticles feature intriguing optical properties that can be utilized to manipulate them by means of light. Light absorbed by gold particles, for example, is very efficiently converted into heat. A single particle can thus be used as a fine tool to apply heat to a nanoscopic area. At the same time, gold nanoparticles are subject to optical forces when they are irradiated with a laser beam which renders it possible to optically manipulate them in two-and three dimensions.

11:40 : Invited talk
Optical Probe Thermometry Using a Laser Trapped Erbium Oxide Nanoparticle
Samual C. Johnson, Susil Baral, Arwa A. Alaulamie, Hugh H. Richardson
Ohio University (USA)

In this talk I will describe a new optical probe technique using a laser trapped erbium oxide nanoparticle that measures absolute temperature below the diffraction limit. We use this new technique to measure the temperature where vapor nucleation occurs in degassed water for a nanoheater limited in size by the profile of the excitation laser.

12:00 : Invited talk
Vapor Formation and Bubble Dynamics around Strongly Heated Nanoparticles
Pawel Keblinski, Kiran Sasikumar
Rensselaer Polytechnic Institute (USA)

We use molecular dynamics simulations to investigate the cavitation dynamics around pulse heated solid

nanoparticles immersed in a fluid. We determine the criterion for formation of the vapor nanocavity and study the temporal evolution of vapor nanobubbles. MD simulations of 8 nm diameter gold nanoparticles in water reveals that vapor formation is not observed, even if the gold melts. Further increase of the heating power leads to the fragmentation of the gold particle.

12:20 : Invited talk
Thermomechanical Dynamics in Plasmonic Nanofluids
J. L. Dominguez Juarez, S. Vallone, M. Moocarme, A. Lempel, H. D. Gafney, Luat Vuong
Queens College of CUNY (USA)

We describe the first experiments of spontaneous oscillatory behavior in binary-solvent plasmonically-absorbing nanofluids, which occurs when collimated light grazes menisci. We characterize self-focusing dynamics that occur in non-local materials, solvent dynamics, new mechanisms for probing nanoparticle-solvent chemistry, and novel thermo-mechanical dynamics.

11:00 - 12:40 — NAC 0/201

Session 1A3

Structured light in metamaterials I

Organized by: Natalia Litchinitser and Richard Hammond

Chaired by: Natalia Litchinitser and Richard Hammond

11:00 : Invited talk
Spinning the Light in Meta-world
Jingbo Sun, Mikhail Shalaev, Jinwei Zeng, Natalia Litchinitser
The State University of New York at Buffalo (USA)

Recent developments in the field of metamaterials opened unparalleled opportunities for tailoring and manipulating light beams giving rise to the new branch of modern optics that relies on the synergy between structured light and structured matter. In this talk, we discuss our recent studies of light-matter interactions in rationally designed metamaterials enabling novel linear and nonlinear phenomena as well as potential applications of structured light on the nanoscale, including metamaterials-based, ultra-compact, integrated structured light sources and converters.

11:20 : Invited talk
Geometric Phase and Interface State in One-Dimensional Parity-Time Symmetric Optical Structures
Han Zhao, Liang Feng
The State University of New York at Buffalo (USA)

We investigated the geometric phase accumulated in one-dimensional (1D) parity-time (PT) symmetric optical structures (also called the Zak phase in 1D systems). Similarly to the Hermitian system, the Zak phase remains either 0 or Pi in the PT symmetric phase, while in the PT broken phase it varies continuously regarding the imaginary index modulation, showing different topological properties associated with different PT phases. The Zak phase difference therefore forms a novel interface state between two PT symmetric optical structures.

11:40 : Invited talk
Engineering knotted optical vortices for interaction with structured matter
Mark R. Dennis, Benjamin Bode, Danica Sugic, David Foster, Alexander Taylor
University of Bristol (United Kingdom)

We describe the theoretical and numerical construction of optical beams with knotted optical vortices with shortened aspect ratios. These have potential for interaction with a variety of different types of structured matter, especially in nematic liquid crystals and cold atomic gases.

12:00 : Invited talk

Exploring Chiral Hotspots in Photonic Metamaterials: Chiroptical Response, Harmonic Generation, and Chiral-Selective Emission Control

Wenshan Cai
Georgia Institute of Technology (USA)

Metamaterials can be designed to exhibit extraordinarily strong chiral responses. We present a chiral metamaterial that produces both distinguishable linear and nonlinear features in the visible to near-infrared range. In additional to the gigantic chiral effects in the linear regime, the metamaterial demonstrates a pronounced contrast between second harmonic responses from the two circular polarizations. Linear and nonlinear images probed with circularly polarized lights show strongly defined contrast. The metamaterial is further exploited for chiral-selective two-photon luminescence from quantum emitters.

12:20 : Invited talk

Optical vortices form chiral nanostructures

Takashige Omatsu
Chiba University (Japan)

Chiral nanostructures (chiral metal nanoneedles and the chiral azo-polymeric reliefs) fabrication by irradiation of the optical vortices is presented. These chiral nanostructures will enable us to pioneer a new generation of materials science, such as metamaterials, chiral selective nanoscale imaging systems, and chiral chemical reactors.

11:00 - 12:50 — NAC Ballroom

Session 1A4

Ultrahigh frequency transport and terahertz plasmonics in nanoscale structures, metamaterials, and 2D materials I

Organized by: Sergey Rudin and Michael Shur

Chaired by: Sergey Rudin and Michael Shur

11:00 : Keynote talk

Transparent Conducting Oxides and Hard Plasmonic Ceramics for Next-Generation Nanophotonics

J. Kim, N. Kinsey, A. Dutta, M. Ferrera, C. DeVault, I. Kitamura, A. V. Kildishev, V. M. Shalaev, A. Boltasseva
Purdue University (USA)

Our research focuses on transparent conducting oxides (TCOs) and transition metal nitrides (TMNs) which have great potential for enabling high performance, tunable, semiconductor compatible nanophotonic devices. Different types of applications have been studied to demonstrate the capability of TCOs and TMNs as plasmonic components, including unique properties in the epsilon near zero (ENZ) regime. For TCOs, tunability in both the intrinsic properties through deposition and annealing, as well as dynamic properties through optical excitation are explored.

11:30 : Invited talk

Transmission line theory of plasmonic crystal in the 2D electron systems: band spectrum and Tamm states

Gregory Aizin
Kingsborough College of the City University of New York (USA)

A transmission line theory of the 1D plasma excitations in periodically modulated 2D electron systems is presented. The theory is used to demonstrate formation of the plasmonic crystals in the 2D electron systems with periodic changes of electron density, gate screening or both. Analytical expressions for the plasmonic energy band spectrum are derived for both infinite and finite size crystals. Formation of the plasmonic Tamm states near the crystal edges is predicted.

11:50 : Invited talk

Engineering materials and fields for active Si-based metamaterials

Luca Dal Negro
Boston University (USA)

I will present results on the engineering of light emission and optical nonlinearity in transparent conductive oxides and nitrides (TCONs) for Si-compatible active metamaterials. In the near-infrared, TCNOs support plasmonic resonances with sub-wavelength field confinement and largely reduced losses. Moreover, their optical dispersion properties can be tuned in the telecom spectral range enabling efficient epsilon-near-zero (ENZ) media without the need of specialized nanofabrication. Applications to nonlinear frequency generation and light emitting hyperbolic metamaterials on Si will be presented.

12:10 : Invited talk

Terahertz radiation induced ratchet and plasmonic effects in two-dimensional systems with a lateral periodic potential

Peter Olbrich, Sergey Ganichev
University of Regensburg (Germany)

Experimental and theoretical work on ratchet and plasmonic effects in various 2D systems with asymmetric lateral superlattice excited by alternating terahertz radiation electric fields is reviewed. We consider the Seebeck ratchet effect and helicity driven photocurrents and show that their generation is based on the combined action of the spatially periodic in-plane potential and modulated light. We also discuss a dramatically enhancement in the vicinity of plasmonic resonances and address the potential for highly sensitive detection of terahertz radiation.

12:30 : Invited talk

Emission and Detection of Terahertz Radiation Using Two-Dimensional Plasmonic Metamaterials

Taiichi Otsuji[1], Akira Satou[1], S. A. Boubanga Tombet[1], Victor Ryzhii[1], Vyacheslav V. Popov[2], Vladimir Mitin[3], Michael S. Shur[4]
[1] *Tohoku University (Japan),* [2] *Kotelnikov Inst. of Radio Eng. and Electron. (Russia),* [3] *University at Buffalo-SUNY (USA),* [4] *Rensselaer Polytechnic Institute (USA)*

This paper reviews the recent advances in emission and detection of terahertz (THz) radiation using two-dimensional (2D) plasmonic metamaterials. First, we present the 2D plasmonic meta-surface in a semiconductor quantum well structure implemented using an asymmetric dual-grating gate (A-DGG) InP-based high electron mobility transistor (HEMT). Second, we discuss the 2D plasmonic meta-surface in graphene featured by the A-DGG structure. Third, we present the concept of the plasmonic coupling between the SPPs and photon-assisted resonant tunneling in a double-graphene-layered meta-surfaces.

11:00 - 12:30 — NAC 1/202

Session 1A5

Optical Forces and Manipulation of Momentum in Metamaterials and Plasmonics I

Organized by: Philippe Tassin and Vincent Ginis

Chaired by: Philippe Tassin and Vincent Ginis

11:00 : Invited talk

Local optical helicity at the nanoscale -visualisation and exploitation-

Kobus Kuipers
FOM Institute AMOLF (Netherlands)

We show that optical singularities readily occur in the near field of nanophotonic structures. We visualize both phase- and polarization singularities in both the electric and magnetic field near plasmonic and photonic crystal structures with near-field microscopy. It turns out that their spatial evolution is distinct and unlike that of freely propagating beams. The local helicity associated with so-called C-points can be used to control the directionality of the emission of circular dipoles.

11:20 : Invited talk
Optical forces in resonant plasmonic nanostructures and metamaterials
Thomas Koschny
Iowa State University (USA)

I will give an overview of optical forces arising between resonant plasmonic nanoparticles like nanospheres, nanowires and SRRs, and show how either strongly attractive or strongly repulsive forces can be achieved depending on the interplay of electric and magnetic interactions. I will discuss how optical forces in resonant metasurfaces can be used for electromagnetic levitation and to implement nonlinearity and tunability in metamaterials. Finally I will also consider optical forces arising from propagating surface plasmons in graphene.

11:40 : Invited talk
Light-assisted Templated Self Assembly of Plasmonic Materials
N. Huang, L. J. Martinez, E. Jaquay, M. L. Povinelli
University of Southern California (USA)

We demonstrate optical trapping of a closely spaced array of gold nanoparticles in the near field of a photonic crystal. The template is designed so that particle-template forces cooperate with interparticle interactions, producing highly stable assemblies of particles.

12:00 : Plasmon-induced Lorentz forces of nanowire chiral hybrid modes
Matthew Moocarme, Benjamin Kusin, Luat T. Vuong
CUNY Queens College (USA)

The light-induced motion of plasmonic materials differs fundamentally from that of dielectric media. We demonstrate that significant translation and torque arise via Lorentz forces and surface-bound currents when linearly-polarized light illuminates metallic nanowires.

12:15 : Angular momentum manipulation in hybrid plasmonic waveguides
Qin Chen, Wanwan Liu, Lin Jin
Chinese Academy of Sciences (China)

Manipulating spin angular momentum (SAM) and orbit angular momentum (OAM) are promising techniques for boosting the capacitance of telecommunications. Conventional optical elements like polarizers and phase plates, or recently developed metallic antennas have been proposed to manage light beam in free space. Here, we propose a simple method to generate angular momentum in hybrid plasmonic waveguides, leading to compact devices and on chip signal processing capability. Both polarization rotation and OAM are demonstrated in sub-waveguides.

11:00 - 12:20 — ASRC Conference Room

Session 1A6

A bottom-up approach towards metamaterials and plasmonics I

Organized by: Dorota Pawlak and Wounjhang Park

Chaired by: Dorota Pawlak and Wounjhang Park

11:00 : Invited talk
Block Copolymer Self-Assembly: Bottom-up Approach to Metamaterials and Plasmonics
Ulrich Wiesner
Cornell University (USA)

While the fundamental understanding of plasmonics and metamaterials has substantially progressed in the last decade, production of interesting functional structures often is limited to expensive top-down approaches. This contribution will describe how block copolymer self-assembly compatible with solution processing and low-overhead manufacturing can be employed to get to such structures in a bottom-up approach. To that end recent advances will be reviewed on photonic behavior of architectures derived from block copolymers and their co-assembly with inorganic constituents.

11:20 : Invited talk
Linear and Nonlinear Optical Properties of ZnWO4 and Eutectics ZnO/ZnWO4
A. Belardini[1], P. Osewski[2], E. Petronijevic[1], D. Pawlak[2], A. Benedetti[1], M. Centini[1], C. Sibilia[1]
[1] *Universita di Roma La Sapienza (Italy),* [2] *Institute of Electronic Materials Technology (Poland)*

We report an overview of linear and nonlinear optical properties of eutectics ZnO/ZnWo4 and ZnWO4. Filtering properties and polarization dependent properties, with together nonlinear optical in the visible region are presented and.

11:40 : Invited talk
Self-assembly of a plasmonic sensor
George Chumanov, Daniel Willett
Clemson University (USA)

A plasmonic sensor comprised of a two-dimensional array of closely spaced silver nanoparticles was fabricated by the bottom-up self-assembly method. The array exhibited a sharp resonance originating from the plasmon coupling between individual nanoparticles. The position of the resonance was sensitive to changes of the dielectric function in the environment. The sharpness of the resonance together with the differential measuring scheme enabled a highly sensitive refractive index sensor. Record sensitivities were achieved.

12:00 : Invited talk
Plasmonic enhancement of photoluminescence of erbium ions and CdTe quantum dots in nanocomposites with silver nanoparticles
Marcin Gajc, Karolina Korzeb, Hancza Surma, Dorota Pawlak
Institute of Electronic Materials Technology - ITME (Poland)

Metallodielectric materials with plasmonic resonances at optical and infrared wavelengths are attracting interest, due to their potential novel applications in photonics, plasmonics and photovoltaics. Here, we present experimental realisations of volumetric nanocomposites simultaneously co-doped with silver nanoparticles and with erbium ions or CdTe quantum dots. With the addition of silver nanoparticles an increase of photoluminescence of erbium ions and CdTe quantum dots has been observed.

11:00 - 12:35 — NAC 1/203

Session 1A7

Acoustic, elastic and thermal metamaterials I

Organized by: Mohamed Farhat and Sebastien Guenneau

Chaired by: Mohamed Farhat and Sebastien Guenneau

11:00 : Invited talk
Homogenization for short waves in metamaterials and photonic crystals
Tryfon Antonakakis[1], Daniel Colquitt[1], Richard Craster[1], Sebastien Guenneau[2], Ben Maling[1]
[1] *Imperial College London (United Kingdom),* [2] *Aix-Marseille University (France)*

Homogenization theory is often limited to static or quasi-static low frequency and long wave situations and unfortunately these are not really the parameter regimes of most interest in elastic, acoustic or electromagnetic wave settings. Often for photonic crystals and metamaterials created from periodic, or near periodic, arrangements of elementary cells one observes effects due to multiple scattering and/or resonance phenomena. By combining physical ideas based upon Bloch's theorem with mathematical techniques based around the method of multiple scales.

11:20 : Invited talk
Localized Acoustic Spoof Plasmons
M. Farhat[1], Pai-Yen Chen[2], Hakan Bagci[1]
[1] *King Abdullah University of Science and Technology (Saudi Arabia),* [2] *Wayne State University (USA)*

We introduce the concept of localized acoustic surface modes (ASMs) that exhibit the same dispersion cha-

racteristics as those of the surface plasmons in electromagnetics and photonics.

11:40 : Invited talk
Phononic metamaterials: Past, present and future challenges
Johan Christensen
DTU Fotonik (Denmark)

The boost experienced by acoustic and elastic (phononic) metamaterial research during the past years has been driven by the ability to sculpture the flow of sound waves at will. In this talk, I like to review some of the key achievements made in this field and wish to address some of the unanswered questions that might lead to a breakthrough in the future.

12:00 : Large Scale Acoustic Metamaterials for Seismic Waves Attenuation: a Feasibility Study of an Innovative Passive Isolation Strategy based on Transient Dynamic Analysis and Scale Demonstrator
Marco Miniaci[1], Federico Bosia[1], Nicola Pugno[2]
[1] *University of Torino (Italy),* [2] *University of Trento (Italy)*

In this work, the feasibility of an innovative passive isolation strategy for seismic waves based on large scale acoustic metamaterials is numerically investigated and experimentally proved on a scaled demonstrator. Results prove the strategy to be practical for civil structures, demonstrating considerable attenuation of surface acoustic waves via finite element analyses and experimental measurements.

12:15 : Invited talk
Metamaterials, from electromagnetic waves to water waves, bending waves and beyond
Guillaume Dupont[1], Mohamed Farhat[2], Sebastien Guenneau[1], Stefan Enoch[1]
[1] *Aix-Marseille University (France),* [2] *King Abdullah University of Science and Technology (Saudi Arabia)*

We will review our recent work on metamaterials for different types of waves. Transposition of transform optics to water waves and bending waves on plates will be considered with potential applications of cloaking to water waves protection and anti-vibrating systems.

11:00 - 12:35 — NAC 1/211

Session 1A8

Near-field optics and nano-optics

Chaired by: Martin Cryan

11:00 : Invited talk
Drawn THz Hyperlenses - Focusing, Magnication and Artefacts
Boris T. Kuhlmey, A. Tuniz, J. Anthony, X. Tang, S. Fleming, A. Argyros
University of Sydney (Australia)

The fibre drawing technique lends itself well to fabrication of large scale hyperlenses for the THz spectrum and beyond. Here we demonstrate magnification by a factor 8 enabling far-field imaging of sub-diffraction details. However not all components of the near field can be imaged through hyperlenses. We discuss what hyperlenses actually image, and artefacts arising from the coupling to diffracting ordinary waves.

11:20 : Solid-Immersion Microsphere Superlens
Zengbo Wang[1], Bing Yan[1], Liyang Yue[1], Richard Leach[2], Boris Luk'yanchuk[3]
[1] *Bangor University (United Kingdom),* [2] *University of Nottingham (United Kingdom),* [3] *Data Storage Institute (Singapore)*

In 2011, we demonstrated the first 50 nm resolution white-light nanoscope based on a microsphere superlens. Here, we present a new generation design of microsphere superlens: the Solid-Immersion Microsphere Superlens (SIMS), which features higher resolution and flexible maneuverability over the previous design.

11:35 : THz streaking at metal nanotips
Lara Wimmer, Georg Herink, Katharina E. Echternkamp, Sergey Yalunin, Claus Ropers

University of Gottingen (Germany)

We present a streaking-type experiment at single metal nanotips using femtosecond near-infrared pulses and ultrashort terahertz transients. The nanometric confinement and enhancement of the terahertz (THz) near-field lead to characteristic streaking spectrograms resulting from quasi-instantaneous photoelectron acceleration. Our setup enables a phase-resolved measurement of the THz near-field transient, a reshaping of photoelectron energy spectra and the observation of hot carrier dynamics excited in the tip probed by field-induced tunneling.

11:50 : Superlocalization of Brownian Nanoparticles by Holography for 3D Stochastic Optical Mapping
Gilles Tessier[1], Ariadna Martinez-Marrades[1], Jean-François Rupprecht[2]
[1] *Institut Langevin ESPCI (France),* [2] *UPMC (France)*

We present a wide field microscopy technique for the 3D mapping of optical intensity using Brownian gold nanoparticles as local probes. Localization by off-axis holography allows stochastic subwavelength optical characterization in water-based systems.

12:05 : All-dielectric nanoparticle array waveguides
Roman Savelev[1], Dmitry Filonov[1], Alexander Krasnok[1], Polina Kapitanova[1], Andrey Miroshnichenko[2], Pavel Belov[1], Yuri Kivshar[2]
[1] *ITMO University (Russia),* [2] *Australian National University (Australia)*

We propose a novel approach for realizing subwavelength waveguides based on chains of high-index dielectric nanoparticles with both electric and magnetic dipole resonances. We reveal that the electromagnetic energy can be efficiently guided by chain of dielectric nanoparticles even through sharp bends and defects. We confirm experimentally the main concept and our theoretical findings in the microwave frequency range.

12:20 : Terahertz nonlinear transmission studies on ultra-long nanogaps of thin-film aluminium oxide
Joon-Yeon Kim[1], Bong Ju Kang[2], Won Tae Kim[2], Joohyun Park[3], Young-Mi Bahk[1], Jiyeah Rhie[1], Hyeongtag Jeon[3], Fabian Rotermund[2], Dai-Sik Kim[1]
[1] *Seoul National University (Korea),* [2] *Ajou University (Korea),* [3] *Hanyang University (Korea)*

We demonstrate a nonlinear response at nanometer-sized gaps by applying intense terahertz fields. We estimate that fields of over 10 MV/cm can be achieved inside the nanogaps, leading to a giant nonlinearity of the thin insulating layer of aluminium oxide that forms the nanogap. Due to the single-cycle nature of terahertz pulses, peak voltages as high as over 10 V across a 10-nm gap is maintained during a sub-picosecond period of time.

11:00 - 12:30 — ASRC Seminar Room

Session 1A9

Plasmonics and nanophotonics I

Chaired by: Stephan Link

11:00 : The unified lasing conditions for SPASER
V. Pustovit[1], A. Chipouline[2], T. V. Shahbazyan[3], A. M. Urbas[1]
[1] *Air Force Research Laboratory (USA),* [2] *Friedrich Schiller University Jena (Germany),* [3] *Jackson State University (USA)*

We here presents the first unified theory of the response of plasmonic nanoshells assisted by optical gain media. We derive a fundamental equation for calculation of SPASER frequency which we claim to be valid for any type of SPASER physical geometry. We demonstrate that cooperative energy exchange between SPASER modes provide a mechanism that is responsible for the spasing and loss compensation process in the laser resonator.

11:15 : Extremely confined gap surface-plasmon modes probed by electron energy-loss spectroscopy (EELS)
Soren Raza, Sergey Bozhevolnyi

University of Southern Denmark (Denmark)

Applying EELS to ultra-sharp convex grooves in gold, we directly probe extremely confined gap surface-plasmon (GSP) modes excited by swift electrons in nanometer-wide gaps. We reveal the resonance behavior associated with the excitation of the antisymmetric GSP mode for extremely small gap widths, down to approximately 5 nm. We argue that excitation of this mode, featuring very strong absorption, has a crucial role in experimental realizations of non-resonant light absorption by ultra-sharp convex grooves with fabrication-induced asymmetry.

11:30 : Plasmonic nanostructures combined with integrated nano-fiber
Kazuhiro Yamamoto[1], Kenzo Yamaguchi[2], Shiyoshi Yokoyama[1], Akira Otomo[3]
[1]Kyushu University (Japan), [2]Kagawa University (Japan), [3]National Institute of Information and Communications Technology (Japan)

Plasmonic nano-structures show diverse optical functions due to their locality and field enhancement. For effective use of plasmonic nanostructures, efficient excitation, detection and modulation systems are needed. Recently, we proposed the integrated tapered optical nano-fiber structures on substrate for such plasmonic applications. The nano-fiber structures are fabricated using focused ion beam milling and wet etching. In this presentation, we report the numerical analysis and experimental results of these nano-fiber applications for plasmon superfocusing and propagation mode control.

11:45 : Multiplexing Raman Imaging of individual Au Nanobridged Nanogap Particles(Au-NNP) inside a Single Live Cell
Yung Doug Suh
Korea Research Inst. of Chemical Technology (Korea)

Gold NNP(Nanobridged Nanogap Particle)-based multiplexing Raman imaging experiment within a single live cell toward drug screening application of Raman nanoscopy will be presented. Internal nanogap on the order of 1 nm or less plays key role to enhance Raman signal of this Au-NNPs. We could observe trajectories of individual Au-NNPs with different spectra inside a single live cell.

12:00 : Nonequilibrium Plasmons with Gain in Photo-inverted Graphene
Joachim Hamm, Adam Page, Fouad Ballout, Ortwin Hess
Imperial College London (United Kingdom)

Graphene supports TM-polarized plasmons in the THz to mid-IR regime. When pumped into inversion these plasmons couple strongly to the electron/hole plasma via stimulated and spontaneous emission processes. We here present the exact (complex-frequency) dispersion of nonequilibrium plasmons and extract the associated stimulated and spontaneous emission rates. Our results show that graphene plasmons can become amplified under realistic conditions (temperature and collision loss) and provide an ultrafast channel for carrier recombination.

12:15 : Investigation of Hot Electron Photoelectric Conversion Based on Nanospikes Array Metasurface
Zhiyang Qi, Qilong Wang, Yusheng Zhai, Ji Xu, Yan Tu
Southeast University (China)

We investigate hot electron photoelectric conversion based on nanospikes array metasurface nanostructures. The proposed structures consist of heavily doped silicon and ultrathin gold films deposited on nanospikes substrate. Well design features of this plasmonic nanostructure including large localized field enhancement, high absorptivity, broad-band and wide-angel. The spectral bandwidth and photoresponsivity can be manipulated through engingeering the geometric parameter of the metasurface structure.

Conference Group Photo

12:45 - 12:55

Lunch and Exhibit Inspection

12:30 - 14:00

14:00 - 16:00 — Aronow Theater

Session 1A10

Symposium 1: Functional Metastructures and Nanomaterials: Properties, Fabrication and Modeling II

Organized by: Alexander Govorov and Hilmi Volkan Demir

Chaired by: Theobald Lohmuller and Luat Vuong

14:00 : Invited talk
Single-Particle Absorption Spectroscopy of Plasmonic Nanostructures
Stephan Link
Rice University (USA)

Single-particle absorption spectroscopy on strongly scattering plasmonic nanoparticles is investigated by photothermal microscopy with a supercontinuum laser. The absorption spectra are compared to scattering spectra of the same individual gold nanoparticles and correlated with electron microscopy images that characterize the size and shape of the nanostructures. For many applications of plasmonic nanostructures, absorption and scattering cross sections and lineshapes are important to distinguish, possible with single-particle spectroscopy that also removes nanoparticle heterogeneity.

14:20 : Invited talk
Hybrid optical-thermal nanoantennas for enhanced light focusing and radiative cooling
Svetlana V. Boriskina, Lee A. Weinstein, Wei-Chun Hsu, Jonathan Tong, Gang Chen
MIT (USA)

Metal nanoantennas supporting localized surface plasmon resonances have become an indispensable tool in bio(chemical) sensing and nanoscale imaging applications. However, the high plasmon-enhanced electric field intensity in the visible or near-IR range that enables the above applications also causes excessive heating of metal. I will discuss the design of hybrid optical-thermal nanoantennas that simultaneously enable intensity enhancement at the operating wavelength in the visible and reduction of the operating temperature via a combination of reduced absorption and radiative cooling.

14:40 : Invited talk
Lithographic Gold/Polymer Nanorods as Efficient Thermoswitchable Plasmonic Systems for Environmental Sensing Applications
Nordin Felidj[1], M. Nguyen[1], X. Sun[1], E. Lacaze[2], C. Mangeney[1]
[1] *University of Paris Diderot (France),* [2] *UPMC (France)*

We introduce a novel kind of hybrid plasmonic core-shell systems made of lithographic gold nanorods, coated by a thermosensitive polymer shell based on poly(N-isopropylacrylamide). We show that the optical response of the plasmonic hybrid structures is strongly modified upon a variation of the external temperature, due to a physical change of the conformation of the polymer coating. This work provides an important step towards the use of hybrid structures for applications, from nanoscale adhesion to molecular sensing.

15:00 : Invited talk
Active 3D plasmonics
Na Liu
the Max Planck Institute for Intelligent Systems (Germany)

Active control of three-dimensional configuration is one of the key steps towards smart plasmonic nanostructures with desired functionalities. We lay out a multi-disciplinary strategy to create active 3D plasmonic nanostructures, which execute DNA-regulated conformational changes on the nanoscale.

15:20 : Invited talk
DNA-based functional plasmonic particle assemblies
Tim Liedl
Ludwig Maximilians Universitat (Germany)

DNA self-assembly and in particular DNA origami are powerful tools to build complex arrangements of na-

noparticles with nanometer positioning accuracy. The DNA-supported structures assemble at high yields and exhibit designed optical properties such as circular dichroism and electric and magnetic resonances.

15:40 : Invited talk
Multi-Functional Near-Infrared Excited Nanoparticles: Harvesting Light for Growing Applications in Biology
Fiorenzo Vetrone
Quebec University (Canada)

This paper presents the synthesis and surface functionalization of near-infrared excited and emitting nanoparticles and demonstrates their potential in multi-functional hybrid nanoplatforms for biological applications.

14:00 - 16:00 — NAC 0/201

Session 1A11

Structured light in metamaterials II

Organized by: Natalia Litchinitser and Richard Hammond

Chaired by: Natalia Litchinitser and Richard Hammond

14:00 : Invited talk
The singularities of crystal optics, including biaxiality, chirality, dichroism and bianisotropy
Michael Berry
University of Bristol (United Kingdom)

Crystal optics requires many parameters. Navigating in crystal space to reveal the essential optical physics involves three types of singularity. For each point in crystal space, there are singularities in the two-dimensional wave-direction space. (1) are degeneracies: the optic axes, namely Hamilton-cone intersections of the index surfaces, or (with absorption) branch points. (2) C points and (3) L lines, where an eigenpolarization is purely circular or purely linear. In crystal space, these singularities interact in topologically identifiable ways.

14:20 : Invited talk
Gate-tunable conducting oxide metasurfaces
Yao-Wei Huang[1], Ho Wai Howard Lee[2], Ruzan Sokhoyan[2], Krishnan Thyagarajan[2], Seunghoon Han[2], Georgia Papadakis[2], Din Ping Tsai[3], Harry A. Atwater[2]
[1] *California Institute of Technology (Taiwan),* [2] *California Institute of Technology (USA),* [3] *National Taiwan University (Taiwan)*

We demonstrate an electrically tunable metasurface element capable of providing phase shifts of nearly 2Pi based on conducting oxide field-effect dynamics. We further show the controllable diffraction patterns by selective gating the nanoantenna array to a 2-level or 4-level grating system with different applied biases. This work provides insight towards dynamic beam steering, reconfigurable imaging, and high capacity data storage based on electrically tunable metasurfaces.

14:40 : Invited talk
Three-Dimensional Metasurface Carpet Cloak
Xiang Zhang, Xingjie Ni
University of California (USA)

We show that ultrathin metasurfaces can be used for creating transformation optics devices by its phase modulation capability. We here experimentally demonstrate a three-dimensional metasurface carpet cloak using the concept of reflection phase manipulation. We design carpet cloak so that at each local point on the interface of the cloaked region the phase of the light scattered by the interface is the same as that reflected from a flat mirror.

15:00 : Invited talk
Active Dielectric and Metallic Metasurfaces: Strong Coupling, Tuning and Nonlinearities

Igal Brener
Sandia National Labs (USA)

Metasurfaces, or arrays of 2D metamaterial resonators can couple efficiently to emitters and several excitations in semiconductors. I will present an overview of active metasurfaces, both metallic and dielectric, and different coupling mechanisms that can be used for active tuning and enhancement of optical nonlinearities.

15:20 : Invited talk
Left-handed optomechanics with dielectric metasurfaces
Davit Hakobyan[1], **Etienne Brasselet**[2]
[1] *University of Bordeaux (France),* [2] *University of Bordeaux (France)*

Counter-intuitive optomechanical effects using dielectric metasurfaces is reported. It is shown experimentally that light-scattering from a dielectric material with subwavelength features can lead to the angular analog of so-called negative optical forces.

15:40 : Invited talk
Structured materials and structured light for photonics
Robert Boyd, M. Zahirul Alam, Peter Banzer, Saumya Choudhary, Israel De Leon, Matthew Horton, Ebrahim Karimi, Sebastian A. Schulz, Jeremy Upham
University of Ottawa (Canada)

We review recent work aimed at studying the optical properties of structured materials. We are particularly concerned with determining how the nonlinear optical properties of materials depend on the nature of the structuring. We also explore specific examples of structured surfaces. For instance, we study the nonlinear optical properties of a surface plasmon polariton, and we show how to form a metasurface that will convert a Gaussian laser beam to one that carries orbital angular momentum.

14:00 - 16:20 — NAC Ballroom

Session 1A12

Metamaterials and negative index materials I

Chaired by: Steven Weiss

14:00 : Keynote talk
Photonic Hypercrystals
Evgueni Narimanov
Purdue University (USA)

Photonics hypercrystals represent a new class of artificial optical media. These hyperbolic metamaterials, with periodic spatial variation of dielectric permittivity on subwavelength scale, combine the features of optical metamaterials and photonic crystals.

14:30 : Invited talk
A New Hollow-H-Shaped Negative Refractive Index Metamaterial
S. S. Islam, M. R. I. Faruque, M. T. Islam
Universiti Kebangsaan Malaysia (Malaysia)

In this paper, a new double negative metamaterial unit cell is presented that was designed on Rogers 3010 substrate material. It displays negative refractive index property with negative permittivity and permeability simultaneously in the multi-band range. In this design, a composite Hollow-H-shaped' unit cell structure was constructed. The proposed design also display resonances in the multi-band frequency range with negative refractive index property of wider bandwidth, when the Rogers RT 6010 is employed instead of Rogers 3010 substrate material.

14:50 : Evidence for the mechanical effect of co-moving potentials on atomic trajectories, approaching the meta-medium regime
Franck Correia[1], **Thierry Taillandier-Loize**[1], **Gabriel Dutier**[1], **Francisco Perales**[1], **Nathalie Fabre**[1], **Jac-**

ques Baudon[1], Martial Ducloy[2], Mohamed Boustimi[3], Valerij Bocvarski[4]
[1] *Paris 13 University (France),* [2] *Nanyang Technological University (Singapore),* [3] *Umm Al Qura University (Saudi Arabia),* [4] *Institute of Physics (Serbia)*

The effect of a special type of time-and-space dependent (so-called co-moving) potential on atomic trajectories is experimentally investigated. Through the use of a beam of argon metastable atoms (Ar* 3P2) passing through a magnetic field alternated in space and modulated in time, negative refraction of the wave packet and deviation of trajectories are expectable with this kind of potential.

15:05 : Finite temperature quantum-electrodynamical generalized responses for relativistic free electrons

Carlos A. A. de Carvalho
Universidade Federal do Rio de Janeiro (Brazil)

We compute finite temperature electromagnetic responses of a relativistic free electron gas from quantum electrodynamics. Our field theory approach yields polarizations and magnetizations as functions of both electric and magnetic fields. In the non-relativistic limit, expressions reduce to well-known results: the Lindhard and Thomas-Fermi formulae, a sum of Pauli and Landau expressions for the magnetic susceptibility, and Drude responses in the long wavelength limit. Generalized expressions should be relevant for astrophyiscal observations, as well as in synchrotron environments.

15:20 : Efficient reflective linear polarization converter based on L-shaped metallic antenna

Julien Jaeck[1], Quentin Levesque[1], Mathilde Makhsiyan[1], Patrick Bouchon[1], Fabrice Pardo[2], Riad Haidar[3], Jean-Luc Pelouard[2]
[1] *Onera - The French Aerospace Lab (France),* [2] *Lab. de Photonique et de Nanostructures (France),* [3] *Onera, The French Aerospace Lab (France)*

This paper demonstrate both theoretically and experimentally that a metasurface of L-shape metal-insulator-metal antennas is a highly efficient linear polarization converter and angularly independent. The nanoantenna geometries are controlled in order to produce a one micrometer wide band in the medium infrared region with over 95 percent of mean polarization conversion ratio. This effect is due to two localized resonances in the L-shaped arms of the antenna. Further engineering could be demonstrated by combining different antennas inside the period.

15:35 : Nano-patterning of active hyperbolic metamaterials for enhanced radiative decay

T. Galfsky[1], E. E. Narimanov[2], V. M. Menon[1]
[1] *City University of New York (USA),* [2] *Purdue University (USA)*

Emitters embedded inside HMM have been shown to experience enhanced radiative decay rate. In this work a patterned hyperbolic metamaterial embedded with an active layer of quantum dots forms an array of nano-resonators which exhibit enhanced radiative decay rate and out-coupling.

15:50 : Flexible Printed Chipless RFID Tag Using Metamaterial-Split Ring Resonator

M. E. Jalil, M. K. A. Rahim, N. A. Samsuri, R. Dewan
University Technology Malaysia (Malaysia)

In this paper, an 8-bits passive chip-less RFID using modified complementary split ring resonator (MCSSR) which is one of type metamaterial structure is introduced which operates from 3 to 7.5 GHz. The flexible chipless tag is designed on Polyethyle Terephtalate (PET) substrate with overall dimension of 25 mm x 20mm. The 8 bits chipless tag with 4 ring resonators is investigated to evaluate the bit performance.

16:05 : Low-profile metamaterial-based L-band antennas

S. N. Burokur[1], A.-C. Lepage[2], S. Varault[2], X. Begaud[1], G.-P. Piau[3], A. de Lustrac[1]
[1] *Paris Sud University (France),* [2] *ESPCI ParisTech (France),* [3] *Airbus Group Innovations (France)*

The aim of the present contribution is to show that metasurfaces like Reactive Impedance Surfaces (RIS) and Artificial Magnetic Conductors (AMC) can be efficiently used in the design of low-profile circularly-polarized L-band antennas. We present the design, simulation and characterization of the compact and low-profile antennas. In order to prove the benefit of these two solutions, they will be compared to a circularly-polarized microstrip patch antenna using the same materials.

14:00 - 16:00 — NAC 1/202

Session 1A13

Optical Forces and Manipulation of Momentum in Metamaterials and Plasmonics II

Organized by: Philippe Tassin and Vincent Ginis

Chaired by: Philippe Tassin and Vincent Ginis

14:00 : Invited talk

Enhanced optical forces in plasmonic and metamaterial nanostructures

Xiang Zhang[1], **Xiaodong Yang**[2]
[1] *University of California (USA),* [2] *Missouri University of Science and Technology (USA)*

Optical forces generated from the gradient of light field have been extensively employed to realize exciting applications for light-matter interactions, such as optical trapping and transport, optomechanical energy conversion, and sensors. We will discuss our recent progress in achieving significantly enhanced optical forces using several new types of plasmonic and metamaterial nanostructures, including asymmetric plasmonic antennas for Brownian ratchet, giant forces in hybrid plasmonic waveguides and hyperbolic metamaterial slot waveguides, and zero forces in slot waveguides of epsilon-near-zero metamaterials.

14:20 : Invited talk

Towards a Precise Measurement of Surface Plasmon Optical Forces by Use of a Calibrated Evanescent Wave

Lulu Liu[1], **Alexander Woolf**[1], **A. Rodriguez**[2], **Simon Kheifets**[1], **Federico Capasso**[1]
[1] *Harvard University (USA),* [2] *Princeton University (USA)*

Tracking the Brownian Motion of a trapped microsphere can enable precise measurement of sub-piconewton surface forces. This technique, however, is severely undermined by the nearby presence of a metal, which distorts optical fields used to trap and track the colloid. In order to make the first precise measurement of the interaction forces between a colloid and a propagating surface plasmon, we introduce a novel metallic antireflection coating and a calibration technique for absolute position particle tracking.

14:40 : Invited talk

Optical Force in Plasmonic and Metamaterial Systems

Shubo Wang[1], **Kun Ding**[1], **Jack Ng**[2], **C. T. Chan**[1]
[1] *Hong Kong University of Science and Technology (Hong Kong),* [2] *Hong Kong Baptist University (Hong Kong)*

We present analytical formula for the optical force acting on a chiral particle. The behavior of chiral particles is qualitatively different from achiral particles due to chirality dependent terms which couple mechanical linear momentum and optical spin angular momentum. We show that such chirality induced coupling can serve as a mechanism to achieve optical pulling force. In addition, it can induce a sideway force that can laterally push particles with opposite chirality to the opposing side of an interface.

15:00 : Invited talk

High Efficiency Metasurface Holography

Thomas Zentgraf[1], **Holger Muhlenbernd**[1], **Guoxing Zheng**[2], **Mitchell Kenney**[2], **Guixin Li**[3], **Shuang Zhang**[2]
[1] *University of Paderborn (Germany),* [2] *University of Birmingham (United Kingdom),* [3] *Hong Kong Baptist University (Hong Kong)*

Plasmonic metasurfaces combine strong light-matter-interaction with high design flexibility and functionality. Here, we demonstrate the potential of ultrathin metasurfaces for use with high efficiency, high resolution holography and beam shaping. The concept is based on a topological phase change of light passing through the metasurfaces. In such a way broadband phase masks with efficiencies surpassing 80 percent in the visible range can be obtained.

15:20 : Invited talk

Optical Forces in Plasmonic and Dielectric Metamaterials

Eric Plum, Jun-Yu Ou, Artemios Karvounis, Weiping Wu, Kevin F. MacDonald, Nikolay I. Zheludev

University of Southampton (United Kingdom)

We demonstrate that nanoscale deformation of reconfigurable metamaterials with light leads to giant optical nonlinearities in plasmonic and dielectric metamaterials. While effective optical nonlinearities already many orders of magnitude greater than in natural media are experimentally observed in plasmonic nanomechanical structures, modelling suggests that the underlying optical forces can be even larger within dielectric metamaterials, promising phenomena such as optomechanical bistability and strongly directionally asymmetric transmission.

15:40 : Invited talk
Nonlinear effects in torsional metamaterials
Ilya Shadrivov
Australian National University (Australia)

Recently, we introduced a new generation of nonlinear metamaterials called magnetoelastic metamaterials. Here we focus on torsional type of magnetoelastic metamaterials, that have extremely strong nonlinearity, and we demonstrate a number of prominent nonlinear effects, including self-oscillations, chaos and spontaneous symmetry breaking.

14:00 - 16:00 — ASRC Conference Room

Session 1A14

A bottom-up approach towards metamaterials and plasmonics II

Organized by: Dorota Pawlak and Wounjhang Park

Chaired by: Anatoly Zayats and Virginie Ponsinet

14:00 : Invited talk
Linear and Nonlinear Plasmonics
Augustine Urbas
Air Force Research Lab (USA)

Fundamental challenges in understanding and implementation still loom in the arena of materials for nanoscale optics and plasmonics. Furthermore, significant limitations for application in nonlinear optics are present in noble metal plasmonic structures due to their stability under optical and thermal load and their properties in other, equally interesting and potentially more useful, spectral regions. In this presentation we develop a connection between the properties of plasmonic materials and opportunities for their use in challenging environments.

14:20 : Invited talk
Building multiscale optical metamaterials from non-conventional active and switchable nanoscale elements
Johann Toudert[1], Javier Martin Sanchez[2], Rosalia Serna[1]
[1] *Instituto de Optica (Spain),* [2] *Johannes Kepler University Linz (Austria)*

We demonstrate the bottom-up engineering of active semiconductor/rare earth-ion nano-hybrids and switchable polaritonic/plasmonic nano-bismuth structures. We show that these non-conventional nanoscale elements can be assembled into multiscale optical metamaterial architectures for integrated nanophotonic solutions with lighting, light modulation and ultra-sensitive environmental sensing functionalities.

14:40 : Invited talk
Metallodielectric eutectic composite for plasmonic applications
Katarzyna Sadecka[1], M. Gajc[1], H. B. Surma[1], J. Toudert[2], D. A. Pawlak[1]
[1] *Institute of Electronic Materials Technology (Poland),* [2] *Laser Processing Group-Instituto de Optica (Spain)*

Metallodielectric composites are very interesting from the point of view of metamaterials and plasmonics. For the fabrication of self-organized metallodielectric micro/nanostructures, one particularly promising approach is based on the directional solidification of eutectics. Here we demonstrate a bulk three-dimensional nano-

plasmonic eutectic composite which was obtained by bottom-up approach. This material exhibits localized surface plasmon resonance (LSPR) at visible wavelengths.

15:00 : Invited talk
Synthesis and Applications of Confined Plasmonic Nanoparticles in Hollow Structures
Miguel A. Correa-Duarte
Universidade de Vigo (Spain)

The synthetic architectures of complex nanostructures, including multifunctional hollow capsules, are expected to play key roles in many different applications, such as drug delivery, photonic crystals, nanoreactors, and sensing. Implementation of novel strategies for the fabrication of such materials is needed because of the infancy of this knowledge, which still limits progress in certain areas.

15:20 : Invited talk
Microfluidic synthesis of acoustic silica microresonators: evidence for a metamaterial with negative refractive index
Simon Raffy, Benoit Mascaro, Thomas Brunet, Jacques Leng, Olivier Mondain-Monval
University of Bordeaux (France)

Using a microfluidic device, we synthesized monodisperse porous silica particles, which act as microresonators when dispersed in a gel phase. The final dispersion presents a broad frequency range over which the phase velocity and the refractive index are negative.

15:40 : Invited talk
Two Dimensional Nanooptics with Graphene Plasmons
Pablo Alonso-Gonzalez[1], Alexey Nikitin[1], F. Golmar[1], A. Centeno[2], A. Pesquera[2], S. Velez[1], J. Chen[1], F. Koppens[3], A. Zurutuza[2], F. Casanova[1], L. E. Hueso[1], Rainer Hillenbrand[1]
[1] CIC nanoGUNE Consolider (Spain), [2] Graphenea SA (Spain), [3] ICFO-Institut de Ciencies Fotoniques (Spain)

Here, I will present a versatile platform technology that, based on resonant optical antenna structures, allows for an efficient coupling of incoming light into propagating graphene plasmons. More importantly, I will show that these antennas and the use of spatial conductivity patterns (e.g. double layer graphene patches) also allow for controlling the graphene plasmons wavefronts, constituting an essential step for the development of graphene plasmonic circuits.

14:00 - 16:00 — NAC 1/203

Session 1A15

Acoustic, elastic and thermal metamaterials II

Organized by: Mohamed Farhat and Sebastien Guenneau

Chaired by: Mohamed Farhat and Sebastien Guenneau

14:00 : Invited talk
Acoustic transparency and opacity using Fano Interferences in Metamaterials
Abdelkrim Khelif[1], A. Elayouch M. Amin[2], M. Farhat[2], M. Addouche[1], H. Bagci[2]
[1] Franche-Comte University (France), [2] King Abdullah University of Science and Technology (Saudi Arabia)

We investigate both experimentally and theoretically how to generate the acoustical analogue of the Electromagnetically Induced Transparency. This phenomenon arises from Fano resonances originating from constructive and destructive interferences of a narrow discrete resonance with a broad spectral line or continuum. Measurements were realized on a double-cavity structure by using a Kundt's Tube. Transmission properties reveal an asymmetric lineshape of the transmission that leads to acoustic transparency.

14:20 : Invited talk
Locally resonant acoustic metamaterials beyond homogenization: subwavelength control of waves, slow waves, negative index and other exotic phenomena

Fabrice Lemoult, Nadege Kaina, Mathias Fink, Geoffroy Lerosey
ESPCI ParisTech (France)

Starting from the very simple example of a soda can metamaterial (an acoustic medium made of Helmholtz resonators), we explain the propagation of waves in locally resonant media without claiming homogenized parameters. This allows to highlight the importance of multiple scattering even at this deep subwavelength scale where usually the quasi-static approximation is performed. This then permits to envisage exotic phenomena such as subwavelength control of waves, slow waves or even negative refraction with a single negative medium.

14:40 : Invited talk
Total absorption in waveguides by admittance conjugation
Vincent Pagneux
LAUM - CNRS Le Mans (France)

We present a method to achieve perfect total absorption for a wall with local admittance (thin coating) by putting inhomogeneities in front of the wall. The first step, using the eigenvectors of the Dirichlet-to-Neumann Admittance operator, is to construct a solution with only outgoing waves from a wall with a local gain admittance. Then, by conjugating this solution, we get a new solution where the incident wave is perfectly absorbed by a wall with a local absorptive admittance.

15:00 : Invited talk
Spectral Effectiveness of Engineered Thermal Devices in the Frequency Regime
David Petiteau[1], Sebastien Guenneau[1], Michel Bellieud[2], Myriam Zerrad[1], Claude Amra[1]
[1] *Institut Fresnel (France),* [2] *Montpellier University (France)*

We analyse several thermal devices such as thermal cloaks or concentrators designed via different geometric transforms. We evaluate quantitatively in the frequency regime the effectiveness of these thermal devices through the calculation of the standard deviation of the isotherms and of the heat flux distribution. Through homogenization process, we also study the effectiveness of engineered multilayered thermal devices using concentric or orthoradial layers. Thus, we determine the number of layers required to approach ideal thermal devices effectiveness.

15:20 : Invited talk
Towards multi-physical fields camouflage using natural materials
Cheng-Wei Qiu, Tianzhi Yang, Tiancheng Han, Xue Bai, Baowen Li, John Thong
National University of Singapore (Singapore)

Manipulation of various physical fields, including optics, electromagnetics, acoustics, thermotics, etc. through different materials has been a long-standing dream for many researchers over the decades. Analogous to invisible cloak and wave-dynamic illusion, thermal metamaterials can potentially transform an actual perception into a pre-controlled perception, thus empowering unprecedented applications in thermal cloaking and camouflage. Here we report our recent works about thermal cloak and multi-physics invisible sensor. The approach can be readily extended and applied in other static fields.

15:40 : Invited talk
Geometric phase and topological transition point in acoustic systems
M. Xiao, G. Ma, Z. Yang, P. Sheng, Z. Q. Zhang, C. T. Chan
Hong Kong University of Science and Technology (Hong Kong)

We constructed a phononic crystal with a topological transition point in the acoustic band structure where the frequencies of an odd mode and an even mode become degenerate. The Zak phases of the bulk bands change upon a shift in system parameters across this transition point. This is an analog of band inversion behavior in the acoustic system. We present a theoretical framework, together with two methods to experimentally determine the Zak phase in this acoustic system.

14:00 - 16:10 — NAC 1/211

Session 1A16

Ultrahigh frequency transport and terahertz plasmonics in nanoscale structures, metamaterials, and 2D materials II

Organized by: Sergey Rudin and Michael Shur

Chaired by: Sergey Rudin and Michael Shur

14:00 : Invited talk

Noncentrosymmetric Plasmon Modes in a Two-Dimensional Plasmonic Crystal

Viacheslav V. Popov

Kotelnikov Institute of Radio Engineering and Electronics (Russia)

The plasmon modes in a two-dimensional plasmonic crystal lacking the inversion symmetry can be used for terahertz detection by generation of the plasmon-photogalvanic current. It is shown that the plasmon modes without inversion symmetry can be excited due to the resonant interaction of different plasmon modes in the planar plasmonic crystal with a noncentrosymmetric unit cell.

14:20 : Invited talk

Time Response of Plasmonic Terahertz Detectors

Greg Rupper[1], Sergey Rudin[1], Michael Shur[2]

[1] *U.S. Army Research Laboratory (USA),* [2] *Rensselaer Polytechnic Institute (USA)*

The plasma wave response of the two-dimensional electron gas of a HEMT transistor can be used for terahertz detection. In this work, we evaluate the time response of these detectors using a hydrodynamic model that includes the effects of pressure and viscosity. We evaluate and compare the impulse response of the HEMT channel and the response of the detector to an amplitude modulated signal. Our results establish the ultimate response time for these detectors.

14:40 : Invited talk

Plasmonic Enhancement of Graphene Heterostructure based Terahertz Detectors

V. Ryzhii[1], Vladimir Mitin[2], T. Otsuji[3], V. Ya. Aleshkin[4], A. A. Dubinov[4], M. Ryzhii[5], M. S. Shur[6]

[1] *Institute of Ultra-High-Frequency Semiconductor Electronics (Russia),* [2] *University at Buffalo (USA),* [3] *Tohoku University (Japan),* [4] *Lobachevsky State University (Russia),* [5] *University of Aizu (Japan),* [6] *Rensselaer Polytechnic Institute (USA)*

We review recent advances in double-graphene-layer (D-GL) graphene plasmon heterostructures for terahertz (THz) detectors. When the band offset is aligned to the THz photon energy, the D-GL structure can mediate photon-assisted resonant tunneling through a thin tunnel barrier layer separating the GLs, resulting in the resonant detection of the THz radiation. The cooperative double-resonant excitation with structure-sensitive graphene plasmons gives rise to extremely high gain and/or responsivity in the THz detectors.

15:00 : Invited talk

Graphene-based devices for Terahertz photonics

Alessandro Tredicucci

University of Pisa and NEST-CNR (Italy)

Graphene, a single-layer of carbon atoms arranged in a two-dimensional honeycomb lattice is nowadays attracting considerable attention for a variety of photonic applications, including fast photodetectors, transparent electrodes in displays and photovoltaic modules, and saturable absorbers. I will illustrate the realization of THz detectors based on antenna-coupled graphene field-effect transistors (FETs), and discuss the development and applications of electrically switchable metamaterial devices.

15:20 : Invited talk

Metamaterial and Metastructure Devices Research for High Frequency RF-Photonics and THz Applications

Weimin Zhou, Daniel Shreiber, Gerard Dang, Monica Taysing-Lara, Grace Metcalfe, Eric Ngo, Matt Ivill, Melanie W. Cole

US Army Research Laboratory (USA)

This paper summarizes our in-house research on novel metamaterials and metastructures with new opto-

electronic properties and use them to design and fabricate devices with new functionalities such as Si-based slow-light, low-loss high-contrast metastructure hollow-core waveguides, tunable 3D split-ring metamaterial-based THz modulators, etc. These devices will provide basic building blocks for future chip-scale semiconductor opto-electronic integrated circuits, and provide new capabilities for ultra-high frequencies RF systems as well as THz systems.

15:40 : Design, Fabrication and Characterization of an Active Single-Negative Tunable Metamaterial Structure in the THz Spectrum
Daniel Shreiber, Weimin Zhou, Gerard Dang, Monica Taysing-Lara, Grace Metcalfe, Eric Ngo, Mathew Ivill, Melanie Cole
US Army Research Lab (USA)

We describe design, fabrication and characterization of a novel active metamaterial structure in the THz spectrum. The proposed surface is based on incorporation of Ba0.6Sr0.4TiO3 (BST) thin film whose dielectric constant can be altered by applying DC bias. Verified numerical model that predicts a resonant frequency as a function of BST dielectric constant is presented. The resonant frequency shift due to applied DC bias is experimentally verified, compared with the model and other benefits are discussed.

15:55 : THz Plasmonics for Testing VLSI under Bias
Michael Shur[1], John Suarez[2], Greg Rupper[3], Sergey Rudin[3], Meredith Reed[3]
[1]Rensselaer Polytechnic Institute (USA), [2]U.S. Army CERDEC (USA), [3]U.S. Army Research Laboratory (USA)

We present simulation and measurement results demonstrating the application of the THz excited decaying plasma waves in field effect transistors for testing silicon VLSI under bias. In agreement with the data and our model, the direct current response induced by the THz wave is strongly affected by the gate leakage current. This technique has potential for non-destructive VLSI testing and evaluation.

14:00 - 16:20 — ASRC Seminar Room

Session 1A17

Plasmonics and nanophotonics II

Chaired by: Stefan Maier and Kristjan Leosson

14:00 : Invited talk
Large Spontaneous Emission Rate Enhancement using Slot-Antenna Coupled WSe2 Monolayers
Michael Eggleston, Sujay Desai, Kevin Messer, Surabhi Madvapathy, Jun Xiao, Seth Fortuna, Xiang Zhang, Eli Yablonovitch, Ali Javey, Ming Wu
University of California (USA)

In this talk I will explore the use of slot-antennas to efficiently enhance spontaneous emission rates in 2D semiconductors. Experimental results will be presented showing a 340x rate increase for WSe2 monolayers coupled to a cavity-backed slot-antenna with 1ps carrier lifetimes.

14:20 : Photon-Spin Drag on a Metasurface
Xiang Zhang, Xingjie Ni
University of California (USA)

Strong spin-orbit interaction can be induced by strong light bending effect on a metasurface - an optically thin layer of plasmonic elements which have unique property of locally tailoring the field amplitude and phase at the nanoscale accompanied by dramatic light confinement. We show that the photon spin angular momentum can be directly transferred to collective motion of electrons on a conductive metasurface with this interaction, revealing as a photon-spin drag effect.

14:35 : Bowtie Nanocavities for Single Plasmon Lasing Devices
Claire Deeb[1], Ankun Yang[2], Yi Hua[2], Teri Odom[2]
[1]Laboratoire de Photonique et de Nanostructures LPN-CNRS (France), [2]Northwestern University (USA)

We demonstrate a three-dimensional (3D) active bowtie nano-resonator that has directional emission, high radiative efficiency, effective cavity feedback, ultrafast response, and room-temperature operation. The 3D bowtie structure consists of a dimer of Au nanoparticles with a gap size of tens of nanometers, arranged in a pattern with tunable periodicity and embedded in dye solution.

14:50 : Resonant Enhancement of Near UV Fluorescence by Aluminum Nanoantenna Arrays
Neciah Dorh, J. Stokes, A. Sarua, M. J. Cryan
University of Bristol (United Kingdom)

This paper demonstrates up to 23-fold increase in fluorescence emission in the near UV from aluminum nanoantenna arrays. A series of aluminum nanorod arrays were fabricated using Focused Ion Beam (FIB) milling and subsequently spin-coated with Exalite 392E dye. Scanning photoluminescence measurements revealed a significant increase in the peak emission over the nanoantennas compared to the surrounding un-patterned aluminum or glass.

15:05 : Studying ultrafast dynamics of advanced optical nanoantennas by photoemission electron microscopy
Matthias Falkner[1], Thomas Kaiser[1], Jing Qi[1], Michael Steinert[1], Christoph Menzel[1], Carsten Rockstuhl[2], Thomas Pertsch[1]
[1] *Friedrich Schiller Universitat (Germany),* [2] *Karlsruhe Institute of Technology (Germany)*

We theoretically and experimentally investigate the ultrafast dynamics of circular plasmonic disc nanoantennas with the help of photoemission electron microscopy. The investigations show detailed insights into the spatio-temporal properties of the plasmonic resonance mechanism without the need for any disturbing interacting probe.

15:20 : Active plasmon and Wood's anomaly sensor for carbon dioxide gas
Kenzo Yamaguchi[1], Masamitsu Fujii[2]
[1] *Kagawa University (Japan),* [2] *Toba National College of Maritime Technology (Japan)*

We have achieved electrically tuned the surface plasmon resonance wavelength at visible range with controlling grating gaps structure by the numerical simulation. In the infrared range, we have also observed unusual diffraction due to Wood's anomaly and showed that the resonance wavelength can be shifted using the structure. Moreover, we decided the relationship between these resonances and structural conditions. Finally, we demonstrated for carbon dioxide gas sensing applications using the Wood's anomaly resonance.

15:35 : Optical Properties of Surface Phonon Polaritons in Asymmetric Silicon Carbide Nanopillars
J. G. Tischler[1], Chase Ellis[1], O. J. Glembocki[1], D. N. Chigrin[2], F. J. Bezares[3], R. Kasica[4], L. Shirey[1], J. C. Owrutsky[1], J. D. Caldwell[1]
[1] *U.S. Naval Research Laboratory (USA),* [2] *RWTH Aachen University (Germany),* [3] *ICFO-The Institute of Photonic Sciences (Spain),* [4] *Center for Nanoscale Technology (USA)*

Interactions between infrared light and polar dielectrics yield fundamental collective oscillations of lattice charges (surface phonon polaritons) that give rise to plasmonic-like effects with low optical losses. We explore such excitations through polarized, mid-infrared spectroscopy performed on asymmetric, rectangular silicon-carbide nanopillar arrays. Spectra reveal over 8 resonances that strongly depend upon the nanopillar geometry and incident polarization. Measurements are in excellent agreement with finite element simulations, which provide insights into the nature of the surface phonon polariton modes.

15:50 : Fine tune of pulley-type ring resonators
Chii-Chang Chen, Dong-Po Cai, Chien-Chieh Lee
National Central University (Taiwan)

We show the theoretical and experimental results of the pulley-type microring in which we propose to enlarge the propagation constant difference between the bus waveguide and the ring waveguide to enhance the Q-factor. The experimental result shows that the Q-factor can be over 170,000 by tuning the bus waveguide width.

16:05 : Fano resonance induced by magnetic toroidal moment in hybrid plasmonic-dielectric nanostructures
Jun-Jun Xiao[1], Qiang Zhang[1], Dezhuan Han[2], L. Gao[3]
[1] *Harbin Institute of Technology (China),* [2] *Chongqing University (China),* [3] *Soochow University (China)*

Fano resonance is ubiquitous in plasmonic structures, resulting from interference between a bright mode and a dark mode. Toroidal dipole resonances, which are in general of high-Q, represent an important response in toroidal metamaterials. We study the Fano resonance effect arising from the toroidal resonances in various plasmonic-dielectric nanostructures. It is shown showed that extinction, transmission, and photoluminescence can feature the Fano interaction which is important for the macroscopic properties, enabling efficient design of unique photonic nanostructures and metamaterials.

Coffee Break and Exhibit Inspection

Session 1P2

Poster session II

16:00 - 16:40

P1: A statistical based optimisation routine for the design of,metamaterial structures
Patrick Bradley
Dublin City University (Ireland)

Due to the increased complexity of Metamaterials geometric structures, exacerbated by the increased interest in generating inhomogeneous and anisotropic metamaterials, direct optimisation of these designs using conventional approaches often becomes impractical and limited. In order to alleviate this issue, we propose an alternative optimisation approach which exploits the Kriging methodology in conjunction with an adaptive sampling plan to simultaneously optimise multiple conflicting objectives.

P2: Metamaterials built by self-folding split ring resonators
Che-Chin Chen[1], Takuo Tanaka[2], Atsushi Ishikawa[2], Ming-Hua Shiao[1], Hai-Pang Chiang[3], Din Ping Tsai[4]
[1] *Instrument Technology Research Center - NARlabs (Taiwan),* [2] *Metamaterials Laboratory - RIKEN (Japan),* [3] *National Taiwan Ocean University (Taiwan),* [4] *Research Center for Applied Sciences - Academia Sinica (Taiwan)*

We present several types of metamaterials (MMs) constructed by three dimensional split ring resonators (3D SRRs). The 3D SRR was assembled from a two dimensional (2D) template by means of a metal-stress driven self-folding method. The desired metamaterials such as infrared-, uniaxial isotropic-, and toroidal MMs can thus be fabricated through arranging the sizes and positions of 2D templates appropriately.

P3: Compact triple-band metamaterial inspired monopole antennas
Yongjun Huang, Xuefeng Zhao, Kaimin Wu, Jian Li, Guangjun Wen
University of Electronic Science and Technology of China (China)

Here we present a comparison analysis on the single loop resonator (SLR) inspired triple-band monopole antennas. Two configurations with rectangular and circular shaped radiation patches are presented. Simultaneously, two feed techniques with coplanar waveguide and microstrip feeds are performed to drive the antennas. And the conventional planar monopole antennas without the SLRs are also analyzed comparatively. Numerical and experimental methods are performed to demonstrate and discuss the proposed designs.

P4: A coplanar wideband antenna based on Metamaterial Refractive Surface
Ridha Salhi, Mondher Labidi, Fethi Choubani
Innov'Com-Sup'Com (Tunisia)

In this paper we firstly present a wide band forked antenna. It can be useful for on-body applications because of its small size. Then, the metamaterial reflective surface(MRS), which is very efficient as a filter, is used in many simulations to optimize the antenna's performance. Finally, a comparative study between different configurations of the fork antenna with MRS is presented.

P5: Design and simulation of Metamaterial Refractive Surface
Ridha Salhi, Mondher Labidi, Fethi Choubani
Innov'Com-Sup'Com (Tunisia)

This paper investigates the performance of metamaterial refractive surface(MRS),where its properties and

geometrical conguration are optimized to operate in the frequency range from 1 GHz to 15 GHz. Indeed, the performance of the considered MRS is studied for dierent parameters, such as periodicity, substrate type and MRS width.

P6: Graphene Magnetite Polymeric Nanocomposites (GMPN)-Array Sensor for Human Brain Tumor Detection Using Specific Absorption Rate (SAR) Technique

Mohd A. B. Jamlos[1], Abdul H. Ismail[2], Mohd F. Jamlos[1]
[1] *Universiti Malaysia Perlis - UniMAP (Malaysia),* [2] *Universiti Malaysia Perlid (Malaysia)*

GMPN-Array sensor is successfully detecting human brain tumor based on SAR technique. The sensor consists of graphene as the radiating element and PDMS Ferrite as the substrate to realize ultra-wide band radiation (2.5 GHz-12.2 GHz) with high energy (2.5dB-6.7dB) in microwave frequency ranges. Amount of energy absorbed by the human brain indicated the present of tumor. Human brain with tumor absorbed more energy and recorded higher SAR value (2.56 W/kg) compared with human brain without tumor (1.07 W/kg).

P7: Performances Analysis of Cylindrical Monopole Plasma Antenna

Hajar Jaafar[1], Mohd Tarmizi Ali[1], Ahmad Nazri Dagang[2], Hanisah Mohd Zali[1], Musfirah Hilmi[1]
[1] *Universiti Teknologi MARA (Malaysia),* [2] *Universiti Malaysia Terengganu (Malaysia)*

This paper presents the analysis of cylindrical monopole plasma antenna with 3 different gases. Three plasma antennas were fabricated using pyrex glass tubes with length 160mm, diameter 10mm and thickness 1mm. The antennas contain 3 different gases which are Neon, Argon and Hg-Ar with three different pressures which are 0.5 torr, 5 torr and 15 torr. In this work, the Dielectric Barrier Discharge (DBD) method was used to produce the plasma

P8: Building a better metasurface: high accuracy fabrication of plasmonic nanostructures

Sebastian Andreas Schulz, Jeremy Upham, Frederic Bouchard, Israel De Leon, Ebrahim Karimi, Robert W. Boyd
University of Ottawa (Canada)

We investigate the relationship between fabrication fidelity and device performance for plasmonic metasurfaces consisting of nanoantenna arrays. We show that intra-structure proximity error correction results in increased fabrication fidelity during electron beam lithography and an associated increase in device performance for plasmonic q-plates. Experimental results show that this proximity error correction strategy increases observed purity values from 0.44 to 0.51, for a corresponding theoretical value of 0.55.

P9: Boost of light trapping with nanostructures for thin film solar cells

Liyang Yue, Bing Yan, Matthew Attridge, Zengbo Wang
Bangor University (United Kingdom)

Thin film solar cells have attracted great attention in recent years due to the beneficial features in terms of low production cost, ease of fabrication and potential to have greater efficiencies. This paper aims to design and optimize micro-nano structures for improving the light trapping and absorption capabilities of thin film and latest perovskite solar cell. An optimized design consisting of double plasmonic nanospheres and nanoholes structure was identified, which could produce 70.2 percent absorption enhancement verified by software simulation.

P10: Polarizability matrix retrieval of a non-planar chiral particle through scattering parameters

T. D. Karamanos, N. V. Kantartzis
Aristotle University of Thessaloniki (Greece)

An efficient technique for the polarizability matrix extraction of non-planar chiral particles is introduced. Assuming that the particle is electrically-small, we model it via dipoles at its shape center. Then, the induced dipole moments are calculated via equivalent models from the surface's S-parameter response of three normal wave incidences. Finally, by inserting the retrieved dipole moments in the first assumption, the desired polarizabilities are obtained from a linear system via the measured or simulated scattering parameters.

P11: Plasmonic properties of ordered arrays of Ag and Au nanostructures embedded in silica fabricated by a combinacion of nanosphere lithography with ion implantation

Octavio Graniel[1], Cecilia Salinas[1], Erick Flores-Romero[1], Ulises Morales[1], Juan-Carlos Cheang-Wong[2]
[1] *Universidad Nacional Autonoma de Mexico (Mexico),* [2] *Universidad de Guanajuato (Mexico)*

Nanosphere lithography uses a mask of self-assembled monolayers of spherical silica particles deposited

onto silica plates to create regular arrays of nanoscale features in the sample by 1-2 MeV Ag and Au ion implantation. By this way, after removal of the silica particles and an adequate thermal annealing of the as-implanted samples, the formation of Ag or Au nano-objects embedded in silica plates was confirmed by the presence of the surface plasmon resonance in the optical absorption spectra.

P12: Fabrication and characterization of a SEIRA total absorber
Richard Knipper, Thomas G. Mayerhofer, Uwe Huebner, Dana Cialla-May, Karina Weber, Hans-Georg Meyer, Jurgen Popp
Leibniz Institute of Photonic Technology (Germany)

Total absorbers are becoming a topic of great interest for spectroscopic applications due to the greatly enhanced signal in applications such as surface enhanced infrared absorption (SEIRA). Here, fabrication and characterization of a total absorber will be discussed, including the performance of the resulting SEIRA device. Application in bio-sensing will be addressed as well as stability and reusability.

P13: Effect of Ar/O2 gas ratio on the optical and electrical properties of ITO/AgOx/ITO multilayer films
Heon Kong, Cheol Jin Park, Jong Bin Yeo, Hyun Yong Lee
Chonnam National University (Korea)

We have investigated the properties of multilayer films for application in transparent conducting electrodes. The ITO/AgOx/ITO multilayer films were deposited by rf sputtering technique at room temperature. The effect of AgOx interlayer film on the optical and electrical properties was studied as a function of Ar/O2 gas ratio. The electrical and optical properties of ITO/AgOx/ITO multilayer films were influenced by the thickness and Ar/O2 gas ratio of the interlayer. The optical thickness was simulated by transfer matrix method (TMM).

P14: The role of asymmetry on Fano resonances in metasurfaces
Morteza Karami, Michael Fiddy
University of North Carolina at Charlotte (USA)

We demonstrate the effect of additional asymmetries in concentric rings metasurface. The diagonal non-concentric rings present spectral ultra-narrow band-pass regions which offer practical applications in filters and modulators. Double and triple ring metasurfaces are investigated.

P15: Graphene based ultrasensitive terahertz sensing with dynamically tunable high-Q double Fano resonances
Huiyun Zhang, Tong-Tong Li, Huan-Huan Lv, Xiao-Yan Huang, Yu-Ping Zhang
Shandong University of Science and Technology (China)

A graphene based ultrasensitive terahertz sensing with dynamically tunable high-Q double Fano resonances is proposed and demonstrated numerically. Numerical calculation results show that a high sensitivity of 933GHz/refractive index unit and figure of merit of 2.48 can be reached. The introduction of graphene in this sensor can make the sensing range actively tunable. These findings can be conveniently used for the design of ultrasensitive real time chemical and biomolecular sensors in the fingerprint region of the terahertz regime.

P16: Morphing applied to metamaterials
Ronald Aznavourian, Sebastien Guenneau
Institut Fresnel (France)

We apply morphing to deduce via numerical interpolation some approximate wave picture of scattering by objects of various shapes deduced from the exact computation (e.g. using a finite element method) of scattering by objects of other shapes, thereafter called the source and destination images.

P17: Elimination of polarization degeneracy in circularly symmetric bianisotropic waveguides
Jing Xu, Bingbing Wu, Yuntian Chen
Huazhong University of Science and Technology (China)

Mode properties of circularly symmetric waveguides with bianisotropic chirality are studied using finite element approach. We find that the polarization degeneracy in circularly symmetric waveguides can be eliminated, by introducing magnetoelectric coupling in the waveguide media. Breaking the polarization degeneracy in high order mode groups is also confirmed numerically. A perturbation model is developed to explain the results and shows excellent agreement. Essentially, the bianisotropic waveguides studied here keeps y-polarized modes unchanged, while turns x-polarized modes into leaky modes.

P18: Infrared Beam-steering Using Mechanically Modulated Graphene Monolayer
P. Y. Chen[1], **M. Farhat**[2]
[1] *Wayne State University (USA),* [2] *King Abdullah University of Science and Technology (Saudi Arabia)*

We propose a graphene-based infrared beam-former based on the concept of surface leaky-wave. The excitation of infrared surface plasmon polaritons over an acoustically modulated one-atom-thick graphene monolayer is typically associated with intrinsically slow light.

P19: Optical properties of nanostructured metamaterials
Bernardo S. Mendoza, W. Luis Mochan
Centro de Investigaciones en Optica (Mexico)

We present a very efficient recursive method to calculate the effective optical response of nanostructured metamaterials made up of particles with arbitrarily shaped cross sections arranged in periodic two-dimensional arrays.

P20: Inverse Transformation Optics with Realistic Material Parameters
Philip Munoz, Orad Reshef, Grant England, Russell McClellan, Eric Mazur
Harvard University (USA)

We present a method to generate transformation functions based on a space of achievable material properties. To validate this approach, we consider the range of effective refractive index achievable using silver nanowires in a dielectric background. Given fabrication constraints, we generate a reduced cloaking transformation and confirm its performance using FDTD and FEM simulations. We explore conditions for finding appropriate mappings in restricted parameter spaces, and strategies for optimizing transformations to account for absorption and scattering.

P21: Planar Textile Antennas with Artificial Magnetic Conductor for Body Centric Communications
Kamilia Kamardin[1], **Mohamad Kamal A. Rahim**[1], **Peter Hall**[2], **Noor Asmawati Samsuri**[1]
[1] *Universiti Teknologi Malaysia (Malaysia),* [2] *University of Birmingham (United Kingdom)*

Two textile antennas namely diamond dipole and coplanar waveguide monopole are designed to test the proposed textile Artificial Magnetic Conductor (AMC). Performance comparison including S11, radiation pattern and gain between the antennas above AMC is observed. Results show gain improvement with reduced backlobes when having AMC. Bending and wetness measurements are also conducted. Bending is found not to cause performance disruption while wetness influences performance distortion. However, once the antennas and AMC dried out, the original performance is retrieved

P22: Plasmonic Antenna for Magneto-Optical Imaging at the Deep Nanoscale
Alex Amy[1], **Paul Dawson**[1], **Mark McMillen**[1], **Tom Loughran**[2], **Rob Hicken**[2], **Paul Keatley**[2], **Euan Hendry**[2]
[1] *Queen's University Belfast (United Kingdom),* [2] *University of Exeter (United Kingdom)*

We report on the modelling and preliminary experimental data on plasmonic antennas that are being designed and constructed for incorporation into a modified atomic force microscope (AFM) head. The antenna structures are fabricated using a silicon templating technique and the AFM head is the key element in a novel time-resolved scanning Kerr microscope (TRSKM), which is targeted to achieve simultaneous ps-time and sub-wavelength spatial-resolution.

P23: Dynamics of coupled magnetic oscillators excited with picosecond acoustic pulses.
Vishal Shokeen, Alain Carvalho, Jiwan Kim, Jean Bigot
IPCMS - CNRS (France)

We report about the magnetization dynamics in two magnetically coupled ferromagnetic films. The structure (Ni/Au/Py) is excited by longitudinal strain pulses generated by femtosecond optical pulses. The measurement of the precession dynamics in both films, using a femtosecond Kerr Magneto-Optical set-up, reveals the coupling between the two oscillators. This work is a new step towards controlling magnetic multilayers or metamaterial devices at a sub-micron scale by inducing a picosecond perturbation of their magnetic moments

P24: Transformation cavity implemented by dielectric posts distributions
Jung-Wan Ryu, Yushin Kim, Inbo Kim, Jae-Hyung Han, Bumki Min, Muhan Choi
Kyungpook National University (Korea)

We have shown that highly directional light emission from high-Q whispering gallery modes can be realized in inhomogeneous dielectric cavities which can be defined by imposing spatially-varying refractive index derived

from the transformation optics theory. We performed numerical calculation of cavity modes and microwave experiment with a dielectric inhomogeneous cavity made of alumina posts. The result is consistent with our previous theoretical expectation.

P25: Equivalent circuit model for designing of double concentric squares AMC
Mohamad Mantash, Anthony Presse, Anne-Claude Tarot, Sylvain Collardey
University of Rennes1 (France)

This paper proposes an equivalent model to estimate the resonant frequency and reflection phase of double concentric square Artificial Magnetic Conductor (AMC). The AMC structure is composed of a double squares of Frequency Selective Surfaces arrays printed on grounded dielectric substrates without vias. This approach is based on the Transmission Line Model for waves normally incident on the structure. The proposed model is validated via a comparison with a full-wave simulation results for different samples and a parametric study.

P26: Miniaturized Bendable 400 MHz Artificial Magnetic Conductor
Anthony Presse, Anne-Claude Tarot
IETR - University of Rennes 1 (France)

A bendable Artificial Magnetic Conductor (AMC) with a resonant frequency of 400 MHz is proposed. The dimensions of the unit cell are 50 x 50 mm2. The miniaturization is achieved with closely coupled patches, which are printed on each side of a 0.127 mm thick dielectric substrate stacked on flexible 3 mm thick silicone over a ground plane

P27: Honeycomb-shaped metamaterial absorber for multiband infrared sensing applications
Erdem Aslan, O. G. Saracoglu, Sabri Kaya, Mustafa Turkmen
Erciyes University (Turkey)

In this study, a novel metamaterial absorber based on honeycomb shaped gold nanoparticles for infrared detection applications are presented. We demonstrate that the proposed perfect absorber has a dual band spectral response with almost unity absorbance and near field enhancements at the corresponding resonance frequencies are significantly higher than the conventional perfect absorbers. Due to the dual resonances and enhanced near field optical properties of this perfect absorber geometry it can be useful for infrared sensing applications.

P28: Colloidal optical waveguides structured by light
Oto Brzobohaty, Jan Kanka, Lukas Chvatal, Pavel Zemanek
ASCR - Institute of Scientific Instruments (Czech Republic)

We present experimental study where we employed dual-beam optical trap to study a self-arrangement of microscopic polystyrene particles into colloidal wave-guides. We investigated magnitude of optical bound between the particles studying thermal motion of self-arranged particles. Such optically bound linear structures can be understood as colloidal wave-guides which self-focus incoming laser light and thus a decreasing of thermal motion of optically bound particles can be observed with increasing number self-arranged particles.

P29: Ultrafast optical-pump terahertz-probe spectroscopy of carrier dynamics in nanoslot-patterned GaAs
Geunchang Choi[1], Young-Mi Bahk[1], Minah Seo[2], Byung Hee Son[3], Yeong Hwan Ahn[3], Dai-Sik Kim[1]
[1]Seoul National University (Korea), [2]Korea Institute of Science and Technology (Korea), [3]Ajou University (Korea)

We show carrier dynamics in the nanoslot-patterned antenna arrays on gallium arsenide (GaAs) substrate using optical pump terahertz probe technique. Compared to the bare GaAs, our slot antennas show decreased carrier relaxation time. Moreover, we observe tendency of decreasing relaxation time of the photo-carrier as the antenna width decreases. This result suggests that, by using nanoslot antenna, fast carrier modulation can be achieved.

P30: Electric field enhancement in few nanometer-width antennas operating at gigahertz range
Kwanghee Lee, Jeeyoon Jeong, Jiyeah Rhie, Dai-Sik Kim
Seoul National University (Korea)

We investigate electric field enhancement inside few-nanometer-sized gap structure in gigahertz frequency range. Sample is fabricated by atomic layer lithography consisting etching procedure to ensure high-throughput, large-scale, and stable structures. We measure transmitted Ku-band (12 18 GHz) wave through the square

ring shaped nanogap arrays by vector network analyzer (VNA) and a pair of rectangular waveguide. Estimated electric field enhancement inside the nanogaps can reach 1,000 and can be even higher with optimized geometry.

P31: Pattern Reconfigurable Monopole Antenna Using EBG Structures
H. A. Majid, M. K. A. Rahim, M. R. Hamid, N. A. Murad, N. A. Samsuri, M. R. Kamarudin, M.F. M. Yusof
Universiti Teknologi Malaysia (Malaysia)

A radiation pattern reconfigurable monopole antenna using Electromagnetic Band-Gap (EBG) Structure is proposed. The proposed antenna consists of twelve mushroom-like EBGs positioned around the monopole antenna. The EBG characteristic can be manipulated by controlling the state of switch. The switch is positioned between the EBG's via and the ground plane. By controlling the state of EBGs, the radiation pattern can be reconfigured to an omni-directional pattern and four directional pattern with different angles.

P32: Band-Notched Reconfigurable EBG CPW-Fed UWB Antenna
H. A. Majid, M. K. A. Rahim, M. R. Hamid, N. A. Murad, N. A. Samsuri, M. R. Kamarudin, M.F. M. Yusof
Universiti Teknologi Malaysia (Malaysia)

A reconfigurable band notched UWB antenna using Electromagnetic Band-Gap (EBG) structure is proposed. Two EBGs are positioned adjacent to the transmission line of the UWB antenna. The band notched characteristic of the EBG can be disabled by switching the state of switch place at the strip line. The structure produces reconfigurable band notched at 4.0 GHz which covers C-band satellite communication (3.625 - 4.2 GHz) systems.

P33: Optical reflectance measurements as simple means to inspect wetting states of Si nanopillar arrays
Minji Gwon[1], Sujung Kim[1], Eunsongyi Lee[1], Dong-Wook Kim[1], Jiaqi Li[2], Xiumei Xu[2], Chang Chen[2]
[1] *Ewha Womans University (Korea),* [2] *IMEC (Belgium)*

We investigated optical spectral response of Si nanopillar (NP) arrays with different wetting states using optical simulations. Reflectance spectra of the NP arrays exhibited a clear distinction depending on the wetting state. Interference at the top and bottom of the NPs was found to determine the spectra of all the arrays at long wavelengths. The Mie resonance, as well as the interference, in the NPs should be taken into account to explain the short wavelength reflectance spectra.

P34: Engineering of Three-Dimensional Chiroplasmon via Glancing Angle Deposition (GLAD) on rigid and flexible substrate
Junhong Deng, Jeff Lau, Fan Bai, Jack Ng, Zhifeng Huang
Hong Kong Baptist University (Hong Kong)

The fabrication of Co- and Bi-axial two-turns silver nanospirals (AgNSs) will be presented with multiple handedness on sapphires. The structure is constituted by one turn AgNS and 1/3, 2/3 or 1 turn with another handedness fabricating by glancing angle deposition. Electric circular dichroism (ECD) of chiral plasmonic properties is studied in UV-visible range, and high amplitude of bisignate ECD signal is found in visible range, which the array of AgNSs on flexible substrates demonstrate a similar gigantic ECD.

P35: Modal Analysis of Graphene Microtubes Utilizing a Two-Dimensional Vectorial Finite Element Method
Vasileios Salonikios, Stamatios Amanatiadis, Nikolaos Kantartzis, Traianos Yioultsis
Aristotle University of Thessaloniki (Greece)

The propagation properties of the surface plasmon polariton waves on a graphene microtube are investigated in the present work. The effective index of various modes, supported on the microtube, is extracted by means of an accurate two-dimensional finite element modal solver that models graphene as a surface boundary condition. Moreover, the electric field distribution of the radial electric component is plotted for a specific frequency, revealing a remarkable behavior of the surface wave propagation.

P36: DNA-Origami as a Template to Study Plasmon-Exciton Interactions
Mauricio Pilo-Pais, Eva-Maria Roller, Tim Liedl
Ludwig Maximilians Universitat (Germany)

We use the DNA-Origami technique to study plasmon-exciton interactions. DNA-templates are used to position with nanometer precision metallic nanoparticles, permitting to tune the plasmon resonance to the one

from the exciton. Furthermore, metallic colloids are preferred over lithographic alternatives due to lower radiative losses. For these reasons, DNA-Origami is an ideal candidate to rationally assemble plasmon-exciton nanostructures. As a proof of concept, we present plasmon-exciton interactions using Jaggregates, displaying spectral shifts even for resonances that are greatly mismatched.

P37: Strong Coupling in Complexes of Aluminium Nanoantennas and J-aggregates, Emission and Polarization of Hybrid States
Elad Eizner, Ori Avayu, Ran Ditcovski, Tal Ellenbogen
Tel Aviv University (Israel)

We show that aluminium is well suited for strong coupling experiments and enables formation of exciton-localized-surface-plasmons (X-LSPs) across the entire visible spectrum potentially down to the ultraviolate regime. Huge Rabi splitting of 400 meV and signatures of emission from X-LSPs states are observed. In addition, we show that the coupling of vacuum LSP fluctuations with the excitons can be polarized. The results open new possibilities to study hybrid states and to actively modify energy transition processes on the nanoscale.

P38: Resonantly enhanced dynamical Casimir effect for surface plasmon polaritons
Vladimir Hizhnyakov, Ardi Loot, Shahabedin Azizabadi
University of Tartu (Estonia)

Dynamical Casimir effect, emission of pairs of quanta of surface plasmon polaritons (SPPs) in a metal-dielectric interface placed in a resonator under laser excitation is considered. In this case the emission is strongly enhanced. A theory is proposed which takes the enhancement into account. It is found that if the amplitude of laser-induced oscillations of the optical length of SPPs coincides with their wavelength a resonant enhancement of the yield of the emission takes place.

P39: Colorimetric monitoring of nanometer distance changes in DNA-templated plasmon rulers
Laurent Lermusiaux, Vincent Maillard, Sebastien Bidault
ESPCI ParisTech (France)

Molecular rulers based on gold nanoparticle groupings translate nanometer distances in spectroscopic information. We demonstrate here that measuring the color of single plasmon rulers on a calibrated camera provides a quantitative estimation of interparticle distances with nanometer precision. This widefield measurement scheme allows us to differentiate plasmon rulers linked by two conformations of the same DNA template, opening exciting perspectives for the low-tech optical sensing of single biomolecules.

P40: Heavily dye-doped polymers allow Tamm Optical States between a periodic structure and an excitonic organic layer
Sara Nunez Sanchez[1], Martin Lopez-Garcia[2], M. Murshidy[3], A. Abdel-Hady[4], M. Serry[4], Ali Adawi[5], Jonh Rarity[2], Ruth Oulton[2], William Barnes[1]
[1] *University of Exeter (United Kingdom),* [2] *University of Bristol (United Kingdom),* [3] *Helwan University (Egypt),* [4] *The American University in Cairo (Egypt),* [5] *University of Hull (United Kingdom)*

Tamm Optical States at the interface of a truncated photonic crystal and an organic polymer have been obtained due to the metal-like optical properties of the heavily dye-doped polymer. The dispersion curves of these novel modes show two cut-off wavelengths controlled by the mismatch of the mode propagation and the high reflectance bandwidth. These results reveal the potential applications of materials doped with strongly interacting excitons in photonic structures through controlled photonic modes.

16:40 - 18:00 — Aronow Theater

Session 1A18

Symposium 1: Functional Metastructures and Nanomaterials: Properties, Fabrication and Modeling III

Organized by: Alexander Govorov and Hilmi Volkan Demir

Chaired by: Svetlana V. Boriskina and Tim Liedl

16:40 : Invited talk

Fluorescence-Tunable Gold Clusters Capped with Lipoic Acid-Polyethylene Glycol Ligands

Hedi Mattoussi
Florida State University (USA)

We combine the use one-pot aqueous growth route with the photochemically sensitive nature of lipoic acid molecules to prepare fluorescent clusters made of gold (AuNCs) with tunable emission ranging from the blue to the red region of the optical spectrum. The growth strategy exploits the natural UV-induced photochemical transformation of LA-based ligands to thiols and thiol radical byproducts that exhibit great affinity to metal-rich complexes. The materials were characterized using UV-Visible absorption and fluorescence spectroscopy, TEM and DOSY-NMR.

17:00 : Invited talk

Quantum Confined Semiconductor Nanocrystals: Elevated Temperature Performance and Sensing Application

Richard Schaller
Northwestern University (USA)

We examine colloidal semiconductor nanocrystals upon temperature elevation, reveal reversible as well as irreversible exciton quenching pathways, and investigate the role of surface termination on exciton integrity with temperature. This work points to strategies to improve upon material performance in high temperature applications. We have also exploited these material properties in biological sensing applications where we make use of the large absorption cross-sections and high optical stability to produce a selective, stable, fast and sensitive all-optical pathogen detection assay.

17:20 : Invited talk

Two-color hybrid plasmonic nano-emitter

X. Zhou[1], X. Yang[2], X. Sun[2], H. V. Demir[2], A. Vial[1], L. le Cunff[1], A. S. Bisht[1], G. P. Wiederrecht[3], R. D. Schaller[3], S. Jradi[1], J. Plain[1], G. Colas des Francs[4], R. Bachelot[1]
[1] *University of Technologie of Troyes (France),* [2] *Nanyang Technological University (Singapore),* [3] *Argonne National Laboratory (USA),* [4] *Bourgogne University (France)*

In plasmonic light-emitting hybrid nanosystems, the monochromaticity of the light emission prevents possible switchable color. Here, we demonstrate two-color anisotropic plasmonic nano-emitters that were fabricated via plasmonic photo-polymerization. By using different QD-doped solutions, quantum emitters of different colors can be positioned selectively in different orientations in the close vicinity of the metal nanoparticles. As a result, the dominant emitting wavelength can be controlled with the direction of the incident polarization.

17:40 : Invited talk

Using Patterned Arrays of Metal Nanoparticles to Probe Plasmon Enhanced Luminescence of CdSe Quantum Dots

Jixin Chen[1], Yang-Hsiang Chan[2], Stacey E. Wark[2], Stephanie L. Skiles[2], Dong Hee Son[2], James D. Batteas[2]
[1] *Ohio University (USA),* [2] *Texas A-M University (USA)*

In this conference, I am presenting a paper published on ACS Nano. A nanostructure with layers of CdSe quantum dots and gold/silver nanoparticles separated by polymers has been fabricated to probe the plasmon-enhanced photoluminescence (PL) of quantum dots (QDs) by confocal microscopy. The results curves of the PL enhancement as a function of the QD-metal separation was analyzed with a model that composed of a quenching factor and an enhancement factor.

16:40 - 18:00 — NAC 0/201

Session 1A19

Structured light in metamaterials III

Organized by: Natalia Litchinitser and Richard Hammond

Chaired by: Natalia Litchinitser and Richard Hammond

16:40 : Invited talk
Controlling Guided Waves in Telecom Waveguides Using One Dimensional Phased Antenna Arrays
Zhaoyi Li, Myoung-Hwan Kim, Nanfang Yu
Columbia University (USA)

We theoretically demonstrate a few novel small-footprint and broadband integrated photonic devices based on optical waveguides patterned with phased antenna arrays. These devices include waveguide mode converters, polarization rotators, perfect absorbers, and optical power diode.

17:00 : Invited talk
Detection of the extraordinary transverse pressure in optical fields
Konstantin Bliokh[1], A. Y. Bekshaev[2], M. Antognozzi[3], S. Simpson[4], M. R. Dennis[3], R. Harniman[3], J. Senior[3], R. Hayward[3], H. Hoerber[3], F. Nori[1]
[1] *Center for Emergent Matter Science - RIKEN (Japan),* [2] *I.I. Mechnikov National University (Ukraine),* [3] *University of Bristol (United Kingdom),* [4] *Institute of Scientific Instruments of the ASCR (Czech Republic)*

We predict theoretically and measure experimentally extraordinary transverse force, which appears in inhomogeneous optical fields. In contrast to the known radiation-pressure and gradient optical forces, this weak force is orthogonal to both the momentum (wave vector) and intensity gradient in the field. Moreover, this transverse force crucially depends on the spin (circular polarization) of light. We show that the new force can be associated with enigmatic spin momentum introduced by Belinfante in relativistic field theory almost 70 years ago.

17:20 : Invited talk
Universal spin-momentum locking of evanescent waves
Todd Mechelen, Zubin Jacob
University of Alberta (Canada)

We show the existence of an inherent property of evanescent waves: spin-momentum locking where the direction of momentum fundamentally locks the polarization of the wave. We show that every case of evanescent waves in total internal reflection, surface states and optical fibers/waveguides possesses this intrinsic spin-momentum locking. We trace the ultimate origin of this phenomenon to complex dispersion and causality requirements on evanescent waves.

17:40 : Invited talk
Boundary structure shapes the response of metamaterials
Mikhail Lapine
University of Technology Sydney (Australia)

We review our recent observations and novel results on the role of the structure of a boundary in metamaterials samples, revealing its tremendous importance as compared to conventional materials. With a series of different geometrical examples, we demonstrate that the properties of metamaterials of finite size deviate significantly from the predictions of an effective medium theory. This effect is well pronounced even for a strongly subwavelength structure, and relevant for fairly large metamaterial pieces including over ten thousand elements.

16:40 - 17:55 — NAC Ballroom

Session 1A20

Photonic and Plasmonic crystals and cavities

Chaired by: Che Ting Chan

16:40 : Impact of Size and Pitch on the Optical Properties of Ordered Arrays of InGaN/GaN Quantum Disc and Core-Shell Nanowires
Duncan Allsopp, Ionut Girgil, Chris Lewins, Emmanual Le Boulbar, Simon O'Kane, Pierre-Marie Coulon, Szymon Lis, Sophia Fox, Philip Shields
University of Bath (United Kingdom)

Different forms of diffractive behavior of highly ordered arrays of regular-shaped InGaN/GaN nanowires fabricated by a top-down process is described. Both core-shell and GaN nanowires containing a single InGaN quantum well are considered. Suppression of light trapping in the substrate layers can cause Bloch mode formation in the nanowire layer and simultaneous suppression of vertical waveguiding in the nanowires.

16:55 : Multi-purpose, Automated Optimization of Photonic Crystal Cavities
Momchil Minkov, Vincenzo Savona
EPFL Lausanne (Switzerland)

Photonic crystal cavities are used in a number of experiments as they offer a combination of small volume and large quality factor. Here, we present a versatile, automated procedure to optimize these structures, and several successful applications. We improve the quality factor of some of the most common designs by approximately an order of magnitude, and in addition we propose some interesting applications with respect to figures of merit other than the quality factor.

17:10 : Hybrid III-V on silicon photonic crystal based optical modulator
Thi Nhung Vu[1], Delphine Marris Morini[1], Fabrice Raineri[2], Rama Raj[2], Diego Perez-Galacho[1], Xavier Leroux[1], Laurent Vivien[1]
[1] *Paris Sud University (France),* [2] *Laboratoire de Photonique et de Nanostructures-CNRS (France)*

We demonstrate a compact and low power consumption III-V on silicon modulator that combines electro-absorption in III-V material with slow light photonic crystal waveguides. The proposed design allows a good compromise between the modulator's figures of merit. An extinction ratio up to 20 dB is obtained, showing a 3 dB cut-off frequency of 15 GHz, and a total energy consumption below 50 fJ/bit.

17:25 : Double pin-hole nanoresonators by sphere-imprinting for particle sizing and spectrum filtering applications
Jing Zhou, Ashwin Panday, L. Jay Guo
University of Michigan (USA)

We use sphere-imprinted method to realize a double pin-hole nanoresonator with wedged sidewalls and demonstrate the applications of accurate sphere size characterizing and fine spectrum filtering.

17:40 : Effect of Ethanol on Dispersion Properties of Photonic Crystal Fiber
Rahul Gangwar, Vanita Bhardwaj, Vinod Singh
Indian School of Mines (India)

We present theoretical study of newly designed structure of ethanol filled sold core photonic crystal fiber. The numerical simulation shows that zero dispersion wavelength can be shifted by selectively filling of ethanol in the holes of photonic crystal fiber. This type of photonic crystal fiber is very useful for communication and sensing applications.

16:40 - 17:10 — NAC 1/202

Session 1A21

Optical Forces and Manipulation of Momentum in Metamaterials and Plasmonics III

Organized by: Philippe Tassin and Vincent Ginis

Chaired by: Philippe Tassin and Vincent Ginis

16:40 : Chirality: a helping hand to tailor optical forces between metasurfaces
Sophie Viaene[1], Vincent Ginis[1], Pieter Verhulst[1], Jan Danckaert[1], Philippe Tassin[2]
[1] *Vrije Universiteit Brussel (Belgium),* [2] *Chalmers University (Sweden)*

Optical forces provide a high-precision tool to move and rearrange subwavelength objects such as nanospheres and nanowires. In this work, we investigate the optical forces that arise when chiral metamaterial sheets are illuminated by circularly polarized electromagnetic radiation. Using the Maxwell stress tensor, we calculate the momentum transfer for several designs of chiral sheets from full-wave numerical simulations. We discuss the effects of the geometrical degrees of freedom and of the different material implementations on the resulting optical forces.

16:55 : Contribution of non-local effects to the Casimir forces
Yan Francescato, Vincenzo Giannini
Imperial College London (United Kingdom)

The Casimir force is one of the few manifestations of quantum behaviour at macroscopic scale, often described as the force acting between two plates due to vacuum fluctuations. While there have been great development in its theoretical understanding the strong effect of non-locality on the electromagnetic modes supported by the plates have been neglected. We show that because the contribution to the force from these modes is dominant considering non-locality is crucial for a qualitatively correct description.

17:10 - 18:00 — NAC 1/202

Session 1A22

Acoustic metamaterials I

Chaired by: Abdelkrim Khelif

17:10 : Invited talk
Experimental Demonstration of a Soft 3D Acoustic Metamaterial with Negative Index
Thomas Brunet, Kevin Zimny, Artem Kovalenko, Benoit Mascaro, Jacques Leng, Christophe Aristegui, Olivier Poncelet, Olivier Mondain-Monval
University of Bordeaux (France)

We report a new class of locally resonant ultrasonic metafluids consisting of a concentrated suspension of macroporous microbeads engineered using soft matter techniques.

17:30 : Enhanced picosecond acoustic response near the surface plasmon resonance of Ni/Au-nanoparticles metastructures
Oleksandr Kovalenko, Yu Liu, Ji-Wan Kim, Gilles Versini, Jean-Yves Bigot
Strasbourg University (France)

In this work we consider the interaction between picosecond acoustic pulses generated in a 300nm thick Ni film and the localized Surface Plasmons of Au nanoparticles. The monolayer of gold nanoparticles, self-organized on top of the Ni film, allows us detecting the acoustic signal as a function of wavelength near their surface plasmon resonance. Near resonance, an amplification factor of 55 is measured as compared to the bare Ni film. Our approach precludes useful applications in opto-acoustics and magneto-acoustics.

17:45 : Time Reversal in bubbly metamaterials

Maxime Lanoy[1], **Valentin Leroy**[1], **Arnaud Tourin**[2]
[1] *ESPCI ParisTech (France),* [2] *Paris Diderot University (France)*

We present a way to combine the isotropic resonance of gas bubbles in water and the coherent multiple scattering of a disordered sample or bubbles in order to focus acoustic energy beyond the diffraction limit using time reversal mirrors. In the realistic case where we consider thermal and viscous losses we show that the low frequency modes have to be involved.

16:40 - 18:00 — ASRC Conference Room

Session 1A23

A bottom-up approach towards metamaterials and plasmonics III

Organized by: Dorota Pawlak and Wounjhang Park

Chaired by: Augustine Urbas and Toralf Scharf

16:40 : Invited talk
Large-area nanorod metamaterials for sensing and magneto-optics
M. Nasir, W. Dickson, G. A. Wurtz, Anatoly Zayats
King's College London (United Kingdom)

We will present new approaches for large-scale, lithography-free fabrication of metamaterials based on aligned plasmonic nanorod arrays. We discuss how to achieve a designer optical properties throughout visible and near-infrared spectral ranges. The capabilities of these metamaterials in chemical sensing and for magneto-optical applications will be considered. These metamaterials open up new possibilities for a practical implementation of variety of photonic applications, including at telecommunication wavelengths.

17:00 : Invited talk
THz polarization control with chiral metamaterials
M. Kafesaki, G. Kenanakis, C. M. Soukoulis, E. N. Economou
IESL-FORTH (Greece)

Various bi-isotropic and bi-anisotropic chiral designs, both passive and optically controllable, are presented, and their capabilities for THz polarization control are discussed.

17:20 : Invited talk
Periodic or Random Nanostructures for Light Scattering Control
Gerard Berginc
Thales (France)

Our paper mainly focuses on the control of light scattering by periodic or randomly rough structures. First designed with bi-periodical structures, antireflective surfaces can be achieved with random patterns. We present some new structures with periodic or random patterns, which have been designed by rigorous numerical methods (FDTD) or analytical methods. We show that random interfaces offer new degrees of freedom and possibilities by the control of their statistical properties.

17:40 : Invited talk
Photonic Anderson localization in compositionally disordered two-dimensional photonic crystals
Myungjae Lee, Minsu Kang, Heonsu Jeon
Seoul National University (Korea)

We employ compositionally disordered photonic crystal (PC), a photonic analogy to semiconductor alloy, as a platform to explore photonic behaviors in disordered photonic systems. A series of two-dimensional hexagonal lattice PCs are fabricated using an InGaAsP multiple-quantum-well slab, compositional disorder is introduced by randomly incorporating the air-holes of different sizes at regular lattice sites. Emission spectra and wavelength-tuned near-field scanning optical microscope images provide clear evidence that localized photonic modes can develop within the disordered structure.

16:40 - 18:00 — NAC 1/203

Session 1A24

Acoustic, elastic and thermal metamaterials III

Organized by: Mohamed Farhat and Sebastien Guenneau

Chaired by: Mohamed Farhat and Sebastien Guenneau

16:40 : Invited talk
Topological Phononic Crystal
Zhaoju Yang, Baile Zhang
Nanyang Technological University (Singapore)

Topological photonics which study topological properties of photonic systems is emerging recently. However a similar method combining the topology and phononic crystals still remains elusive. Our work transfers the classic quantum Hall effect into a phononic crystal. The time-reversal symmetry of the phononic crystal is broken by introducing a circulating fluid flow in each unit cell. Topologically-protected edge states are demonstrated at the boundaries of the phononic crystal, being immune to backscattering from disorders.

17:00 : Invited talk
Localization of flexural waves in thin plates
Patrick Sebbah[1], F. Feppon[2], A. Labbe[2], C. Gillot[2], A. Garelli[2], M. Ernoult[2], G. Lefebvre[1], M. Dubois[1], A. Gondel[1], S. Mayboroda[2], M. Filoche[2]
[1] *Institut Langevin - ESPCI (France),* [2] *Ecole Polytechnique (France)*

We investigate flexural wave localization following two different routes. The first approach consists in structuring thin plates to force elastic energy in specific locations. We show that regions of localization can be predicted from the knowledge of the constraints imposed on the plate. Reciprocally, the inverse problem is solved and the positions of fixed points are found which force confinement in a predetermined region. The second approach is to introduce resonant scatterers to confine energy by multiple scattering.

17:20 : Invited talk
Locally resonant elastic metamaterials and seismic applications
Andrea Colombi[1], P. Roux[2], S. Guenneau[3], R. V. Craster[1]
[1] *Imperial College London (United Kingdom),* [2] *Joseph Fourier University (France),* [3] *Institut Fresnel (France)*

Two applications of locally resonant elastic metamaterials are here presented. In the first one, we introduce a directional cloak that both protect from elastic waves and cancel the back scattering produced by an obstacle over a broad frequency band. In the second study we introduce the results from numerical simulations and actual seismic observations showing how locally resonant metamaterials can successfully control surface waves in a typical seismological context characterised by a semi infinite halfspace and forest-tree resonators.

17:40 : Invited talk
High Frequency Homogenization for Travelling Waves in Periodic Media
Richard Craster[1], Davit Harutyunyan[2], Graeme W. Milton[2]
[1] *Imperial College (United Kingdom),* [2] *University of Utah (USA)*

The effective equations governing the spatial and time modulations of travelling waves in periodic media are obtained using an extension of the high frequency homogenization approach of Craster, Kaplunov and Pichugin. The effective moduli entering these equations can be obtained by solving appropriate equations at the cell level.

16:40 - 17:50 — NAC 1/211

Session 1A25

Metamaterials and negative index materials II

Chaired by: Cheng-Wei Qiu

16:40 : Invited talk
Metasurfaces for Far-Field Wireless Power Transfer
Omar Ramahi, T. Almoneef, B. Alavikia, A. Ashoor
University of Waterloo (Canada)

The concept of electromagnetic energy harvesting and wireless power transfer had been proposed more than half a century ago. In all published works related to electromagnetic energy collection, classical antennas have been used while the focus shifted to the rectification circuitry. Recent works showed that the weakest link in the traditional energy harvesting chain is the antenna itself. Here, we show that metasurfaces provide a viable alternative to classical antennas yielding efficiencies approaching unity.

17:00 : Invited talk
The Lattice World, Quantum Foam and the Universe-Wide Metamaterial
David Crouse
The City University of New York (USA)

The concept of a universe-wide gravity crystal that combines Heisenberg's Lattice World and Wheeler's Quantum Foam is described. It is assumed that space is a crystal with a lattice constant equal to the Planck length and a basis of a Planck mass. Inertial anomalies are calculated that include a parameter that connects the external gravitational field and gravitational flux. Similar to the electric permittivity and magnetic permeability of metamaterials, this parameter can take on positive, zero and negative values.

17:20 : Phase Matching and Tree-wave Mixing of Contra-propagating Light Pulses in Negatively Dispersive Metamaterials
Alexander K. Popov[1], Sergey A. Myslivets[2], Alexander V. Kildishev[3], Alexander O. Korotkevich[4]
[1] *Birck Nanotechnology Center-Purdue University (USA),* [2] *Siberian Federal University (Russia),* [3] *Purdue University (USA),* [4] *University of New Mexico (USA)*

We show that particular spatial distributions of nanoscopic plasmonic building blocks in metamaterials may enable extraordinary nonlinear-optical propagation processes commonly attributed to negative-index metamaterials. The possibility of great enhancement of frequency conversion and tailoring of shapes of the coupled pulses is demonstrated with numerical simulations.

17:35 : A dual-band Textile Artificial Magnetic Conductor incorporation with Textile Diamond Antenna
Muhammad Azfar B. Abdullah, Mohamad Kamal B. A. Rahim, N. A. Samsuri
Universiti Teknologi Malaysia (Malaysia)

A dual-band textile artificial magnetic conductor (AMC) incorporation with two textile diamond antennas are proposed. The diamond antennas are positioned above the dual-band textile AMC. The two textile diamond antennas and the AMC are designed to operate at 2.45GHz and 5.8GHz which comply the ISM band. The proposed designs produce directive radiation pattern and high gain about 6dB.

16:40 - 18:00 — ASRC Seminar Room

Session 1A26

Advances in Metamaterials and Plasmonics

Chaired by: Mo Mojahedi

16:40 : Invited talk
Dielectric and metal-dielectric metamaterials
Venu Gopal Achanta

Tata Institute of Fundamental Research (India)

Metamaterials with different functionalities are interesting for light manipulation and control. We will present some of our recent results on all-dielectric and metal-dielectric metamaterials to demonstrate omni-directional reflectionless transmission over broad wavelength range, plasmon mediated linear and nonlinear optical response of plasmonic quasicrystals, giant Goos-Hanchen shift, broadband filters, single and multi-band polarizers, ultrafast control of metamaterial resonances and tunable trapped mode resonances.

17:00 : Second Harmonic Generation in Plasmonic Nanostructures: Multiresonant Nanoantennas and Eigenmodes

Jeremy Butet, Kuang-Yu Yang, Gabriel Bernasconi, Olivier Martin
Swiss Federal Institute of Technology (Switzerland)

During this talk, we will present our recent advances in the study of second harmonic generation (SHG) in plasmonic nanoantennas. The mechanisms of SHG enhancement in multiresonant nanostructures will be discussed in details and the role played by the different eigenmodes in the nonlinear response of plasmonic nanostructures will be addressed pointing out the influence of the symmetry at the excitation and emission wavelengths.

17:15 : Metasurface Absorbers for Solar Thermal Applications

Chenglong Wan, N. A. Fox, M. J. Cryan
University of Bristol (United Kingdom)

Solar thermal absorbers are required to absorb strongly in the visible regime but prevent thermal radiative loss at longer wavelength. This paper explores the use of amorphous carbon in order to obtain very strong solar absorption, and assesses the use of Metal-Insulator-Metal (MIM) structures with carbon as the insulator layer to obtain a broadband strong absorber across the solar spectrum but maintain very low emissivity in the thermal infra-red bands.

17:30 : Optical vortex beam shapers based on all-dielectric Huygens' metasurfaces

Katie E. Chong[1], Isabelle Staude[1], Anthony James[2], Jason Dominguez[2], Sheng Liu[2], Salvatore Campione[2], Ganapathi S. Subramania[2], Ting S. Luk[2], Manuel Decker[1], Dragomir N. Neshev[1], Igal Brener[2], Yuri S. Kivshar[1]
[1] *The Australian National University (Australia),* [2] *Sandia National Laboratories (USA)*

Based on a recent demonstration of all-dielectric Huygens' metasurfaces, we fabricate ultra-thin silicon vortex beam-shapers with 70 percent transmittance efficiency at telecom wavelengths. Our beam-shapers consist of arrays of silicon nanodisks and are capable of converting a Gaussian beam into a vortex beam independent of the polarization of the incident beam and without polarization-conversion losses. Our realized beam-shapers demonstrate the feasibility of functional meta-devices in the optical regime, opening a door to real-world low loss flat optics.

17:45 : Independently tunable polarization-insensitive dual-band metamaterial perfect absorber based on graphene at mid-infrared frequencies

Yuping Zhang[1], T. T. Li[1], H. Y. Zhang[1], John O'Hara[2], A. J. Taylor[3], H. T. Chen[3], A. K. Azad[3]
[1] *Shandong University of Science and Technology (China),* [2] *Oklahoma State University (USA),* [3] *Los Alamos National Laboratory (USA)*

We design a dual-band absorber formed by combining two cross-shaped metallic resonators of different sizes in a unit cell. Simulations indicate that absorption efficiencies greater than 98 percent can be achieved for both resonant frequencies with near perfect polarization-independence at normal incidence. We employ a design scheme that allows independent tuning of individual resonance by electrostatically changing the Fermi energy of graphene layer. The absorption remains >90 percent for a wide angle of incident up to 50 degrees for both resonances.

Wednesday 5th August, 2015

08:30 - 09:50 — Aronow Theater

Session 2A1

Plenary Session II

Chaired by: Vladimir Shalaev

08:30 : Plenary talk
From Achromatic Flat Optics to Disordered Metasurfaces with Functional Connectivity
Federico Capasso
Harvard University (USA)

Recent advances by my group in metasurface physics and applications are reported, which demonstrate two important new functionalities: the so far elusive achromatic behavior of metasurfaces and the design and realization of disordered holey metallic metasurfaces with deep subwavelength features, which show reproducible and tunable optical properties by controlling the connectivity of the metasurface.

09:10 : Plenary talk
Metaplatforms
Nader Engheta
University of Pennsylvania (USA)

Over the past several years, the field of metamaterials has witnessed various stages of development and growth. Started with tailoring material parameters to achieve wave manipulation at will, it has now become a broader scientific and technological endeavor, and is encompassing a new way of thinking and methodology. We now investigate platforms, paradigms, systems and subsystems for more complex wave-matter interaction and functional devices.

Coffee Break and Exhibit Inspection

Session 2P1

Poster session III

09:50 - 10:30

P1: GaN Nanorod Cavities as a Fluorescence-Sensing Platform
Nikolai Hueting[1], Philip Shields[2], Duncan Allsopp[2], Martin Cryan[1]
[1] *University of Bristol (United Kingdom),* [2] *University of Bath (United Kingdom)*

GaN photonic crystal nanorod cavities are presented as a central building block of a fluorescence-sensing platform. The cavities are fabricated with nano-imprinting and subsequent high aspect ratio etching. The high electric field strength in the air region allows the placement of fluorescent substances in the high field region. The modified emitter environment leads to enhanced emission via Purcell enhancement.

P2: Terahertz wave emission from plasmonic chiral metasurfaces
Takahiro Matsui[1], Satoshi Tomita[1], Motoki Asai[2], Yuzuru Tadokoro[2], Keisuke Takano[2], Makoto Nakajima[2], Masanori Hangyo[2], Hisao Yanagi[1]
[1] *Nara Institute of Science and Technology (Japan),* [2] *Osaka University (Japan)*

We fabricated plasmonic chiral metasurfaces with pinwheel-like structures on silver films using a focused ion beam milling technique. In a time-domain spectroscopy, we have succeeded in observing terahertz wave emission from the metasurfaces irradiated by a near-infrared Ti:sapphire ultra-short pulsed laser.

P3: Extremely compact metamaterial absorber based on the meandered electric resonators with low

dielectric constant media
Yongjun Huang, Haibin Sun, Xuefeng Zhao, Jian Li, Guangjun Wen
University of Electronic Science and Technology of China (China)

We analyze and discuss an extremely compact metamaterial absorber by introducing meandered lines into the electric resonant cells and covering another dielectric layer on it. The size reduction procedures are presented step by step and such extremely compact metamaterial absorber with in-plane (lateral) dimension of lambda/28 and vertical thickness of lambda/37 is obtained. The proposed extremely compact metamaterial absorber shows near-unity absorption under a wide range of incident angles for both TE and TM radiations.

P4: Efficient fiber-optical tweezing of dielectric nanoparticles with coaxial plasmonic apertures
Amr Saleh, Jennifer Dionne
Stanford University (USA)

In this work, we propose a novel design for fiber-based plasmonic tweezers. We combine a coaxial plasmonic aperture that has powerful trapping capabilities with a bull's eye structure on a fiber tip. We show that with this design, the power required for optical trapping is reduced by a factor of seven. This design opens the door for low power three dimensional optical trapping of dielectric particles with sizes previously inaccessible with conventional optical tweezers.

P5: Photonic Band Structure of Graphene - Dielectric Superlattices
Alejandro Hernandez-Lopez[1], Martha Palomino[1], Felipe Ramos-Mendieta[2]
[1] *Benemerita Universidad Autonoma de Puebla FCFM (Mexico),* [2] *Universidad de Sonora DIFUS (Mexico)*

We investigate the photonic band structure of superlattices constituted by alternated graphene and dielectric layers. The bands result from the coupling of the transverse magnetic plasmons supported by the graphene sheets. The dispersion relations are calculated for doped graphene in the THz spectrum. The band structure is compared with reflection spectra calculated using the ATR technique.

P6: High plasmon concentration and electric wave guide in a 2D photonic crystal made of metallic rods embedded in air
Danny Calvo-Velasco, Nelson Porras-Montenegro
Universidad del Valle (Colombia)

Using the revised plane wave method (RPWM), we calculated the photonic band structure (PBS) considering TE polarization of a square 2D photonic cristal (PC) made of square metallic rods embedded in air. Comparing different plasma frequencies, we found a characteristic band distribution related with the existence of plasmon-polaritons in the surface of the rods, also we found that this type of rod shape contributes to a high concentration of the electromagnetic field close to the rod corners.

P7: Polarization - Selective Optical Darkness in Metamaterials built from Nano-Bismuth
Johann Toudert, Rosalia Serna
Instituto de Optica (Spain)

We extend the concept of polarization - selective optical darkness to metamaterials based on bismuth nanostructures (nano-Bi). It will be shown that in nano-Bi based metamaterials, this phenomenon can be achieved due to the near UV - visible polaritonic resonances permitted by the near IR interband transitions of Bi.

P8: Subwavelength Grating Waveguides for Integrated Photonics
Hamdam Nikkhah, Trevor Hall
University of Ottawa (Canada)

Subwavelength grating waveguides (SWG) are locally periodic structures with parameters that may vary slowly on the scale of a wavelength. Here the implementation of a Luneburg lens as a SWG to provide Fourier optics on a chip and the design of the adiabatic structures that must be provided to interface SWG structures to conventional waveguides are considered. Preliminary findings are reported on the dispersion engineering of multimode interference couplers towards the ideal port phase relations needed in coherent applications.

P9: Preparation of Few-layered g-C3N4 Nanosheets Film and Microstructure Research
Hui Miao, Xiaoyun Hu, Hao Wu, Yuanyuan Hao, Qian Sun, Guowei Zhang, Dekai Zhang, Jun Fan, Jintao Bai, Xun Hou
Northwest University (China)

In this paper, few-layered g-C3N4 nanosheets film was successfully prepared by liquid exfoliation and vacuum filtrated self-assembled method. The obtained g-C3N4 nanosheets film displayed transparent character and tunable thickness. The blue-shift of the PL spectra of the nanosheets film indicated the energy gap increased, which is the changing process of g-C3N4 from indirect-gap semiconductor to direct-gap semiconductor. The photocurrent test showed the as prepared film had a good photocurrent response nearly 0.19uA to each switch-on and switch-off event.

P10: Sub-wavelength super-oscillation in the single photon regime
Charles Altuzarra[1], Guanghui Yuan[1], Stefano Vezzoli[1], Edward Rogers[2], Christophe Couteau[1], Cesare Soci[1], Zexiang Shen[1], Nikolay I. Zheludev[1]
[1] *Centre for Disruptive Photonic Technologies at NTU (Singapore),* [2] *University of Southampton (United Kingdom)*

We report on the first experimental demonstration of super-oscillatory behaviours in the single photon regime, where the quantum wave-function of a single photon can be localized into length scale much smaller than the smallest wave length contained in its Fourier spectrum.

P11: Efficient thermal-light and light-thermal conversion by a selective emitter/absorber
Jing Zhou, Xi Chen, L. Jay Guo
University of Michigan (USA)

We use a diluted refractory metal as a selective emitter/absorber to enhance the efficiencies of thermal-light and light-thermal conversions. The absorptivity (emissivity) was measured at high temperatures up to 750C.

P12: Discrete solitons in graphene multilayers
Yuliy Bludov[1], Daria Smirnova[2], Yuri Kivshar[2], Nuno Peres[1], Mikhail Vasilevskiy[1]
[1] *Universidade do Minho (Portugal),* [2] *Australian National University (Australia)*

We study nonlinear properties of multilayer metamaterials created by graphene sheets separated by dielectric layers. We demonstrate that such structures can support localized nonlinear modes described by the discrete nonlinear Schrodinger equation and that its solutions are associated with stable discrete plasmon solitons. We also analyze the nonlinear surface modes in truncated graphene metamaterials being a nonlinear analog of surface Tamm states.

P13: An equivalent realization of coherent perfect absorption under single beam illumination
Sucheng Li, Jie Luo, Shahzad Anwar, Shuo Li, Weixin Lu, Zhi Hong Hang, Yun Lai, Bo Hou, Mingrong Shen, Chin-Hua Wang
Soochow University (China)

We have experimentally and numerically demonstrated that the coherent perfect absorption (CPA) can equivalently be accomplished under single beam illumination. Practically, we introduce mushroom structures to the CPA configuration. By covering them with an ultrathin conductive film of sheet resistance 377 Ohms, the perfect microwave absorption is achieved when the film is illuminated under single beam. Our work proposes an equivalent way to realize the CPA under the single beam illumination, and might have applications in engineering absorbent materials.

P14: Enhanced absorption of graphene by exciting magnetic polaritons and surface plasmon polaritons
Bo Zhao[1], Junming Zhao[2], Zhuomin Zhang[1]
[1] *Georgia Institute of Technology (USA),* [2] *Harbin Institute of Technology (China)*

The minimal absorption of graphene in visible and near-inferred range has severely limited its application. This work demonstrates that the absorptance in a monatomic graphene layer can be greatly enhanced to nearly 80 percent when magnetic polaritons (MPs) or surface plasmon polaritons (SPPs) are excited in deep metal gratings. The plasmon frequency is essentially not affected by the additional graphene layer. Meanwhile, the enhanced graphene absorptance is angular dependent for SPPs but independent for MPs.

P15: Wavefront shaping in cavities: waves trapped in a box with taylored boundaries.
Matthieu Dupre, M. P. Del Hougne, M. Fink, F. Lemoult, G. Lerosey
ESPCI ParisTech (France)

Using electronically tunable metasurfaces that modify locally the boundaries of a cavity, switching them from electric to magnetic conductors, we show that we can control eigen modes and frequencies in cavities, allo-

wing wavefrontshaping, transmission enhancement between antennas and eigenfrequencies positionning at will.

P16: Luneburg-fisheye lens featuring dual function at terahertz frequencies
Shuo Liu, Xiang Wan, Tiejun Cui
Southeast University (China)

We present a planar Luneburg-fisheye lens capable of realizing both Luneburg and fisheye functions at terahertz frequencies. The deliberately designed anisotropic structure exhibits different effective surface index along the x- and y-directions. By arranging such units with the corresponding geometrical parameters on a quartz substrate, we can realize point source to point source (the fisheye function) or point source to plane wave (the Luneburg function) conversions when a terahertz point source is placed at the x- and y-axes.

P17: Theory of Numerical Pinning Model with Maxwell Stress
Masanori Tsuchimoto
Hokkaido University of Science (Japan)

The numerical pinning model for high-Tc superconductor (HTS) is explained with Maxwell stress. Stable levitation of a permanent magnet with YBCO tapes is obtained without shielding currents in experiments. Though present experiments are for large scale applications, basic theory comes from pinning of flxsoids in HTS. The pinning force is discussed with the critical currents of the YBCO tape by using the numerical pinning model.

P18: Influence of TeO2 layer on the reversible optical properties Ta2O5/SiO2 one-dimensional photonic crystals
Cheol Jin Park, Heon Kong, Jong Bin Yeo, Hyun Yong Lee
Chonnam National University (Korea)

In this work, we have investigated the optical properties of one-dimensional photonic quasi-crystal (1D-PQC) with a defect layer of TeO2-based chalcogenide. First, optical constants of Ta2O5, SiO2 and TeO2 were measured by ellipsometer. The 1D-PQC was designed using the transfer matrix method (TMM). Designed structures were fabricated by rf sputtering system. The deposition rates of the each film measured by scanning electron microscope (SEM). The optical properties of 1D-PQC were evaluated before and after exposing He-Ne and He-Cd laser.

P19: Modeling of a wideband single-feed circularly polarized microstrip antenna for UHF RFID applications
Tao Zhou, Xi-Wang Dai, Mian Pan, Hai-jun Gao, Zhi-Qun Cheng, Ling-Ling Sun
Hangzhou Dianzi University (China)

The modeling of a microstrip antenna for RFID application at 2.4 GHz is proposed. It consists of a single probe feed meandered microstrip line and a corner truncated microstrip patch. The CP operation is realized by adjusting the truncated corners, the meandered microstrip line and the thickness of air layer. The wideband impedance bandwidth of the anatenna defined by VSWR less than 2.0 is 470MHz, the axial ratio bandwidth less than 3dB is enhanced to 240MHz.

P20: Polarization Independent Terahertz Metamaterial Absorber and its Electric Circuit Analogous
Mohammad Hokmabadi, Muliang Zhu, Patrick Kung, Seongsin Kim
The University of Alabama (USA)

Here, we design a THz metamaterial absorber with a polarization independent response. A model is suggested as its electric circuit analogous. By using a hybrid approach, the effective parameters of the model are uniquely determined. The proposed approach is based on calculation, fitting, and the physical mechanism of the absorption interpreted by the model. This model and the proposed approach is applicable for all metamaterial absorbers with arbitrary frequency selective surfaces (FSS).

P21: Investigation of Robust Flexible Conformal THz Perfect Metamaterial Absorber
Juhyung Kim, Mohammad Hokmabadi, Soner Balci, Elmer Rivera, David Wilbert, Patrick Kung, Seongsin Kim
The University of Alabama (USA)

The flexible metamaterials have promised to greatly expand our ability to realize a wide range of novel applications including new methods of sensing and cloaking. We performed a new experiment for the robust flexible

THz frequency perfect absorber, which was fabricated as a combination of multilayer polyimides and multilayer frequency selective surfaces, which works for dual-band absorption, on various 3D printed conformed surfaces, thus verified their ability as a thin film absorber in the real world application.

P22: Deposition and characterization of erbium doped alumina coatings by reactive cosputtering
Priyanka Nayar, Yujie Deng, Ming Hui Lu
Nanjing University (China)

Thin films of amorphous erbium doped alumina of thickness 400-500 nm were fabricated on thermally oxidized silicon and fused silica substrates using cosputtering technique and the influence of the deposition parameters (substrate temperature, RF power, oxygen pressure) used during the growth on their structural and optical characteristics have been studied. The main aim is to optimize the deposition parameters so as to obtain the best optical performance of the deposited films for applications in optical communication window.

P23: Design and Analysis of A Compact Triple Band-Notched UWB antenna using rectangular Split-Ring Resonators (SRRs)
Amine Hedfi, Mohamed Hayouni, Fethi Choubani
Innov'Com Research Laboratory-Sup'Com (Tunisia)

A compact WiMAX, WLAN and downlink of X-band satellite communication systems triple band-notched monopole UWB antenna is proposed. The first and second notched bands are respectively achieved using a quarter wavelength straight open-ended and a semi-elliptic slots etched in the radiating patch while the third notched band is achieved using two rectangular split ring resonators (SRRs) near the feed line-patch junction of the antenna.

P24: Continuous to Periodical Segmented Waveguide Coupling Design
Anderson Dourado Sisnando[1], Vitaly Felix Rodriguez-Esquerre[1], Cosme Eustaqui Rubio Mercedes[2]
[1] *Federal University of Bahia (Brazil),* [2] *State University of Mato Grosso do Sul (Brazil)*

The coupling efficiency between continuous and periodic segmented waveguides using segmented taper has been successfully and efficiently designed and optimized by using the genetic algorithms (GA) in conjunction with the finite element method (FEM-2D). The coupling efficiency of the optimized structure as a function of the operating wavelength has been also analyzed.

P25: Probing graphene nonlinear dielectric susceptibility tensor using a photon sieve
Michael Lobet[1], Michael Sarrazin[1], Francesca Crechet[1], Nicolas Reckinger[1], Alexandru Vlad[2], Jean-François Colomer[1], Dan Lis[1]
[1] *University of Namur (Belgium),* [2] *UCLouvain (Belgium)*

An original method to constrain the values of the second-order susceptibility of graphene deposited on a gold substrate is presented, which combines second-harmonic generation experiments with semi-analytical computations to solve the inverse scattering problem. A gold photon sieve is used to trap the light and allow surface plasmons propagation in order to provide an intense effective pump. Three non-degenerate terms of the second-order susceptibility can be constrained for a second harmonic signal at 780 nm.

P26: Analytical model and performances at large scanning angles of an ultra-wideband self-complementary connected array antenna
Stefan Varault[1], Michel Soiron[2], Andre Barka[3], Anne-Claire Lepage[1], Xavier Begaud[1]
[1] *ESPCI ParisTech (France),* [2] *SART (France),* [3] *ONERA-The French Aerospace Lab (France)*

We present in this work a comprehensive analytical model of a self-complementary connected array antenna. This circuit model is used to dimension and optimize the structure with a minimum computational burden. The final design involves a meta-surface on top of the radiating aperture, together with a substrate made from an artificial anisotropic dielectric. This multilayer achieves a reflection coefficient |S11|<-10dB over a 5:1 bandwidth ratio for incidences as high as 60 degree in both TE and TM polarizations.

P27: Tunable graphene-coated spiral dielectric lens as a circular polarization analyzer
Bofeng Zhu, Guobin Ren, Martin Cryan, Yixiao Gao, Chenglong Wan, Shuisheng Jian
University of Bristol (United Kingdom)

We propose a tunable circular polarization analyzer based on a graphene-coated spiral dielectric lens. The analyzer focuses circular polarization with opposite chirality while defocusing that with same chirality, producing spatially separated solid dot or donut shape fields. The focusing and defocusing effects are independent

of the chemical potential of graphene, and depend only on the dielectric permittivity and grating occupation ratio. The operation wavelength of analyzer can be tuned by adjusting the graphene chemical potential without degrading the performance.

P28: Computational Analysis of Gold/Titanium Nitride Core/Shell Nanoparticles for Integration into Heat Assisted Magnetic Recording
James Bennington, Robert Bowman, Paul Dawson
Queen's University Belfast (United Kingdom)

We demonstrate computationally the localized surface plasmon resonance (LSPR) of gold/titanium nitride, core/shell nanostructures with varying shell thicknesses and show their similarity compared to pure gold structures of similar size. We suggest that owing to titanium nitrides well documented performance as a diffusion barrier in Ultra Large Scale Integration (ULSI) and the demonstrated plasmonic properties of our core/shell structures that it is a prime candidate as a thermal solution for heat assisted magnetic recording (HAMR) near field transducers (NFTs).

P29: LCR Model for Hyperbolic Metamaterials
Christopher Rosenbury, Daniel Fullager, Michael Fiddy
University of North Carolina at Charlotte (USA)

We show that a previously derived LCR model for a plasmonic waveguide can be generalized to a model for hyperbolic metamaterials (HMMs). An analysis of previous work and a generalization into a multilayer structure is presented. A comparison with simulations is provided. The physical significance and practical applications are discussed.

P30: Numerical modal analysis in dispersive and dissipative plasmonic structures.
Yoann Brule, Guillaume Demesy, Boris Gralak
Institut Fresnel (France)

Modal analysis is an essential tool since it straightly provides the lighting conditions under which a plasmonic structure can sing. Modes appear as solutions of source free Maxwell's equations. For dispersive and dissipative structures, the associated spectral problem is not standard, being generally non linear in frequency and not selfadjoint. We developed and implemented two finite element formulations to tackle this non standard eigenvalue problem in a 2D multi-domain closed cavity. Their numerical validity are checked against the analytical solution.

P31: Coupling enhancement of metamaterial structures on graphene
Humeyra Caglayan
Abdullah Gul University (Turkey)

Split ring resonators (SRRs) are used in order to localize and enhance incident electromagnetic field. Electrically controllable sheet concentration of graphene provides a platform where the optical conductivity of the graphene layer can be tuned. The spectral response of SRR arrays can be modulated by applying gate voltage. We showed that the tuning range can be increased by designing SRR structures with higher effective mode area.

P32: Bi Directional Surface Plasmon Vortex Creation in a Metasurface under Linearly Polarized Excitation
Chung-Yin Lin, Ching-Fu Chen, Chen-Ta Ku, Chen-Bin Huang
National Tsing Hua University (Taiwan)

A nanocavity in a gold thin film is optimized and arranged to form a metasurface. We numerically demonstrate that surface plasmon vortices with directional-tunable orbital angular momenta can be generated under linearly-polarized optical excitation.

P33: Intuitive analysis of modes guided in a subwavelength metallic groove
Tong Zhu, Haitao Liu
Nankai University (China)

Metal-insulator-metal waveguide modes can be guided by a subwavelength metallic nanogroove. Here we propose an analytical model for reproducing the dispersion diagram and the field distribution of the guided modes in the nanogroove. With the model, the number of propagative modes for finite-depth grooves and the cut-off frequency can be obtained. The model reveals that the modes guided by the groove can be understood

due to an excitation of the fundamental mode.

P34: Step-Phasors and Non-Smooth Light Transmission through a Sub-wavelength Slit
Alexander Ewen Chen[1], **Jian-Shiung Hong**[2], **Kuan-Ren Chen**[2]
[1] *The Pennsylvania State University (USA),* [2] *National Cheng Kung University (Taiwan)*

We present a novel method using step phasors to study the early dynamics of light transmission through a sub-wavelength slit and to describe transmitted electric field components. The resultant transmitted electric field is based on the superposition of the step phasors and can be a non-smooth wave function. Besides academic importance, these findings are of immediate interest towards applications of pulsed nano-photonics.

P35: Controllable surface plasmon polariton excitation by usage of a nanoantenna metasurface
Holger Muhlenbernd[1], **Philip Georgi**[1], **Nitipat Ong Pholchai**[2], **Lingling Huang**[3], **Shuang Zhang**[4], **Thomas Zentgraf**[1]
[1] *University of Paderborn (Germany),* [2] *King Mongkut's University (Thailand),* [3] *Beijing Institute of Technology (China),* [4] *University of Birmingham (United Kingdom)*

Surface plasmon polaritons (SPPs) are used for many technical and scientific applications, reaching from integrated optics to bio sensing. For many applications it is necessary to control the amplitude and phase of SPPs. This challenge we solved by using a metal insulator metal metasurface containing nanoantennas. With this structure we can change the phase and the amplitude of the excited SPPs continuously simply by changing the polarization state and angle of the incoming light.

P36: Nanoshells Tuning for Cancer Therapy
Ahmed Abbas, Mostafa El Said, Samir Fahmy Mahmoud
Cairo University (Egypt)

Nanoshells have received considerable attention overthe last decade.Nanoshells are spherical nanoparticles consisting of a dielectric core covered by a thin metallic shell which is usually gold.When illuminated by a plane wave at the right frequency, a significant local electric field enhancement occurs near the metal-dielectric interface due to the strong surface plasmon resonance (SPR).

P37: Silicon Nanospheres for Enhancing Light-Matter Interactions at the Nanoscale
Hao Wang, Huanjun Chen
Sun Yat-sen University (China)

In our study, by combining the silicon nanosphere with the Au nanosphere, we demonstrated theoretically and experimentally the unidirectional visible light scattering behaviors of Janus dimer structures. Such exotic behavior originates from the hybridization of the electric and magnetic dipole mode in the dimers. We further showed that by coating the silicon nanosphere with a molecular layer, strong coupling effect can be induced between the exciton transition of the molecules and the magnetic dipole resonance in the silicon nanosphere.

P38: Shape Optimization for Enhancement of Second Harmonic Generation by Double Resonance Conditions
Nicholas Wang, Andrew P. Lawson, Patrick C. McAvoy, Isaak D. Mayergoyz, Oded Rabin
University of Maryland College Park (USA)

Plasmonic nanostructures may facilitate second harmonic generation(SHG) in non-linear optic media by local enhancement of optical electric fields in their immediate vicinity. We demonstrate computationally that by tailoring the material and shape of the plasmonic nanostructure, localized surface plasmon resonances can be tuned to occur simultaneously at the fundamental and the doubled frequencies. We report on metal nanorods and nanotubes that are optimized for the enhancement of SHG with incident radiation in the infrared and emission in the visible.

P39: Coupling efficiency of light to surface plasmon polariton on a polymer-metal interface at different incidence angles.
Eduardo Pisano, Cesar E. G. Ortiz, Rodolfo Cortes, Victor M. Coello
Centro de Investigacion Cientifica y de Educacion Superior de Ensenada (Mexico)

In this work, experimental result of the coupling efficiency of light to surface plasmon polaritons (SPPs) is presented. The SPP modes were excited at a polymer-metal interface. The measurements were made at different incidence excitation angles using a polymer edge nanostructure for SPP launching. The structure is similar to that used in dielectric-loaded surface plasmon polariton waveguides. The analysis of the coupling

efficiency dependence might lead to a compensation solution for SPP propagation length losses.

P40: Factors Determining the Light Amplification Spectra in Surface Plasmon-Enhanced Organic Light Emitters

Takahiro Inui[1], Yuta Mizoguchi[1], Takuya Yoneda[1], Hiroto Kawase[1], Kenichi Kasahara[1], Naoki Ikeda[2], Yoshimasa Sugimoto[2]

[1] *Ritsumeikan University (Japan),* [2] *NIMS (Japan)*

The determinant factors of the photoluminescence enhancement spectra due to surface plasmon scattering with an organic material whose peak emission was distant from the plasma wavelength of a metal were investigated. The surface plasmon scattering cross section was estimated by placing a nanostructure on Ag. Although enhancement decrease occurring at longer wavelengths remains to be investigated, the reason why light amplification didn't occur near the plasma wavelength was explained by a short propagation distance of the surface plasmon.

10:30 - 12:20 — Aronow Theater

Session 2A2

Symposium 1: Functional Metastructures and Nanomaterials: Properties, Fabrication and Modeling IV

Organized by: Alexander Govorov and Hilmi Volkan Demir

Chaired by: Dongling Ma and Nianqiang Wu

10:30 : Keynote talk

Electronically Tunable Metamaterials

Harry A. Atwater[1], Georgia Papadakis[1], Michelle C. Sherrott[1], Victor W. Brar[1], Min S. Jang[2], Seyoon Kim[1], Laura Kim[1], Mansoo Choi[2], Luke A. Sweatlock[3]

[1] *California Institute of Technology (USA),* [2] *Seoul National University (Korea),* [3] *Northrop Grumman Aerospace Systems (USA)*

In recent years, the progress in optical metamaterials has led to new physics such as near zero optical parameters, diverging density of states and optical band structure engineering. We discuss several approaches for achieving dynamically gate-tunable metamaterials and metasurfaces, including finite-thickness layered metamaterials and metasurfaces using conducting oxide thin films as active elements and active, gate-tunable radiative emission from graphene metamaterials.

11:00 : Invited talk

Resonant Dipole Nanoantenna Arrays for Enhanced Terahertz Spectroscopy

Andrea Toma[1], Salvatore Tuccio[1], Mirko Prato[1], Francesco De Donato[1], Andrea Perucchi[2], Paola Di Pietro[2], Sergio Marras[1], Carlo Liberale[1], Remo Proietti Zaccaria[1], Francesco De Angelis[1], Liberato Manna[1], Stefano Lupi[3], Enzo Di Fabrizio[4], Luca Razzari[5]

[1] *INRS-EMT (Italy),* [2] *INSTM UdR Trieste-ST and Sincrotrone Trieste (Italy),* [3] *Universita di Roma La Sapienza (Italy),* [4] *King Abdullah University of Science and Technology (Saudi Arabia),* [5] *INRS Energie-Materiaux et Telecommunications (Canada)*

Our recent studies on dipole nanoantenna arrays resonating in the terahertz frequency range (0.1- 10 THz) will be presented. The main near- and far-field properties of these nanostructures will be shown and their application in enhanced terahertz spectroscopy of tiny quantities of nanomaterials will be discussed.

11:20 : Invited talk

Aluminum nanostructures for UV plasmonics

Julien Proust, Silvère Schuermans, Dmitry Khlopin, Feifei Zhang, Jerome Martin, Davy Gerard, Thomas Maurer, Jerome Plain

University of Troyes (France)

We report on the synthesis of aluminum nanoparticles by different ways. For all the different technique, the

optical properties have been carefully studied. Particularly, it appears that the chemical ways induce hybrid metal / oxyde nanoparticles showing a strong photoluminescence.

11:40 : Invited talk
The Design and Fabrication of Aluminum-based Nano-hole Arrays Using Nanosphere Lithography
Morgan McElhiney[1], Mark Mirotznik[1], Z. Zander[2], Brendan DeLacy[2]
[1] *University of Delaware (USA),* [2] *U.S. Army Edgewood Chemical Biological Center (USA)*

We detail the computational design, fabrication and optical characterization of an aluminum-based nano-hole array. Arrays of aluminum nano-holes were patterned on a silica-coated aluminum base mirror plane using nanosphere lithography. This architecture provided a means of exploring the coupling of the localized surface plasmon resonance (LSPR) exhibited by the aluminum nano-hole array with the Fabry-Perot cavity resonance that is generated within the silica spacer layer. Finite difference time domain (FDTD) calculations and infrared spectroscopy were used to design and characterize the structures, respectively.

12:00 : Invited talk
Semiconductor Nanowires for Optoelectronic Device Applications
Chennupati Jagadish
Australian National University (Australia)

In this talk, I will review recent progress in III- V compound semiconductor nanowire research and discuss ways to control the size, shape, composition and crystal phase in turn their electrical and optical properties I will present results on devices such as nanowire lasers, nanowire THz detectors, nanowire solar cells and nanowire plasmonics.

10:30 - 11:30 — NAC 0/201

Session 2A3

Structured light in metamaterials IV

Organized by: Natalia Litchinitser and Richard Hammond

Chaired by: Natalia Litchinitser and Richard Hammond

10:30 : Invited talk
Observation of power controlled discrete vortices in optically induced nonlinear waveguide array
Falko Diebel[1], Daniel Leykam[2], Martin Boguslawski[1], Patrick Rose[1], Cornelia Denz[1], Anton Desyatnikov[2]
[1] *Universitat Munster (Germany),* [2] *The Australian National University (Australia)*

We introduce a circular array of four coupled nonlinear waveguides, optically induced in a photorefractive crystal using an incoherent superposition of nondiffracting Bessel beams. The array supports nonlinear vortex breather modes, in which the vortex charge and orbital angular momentum reverse periodically during propagation, with the period controlled by the optical power. Propagating a discrete vortex beam through the crystal, we experimentally observe charge reversal at low power and the conservation of its charge in the nonlinear regime.

10:50 : Invited talk
Nanoscale Plasmonic Patch Antennas for Control of Optical Processes
Maiken Mikkelsen
Duke University (USA)

Here, we provide an overview of our recent demonstrations and latest progress on controlling radiative processes and nonlinear effects using a large-area plasmonic nanopatch antenna platform. In particular, we demonstrate large enhancements of fluorescence and spontaneous emission rates of dye molecules embedded in plasmonic nanoantennas with sub-10-nm gap sizes and observe nearly five orders of magnitude enhancements in third-harmonic generation efficiency.

11:10 : Invited talk

Ultrathin metasurfaces with ultrahigh cross-polarization manipulation efficiency

Cheng-Wei Qiu, Lei Zhang, Xumin Ding, Fei Qin
National University of Singapore (Singapore)

Metasurfaces operating in the cross-polarization scheme have shown an interesting degree of control over the wavefront of transmitted light. Nevertheless, their inherently low efficiency raises certain concerns in industrial applications. In this work, two types of ultrathin metasurfaces with ultrahigh cross-polarization manipulation efficiency were introduced at visible and microwave ranges, which almost approached the theoretical limit. Also, our designs interestingly show that the conversion efficiency could be as good as that of dielectric metasurfaces.

11:30 - 12:10 — NAC 0/201

Session 2A4

Chiral and Nonlinear Metamaterials: Properties, Fabrication, and Applications I

Organized by: Ventsislav K. Valev and Nicolae C. Panoiu

Chaired by: Ventsislav K. Valev and Nicolae C. Panoiu

11:30 : Invited talk

Nonlinear processes in plasmonic metamaterials

A. D. Barbosa Neira, G. Marini, S. Peruh, A. Krasavin, N. Olivier, M. Nasir, W. Dickson, G. A. Wurtz, Anatoly Zayats
King's College London (United Kingdom)

Experimental studies and numerical modeling of nonlinear optical processes in plasmonic metamaterials based on assemblies of metallic nanorods will be presented. Second- and third-order nonlinear optical response originating from a plasmonic component of the metamaterial will be discussed. Nanorod-based plasmonic metamaterials can be used for engineering strongly enhanced nonlinear optical properties with the required spectral and temporal response.

11:50 : Invited talk

Optical characterization of self-assembled chiral meta and nano surfaces by nonlinear second harmonic generation.

Marco Centini, Alessandro Belardini, Alessio Benedetti, Mario Bertolotti, Concita Sibilia
Universita di Roma La Sapienza (Italy)

We report an overview of second harmonic generation measurements showing nonlinear circular dichroism raised by self-assembled nanopatterned surfaces of different morphologies and material components. Straight metallic wires, curved metallic wires, partially metallized spheres and carpets of tilted nanorods have been characterized to investigate the importance of the geometry obtained by different experimental fabrication techniques and to establish the criteria for optimized circular dichroism.

10:30 - 12:35 — NAC Ballroom

Session 2A5

Nonlinear and Reconfigurable Plasmonics and Metamaterials I

Organized by: Christos Argyropoulos and Pai-Yen Chen

Chaired by: Christos Argyropoulos and Pai-Yen Chen

10:30 : Invited talk

Saturation in spasers with retardation: bistability, fields, cross-sections, quenching, boundary losses, and heating

Nikita Arnold[1], **Klaus Piglmayer**[1], **Alexander Kildishev**[2], **Thomas Klar**[1]
[1] *Johannes Kepler University (Austria),* [2] *Purdue University (USA)*

Several spaser geometries are studied within electrodynamic framework in the generating and driven regimes. Gain is modelled using an inverted Lorentzian dielectric function with saturation broadening. The spasers with retardation and spatially inhomogeneous saturation are treated numerically, and the results are compared with the analytical guidelines. Quadrupolar modes of silver shells and dipolar modes of spheroids demonstrate thresholds close to the theoretical minimum. The role of quenching, boundary losses, and heating is also discussed.

10:50 : Invited talk

Self-action of Surface Plasmon Polaritons

Alexandre Baron, Thang B. Hoang, Chao Fang, Maiken H. Mikkelsen, David R. Smith
Duke University (USA)

We investigate theoretically and experimentally the nonlinear propagation of surface plasmon polaritons (SPP). Our observations reveal that the SPP undergoes strong ultrafast self-action through self-induced absorption, consistently with a large, third-order nonlinear susceptibility of gold and provide a self-consistent theory of self-action of SPPs at an air/metal interface. The implications for the nonlinear physics of plasmonics and metamaterials are important as they evidence that nonlinear absorption has a significant effect on the propagation of SPPs excited by intense pulses.

11:10 : Invited talk

Quantum Effects in Nanoantennas and Their Applications in Tunability, Mixing, and Rectification

Pai-Yen Chen[1], **Mohamed Farhat**[2]
[1] *Wayne State University (USA),* [2] *King Abdullah University of Science and Technology (Saudi Arabia)*

We present here that by tailoring the geometry of nanoantennas and the electronic band structure, a nanoantenna, within the quantum mechanical realm, can induce linear and high-order quantum conductivities that are considerably enhanced by the surface plasmon resonance. We will present their nanophotonic applications including (i) modulatable and switchable radiators and metamaterials, (ii) optical rectification for detection and energy harvesting, and (iii) harmonic sensing for the physical properties of nanoparticle, e.g. DNA and molecules, loaded inside the nanogap.

11:30 : Invited talk

Nonlinear optics with polaritonic metasurfaces coupled to intersubband transitions

Jongwon Lee[1], **Nishant Nookala**[1], **Mykhailo Tymchenko**[1], **Juan Gomez-Diaz**[1], **Frederic Demmerle**[2], **Gerhard Boehm**[2], **Markus-Christian Amann**[2], **Andrea Alu**[1], **Mikhail Belkin**[1]
[1] *University of Texas at Austin (USA),* [2] *Technische Universitat Munchen (Germany)*

We report highly-nonlinear metasurfaces based on combining electromagnetically-engineered plasmonic nanoresonators with quantum-engineered intersubband nonlinearities. Experimentally, effective nonlinear susceptibility over 480 nm/V was measured for second-harmonic generation at normal incidence.

11:50 : Computational study of second-harmonic generation in diffraction gratings made of centrosymmetric materials using the nonlinear generalized source method

Martin Weismann[1], **Dominic F.G. Gallagher**[2], **Nicolae C. Panoiu**[1]
[1] *University College London (United Kingdom),* [2] *Photon Design Ltd (United Kingdom)*

We present a new numerical method for the analysis of second-harmonic generation in diffraction gratings containing centrosymmetric materials. Our numerical method extends the generalized source method (GSM) and incorporates both the surface second harmonic (SH) polarization and the nonlocal bulk polarization into the algorithm to calculate the optical field at the SH. We study the convergence characteristics of the nonlinear GSM for plasmonic and dielectric gratings and investigate the contribution to the nonlinear response of surface and bulk polarization effects.

12:05 : Three wave mixing in metamaterial based nonlinear photonic crystals

Shay Keren-Zur, Nadav Segal, Tal Ellenbogen
Tel Aviv University (Israel)

Nonlinear metamaterials open exciting possibilities for integrated nonlinear optics. We show how to obtain

exceptional control of nonlinear optical interactions in metamaterials by constructing nonlinear metamaterial-based photonic crystals. These allow us to obtain engineered nonlinear diffraction, all-optical scanning, focusing and beam shaping of the nonlinear output. We also show that multilayered structures can boost the nonlinear conversion by orders of magnitude and extend the common analysis of second harmonic generation to arbitrary three wave mixing processes.

12:20 : Tunable terahertz and microwave metamaterials based on pi-conjugated polymer actuators
Tatsunosuke Matsui[1], Yuto Inose[1], David A. Powell[2], Ilya V. Shadrivov[2]
[1] *Mie University (Japan),* [2] *Australian National University (Australia)*

We demonstrate electro-active tuning of the resonant response of metamaterials utilizing pi-conjugated polymer actuators in terahertz (THz) and microwave frequency ranges. Linear actuators made from heavily doped polypyrrole film are utilized to change the relative lateral position of two THz metasurfaces with a control voltage, and accordion-shaped origami actuators are used to change the distance between two microwave split-ring resonators (SRRs). In both cases this results in significant tunability of the metamaterial resonances with a change of bias voltage.

10:30 - 12:30 — NAC 1/202

Session 2A6

Geometrical techniques for controlling electromagnetic waves I

Organized by: Simon Horsley and Oscar Quevedo-Teruel

Chaired by: Simon Horsley and Oscar Quevedo-Teruel

10:30 : Invited talk
Understanding the performance of qTO-enabled flattened gradient-index optics through polynomial-decomposition-based analytical mappings
S. D. Campbell, Donovan E. Brocker, Jogender Nagar, Douglas H. Werner, Pingjuan L. Werner
The Pennsylvania State University (USA)

Recent advances in the field of Transformation Optics (TO) have renewed the interest in gradient-index (GRIN) optical systems. By transforming a classically-inspired aspherical lens to a flat geometry using TO, we can achieve a design with better field-of-view performance than traditional radial GRIN lenses. In order to understand the underlying physics of this performance improvement, we decompose the TO solution into a 2D-polynomial basis and propose to analyze its wavefront error to determine which terms minimize oblique-angle optical aberrations.

10:50 : Invited talk
Controlling Electromagnetic Waves with Inhomogeneous Metamaterials
Di Bao, Tie Cui
Southeast University (China)

Metamaterials have provide great flexibility in manipulate electromagnetic wave, and many methodologies have been proposed to designed novel devices, such as geometrical optics, quasi-conformal mapping and transformation optics. In this presentation, we presented several metamaterial devices, including flat lens antenna, flattened Luneburg lens, invisible cloak and illusion devices.

11:10 : Invited talk
Transformation optics: A tool to study symmetries in plasmonics
Matthias Kraft[1], John Pendry[1], Stefan Maier[1], Yu Luo[2]
[1] *Imperial College London (United Kingdom),* [2] *Nanyang Technological University (Singapore)*

Symmetry is one of the most fundamental properties of an object: it both identifies the object and classifies its properties. An example would be a crystal whose translational symmetry allows us to classify electrons states by their Bloch wave vector. However, sometimes symmetry is hidden from view. We employ the new technique of Transformation Optics as a tool to reveal hidden symmetries in plasmonic systems, and to calculate their

optical properties.

11:30 : Invited talk
Controlling Microwave Surface Waves
Rhiannon Mitchell-Thomas[1], Oscar Quevedo-Teruel[2], Simon Horsley[1]
[1] *University of Exeter (United Kingdom),* [2] *KTH Royal Institute of Technology (Sweden)*

Geometrical optics allows for an analogy between flat and curved two dimensional geometries to be made, when radially dependent refractive index profiles are employed. This paper examines the applications of this equivalence, which include cloaking, conformal lensing and removing singularities in refractive indices. Examples of each will be given, and will be illustrated with both numerical and experimental data.

11:50 : Invited talk
Conformal transformation for nanoantennas
Victor Pacheco-Pena[1], Miguel Beruete[1], Antonio I. Fernandez-Dominguez[2], Yu Luo[3], Miguel Navarro-Cia[4]
[1] *Universidad Publica de Navarra (Spain),* [2] *Universidad Autonoma de Madrid (Spain),* [3] *Nanyang Technological University (Singapore),* [4] *Imperial College London (United Kingdom)*

Modeling the response of nanoantennas excited by a localized emitter is extremely computational intensive. Transformation optics can ease this task. Here we show the conformal transformation required to model a plasmonic bow-tie as a parallel-plate plasmonic waveguide. The eigenmodes of a parallel-plate plasmonic waveguide can be calculated analytically, enabling the calculation of the eigenmodes and the absorption cross section of the original bow-tie via the transformation. Full-wave simulations corroborate the approach

12:10 : Invited talk
Antenna Aperture Synthesis Using Cascaded Sheet Admittances
Brian Tierney, Anthony Grbic
University of Michigan (USA)

A technique for the synthesis of arbitrary radiation patterns using leaky-wave modes is presented. Complete control of the antenna aperture magnitude, phase, and polarization is demonstrated using impedance surfaces consisting of cascaded sheet admittances separated by dielectric layers and backed by a ground plane.

10:30 - 12:10 — ASRC Conference Room

Session 2A7

A bottom-up approach towards metamaterials and plasmonics IV

Organized by: Dorota Pawlak and Wounjhang Park

Chaired by: Marie Kafesaki and Harald Giessen

10:30 : Invited talk
Study and effective medium modeling of the strong optical anisotropy of self-assembled lamellar metallo-dielectric nanocomposites
Xuan Wang[1], Kevin Ehrhardt[1], Clemence Tallet[1], Julien Vieaud[1], Olivier Merchiers[2], Philippe Barois[1], Marc Warenghem[3], Ashod Aradian[1], Virginie Ponsinet[1]
[1] *Univiversity of Bordeaux (France),* [2] *CETHIL - INSA de Lyon (France),* [3] *Artois University (France)*

In this presentation, we describe the study of thin films of self-assembled ordered nanocomposites of polymers and gold nanoparticles. The spectral variation of their anisotropic effective dielectric permittivity is determined by variable-angle spectroscopic ellipsometry using appropriate effective medium models, as a function of the nature, density and spatial organization of the gold nanoparticles

10:50 : Invited talk
Meta-atom characterization by Gouy phase shift interferometry in highly focused light fields
Toralf Scharf[1], K. Achouri[1], M. Kim[1], J. Dintinger[1], A. Cunningham[2], T. Burgi[2], S. Muhlig[3], C. Rockstuhl[3]

[1] *Ecole polytechnique federale de Lausanne EPFL (Switzerland),* [2] *University of Geneva (Switzerland),* [3] *Karlsruhe Institute of Technology (Germany)*

We studied a new way to measure effective optical scattering properties of meta-atoms that is based on a special kind of interferometry to characterize material parameters of single meta-atom structures. The technique is based on a special kind of common path interferometry where a particle is passed though a focus point of a confocal setup and the on axis intensity response is recorded. We compare measurement and simulations for different wavelengths and different nanoparticles including meta-atoms of different variants.

11:10 : Invited talk

Metal-dielectric microstructures with directionally solidified eutectics as templates

Maria Acosta[1], **Sergio Rodrigo**[1], **Luis Martin-Moreno**[1], **Carlos Pecharroman**[2], **Javier Sese**[3], **Rosa Merino**[1]
[1] *CSIC-Universidad de Zaragoza (Spain),* [2] *Instituto de Ciencia de Materiales de Madrid-CSIC (Spain),* [3] *Universidad de Zaragoza (Spain)*

We demonstrate the feasibility of directionally solidified eutectics as templates to fabricate metal-dielectric arrangements with periodicity and building units in the micron scale. As a proof of concept, we have built optically thick holey metallic layers where the holes are filled with polaritonic LiF. Their optical properties are investigated in the whole IR range

11:30 : Invited talk

3D Optical Metamaterials by Self-Assembly and Templated Directed Solidification of Eutectics

Kaitlin I. Tyler, Julia Kohanek, Jinwoo Kim, Paul V. Braun
University of Illinois Urbana Champaign (USA)

Nanoscale integration of materials in three dimensions is critical for the realization of a number of highly functional optical metamaterials. Our team is applying unique template-based and post-synthetic materials transformations to produce novel 3D microstructures derived from directionally solidified eutectics. Three main eutectic systems have been investigated: molten salts, metals, and organics. The molten salts have shown novel microstructures via 3D template confinement, the metals have inherently interesting optical properties, and the organics can demonstrate different faceting during solidification.

11:50 : Invited talk

New supramolecular strategies for the assembly of plasmonic nanoparticles

Joao Paulo Coelho[1], **Gloria Tardajos**[1], **Gustavo Fernandez**[2], **Andres Guerrero-Martinez**[1]
[1] *Universidad Complutense de Madrid (Spain),* [2] *Universitat Wurzburg Am Hubland (Germany)*

The self-assembly of the supramolecule-stabilized gold nanoparticles under controlled temperature and humidity conditions proposed herein, paves the way for a new methodology to prepare reusable plasmonic supercrystals in both aqueous and organic solutions, with potential applications in nanoparticle imprinting and sensing.

10:30 - 12:30 — NAC 1/203

Session 2A8

Acoustic, elastic and thermal metamaterials IV

Organized by: Mohamed Farhat and Sebastien Guenneau

Chaired by: Mohamed Farhat and Sebastien Guenneau

10:30 : Seismic holes for controlling surface waves

Stephane Brule[1], **Sebastien Guenneau**[2], **Stefan Enoch**[2]
[1] *Menard Soletanche-Freyssinet Group Vinci (France),* [2] *Institut Fresnel (France)*

The concept of controlling seismic waves is in progress and first full-scale experiments had confirmed the interest which we can have for this new axis of research. Here we show the dynamic response of a meter-scale grid of vertical empty cylindrical holes, under the excitation of a 50 hz source.

10:45 : Numerical analysis of spherical cloaks with symmetric and asymmetric elasticity tensors.
Andre Diatta, S. Guenneau
Institut Fresnel (France)

We present some general framework for elastodynamic cloaking, with an emphasis on a markedly enhanced control of solid waves in heterogeneous anisotropic media. Potential applications are in seismic wave protection by detouring coupled pressure and shear waves around a region one would like to protect. We give a brief review on spherical elastodynamic cloaks with a rank-4, asymmetric, elasticity tensor. We also discuss the importance of geometric transforms in the design of perfectly matched elastic layers.

11:00 : Experimental demonstration of ordered and disordered multi-resonant metamaterials for Lamb waves
Matthieu Rupin[1], Fabrice Lemoult[1], Geoffroy Lerosey[1], Philippe Roux[2]
[1] *ESPCI ParisTech (France),* [2] *Institut des Sciences de la Terre (France)*

We demonstrate the experimental realization of a multi-resonant metamaterial for Lamb waves, i.e. elastic waves propagating in plates. The metamaterial effect comes from the resonances of long aluminum rods that are attached to an aluminum plate. Using time-dependent measurements, we experimentally prove that such a medium exhibits wide band gaps as well as sub- and supra-wavelength modes for both a periodic and a random arrangement of the resonators.

11:15 : Opto-Mechanical Interactions in Split Ball Resonators
Yue Sun, Sergey V. Suchkov, Andrey E. Miroshnichenko, Andrey A. Sukhorukov
Australian National University (Australia)

We demonstrate that a gold split-ball resonator in the form of a spherical nanoparticle with a cut supports optical magnetic and acoustic modes, which are strongly co-localized near the cut, enabling strong opto-mechanical interactions. We simulate the excitation of the acoustic vibrations through laser heating and optical forces induced by the optical magnetic resonance, and determine that a laser pulse which gives 100K temperature change yields acoustic oscillations resulting in 10 percent modification of the optical scattering.

11:30 : Fick's second law transformed: one path to cloaking in mass diffusion
Tania Puvirajesinghe[1], S. Guenneau[2]
[1] *CRCM - Inserm (France),* [2] *Institut Paoli-Calmettes (France)*

We have adapted the concept of transformational thermodynamics, for the diffusion and transport of mass concentration. We initially used finite-element computations to model liposome particles surrounded by a cylindrical multi-layered cloak in a water-based environment [1]. Independent research groups have applied our model to applications implicating the protection of steel [2] as well as for the design of water-based invisibility cloaks [3]. We now investigate the utility of the biocloak for vectorization of drugs [4].

11:45 : Use of metamaterials and transformation thermodynamics for the manipulation of mass flow in engineering systems
Juan Restrepo-Florez, Martin Maldovan
Georgia Institue of Technology (USA)

In this work, the use of transformation thermodynamic techniques is applied for the design of a mass flux concentrator. We study the effect of different design parameters (number of layers and volume fraction of the materials) on the performance of the device, the objective of this work is to extend the ideas of optical and thermal metamaterials to mass-transfer manipulation devices.

12:00 : Negative Refraction of Lamb Waves
Benoit Gerardin[1], Jerome Laurent[2], Claire Prada[1], Alexandre Aubry[1]
[1] *ESPCI ParisTech (France),* [2] *Institut Langevin (France)*

Negative index materials have received considerable attention in recent years since they offer many potential applications to manipulate waves in unusual ways. Here we present theoretical, numerical and experimental results on several simple devices based on negative refraction.

12:15 : Experiments on gradient-index lenses in elastic plates
Patrick Sebbah[1], G. Lefebvre[1], M. Dubois[1], R. Beauvais[1], Y. Achaoui[2], R. Ing[1], S. Guenneau[2]
[1] *Institut Langevin - ESPCI (France),* [2] *Institut Fresnel (France)*

We investigate the possibility to design gradient-index lenses for flexural waves propagating in thin plates. We

experimentally explore the dynamics of an elastic plate whose thickness varies radially. We design the right thickness profile to form the equivalent in elastodynamics of the Maxwell's fisheye lens in optics. Its imaging properties for a Gaussian pulse are very similar to those predicted by ray trajectories (great circles) on a virtual sphere.

10:30 - 12:30 — NAC 1/211

Session 2A9

Advances in Hybrid Plasmonics I

Organized by: Mohamed Swillam

Chaired by: Mohamed Swillam

10:30 : Invited talk
Plasmonic-photonic crystal coupled nanolaser
Ali Belarouci[1], Taiping Zhang[2], Segolene Callard[2]
[1] *Sherbrooke University (Canada),* [2] *Ecole Centrale de Lyon (France)*

We propose and demonstrate a hybrid photonic-plasmonic nanolaser that combines the light harvesting features of a dielectric photonic crystal cavity with the extraordinary confining properties of an optical nanoantenna. For this purpose, we developed a novel fabrication method based on multi-step electron-beam lithography. We show that it enables the robust and reproducible production of hybrid structures. Coherent coupling of the photonic and plasmonic modes is highlighted and opens up a broad range of new hybrid nanophotonic devices

10:50 : Invited talk
Surface Plasmon Enhanced Optoelectronics
Pierre Berini
University of Ottawa (Canada)

Metallic nanoantennas and gratings can couple efficiently incident optical beams to SPPs. Such nanostructures ensure strong field overlap with active regions when formed on semiconductors while operating simultaneously as a device electrode. The excitation of SPPs thereon alters trade-offs between modulation/speed in modulators, or responsivity/speed in photodetectors, because the active region can be shrunk to the nanoscale while maintaining good performance due to field enhancement. SPP-enhanced photodetectors and modulators on silicon are reviewed and discussed.

11:10 : Invited talk
Integrated Hybrid Plasmonic-Photonic Structures for Enhanced Light-matter Interaction
Mayamreza Chamanzar, Hamed Mousavi, Ye Luo, Hossein Taghinejad, Mohammad Taghinejad, Ali A. Eftekhar, Ali Adibi
Georgia Institute of Technology (USA)

Recent progress in the integration of highly-controlled nanoplasmonic structures with nanophotonic structures in an integrated platform for enhancement of light-matter interaction will be discussed, and its advantages for a few important practical applications will be discussed. On one hand, the use of integrated nanophotonic structures for highly efficient coupling of light into plasmonic nanostructures will be demonstrated.

11:30 : Invited talk
Graphene and metal-insulator-semiconductor (MIS) plasmons
Lin Chen[1], Wei Hong[1], Xun Li[2]
[1] *Huazhong University of Science and Technology (China),* [2] *McMaster University (China)*

Surface plasmon polaritons (SPPs) provides the capability of manipulating light signal with nanoscale dimension. Here we will present our recent work on the design of novel plasmonic waveguides based on graphene and metal-insulator-semiconductor (MIS). And their potential applications have also been briefly discussed.

11:50 : Invited talk

Photothermal switching of silicon resonators integrated with metal-insulator-metal absorbers

Xi Chen[1], Yuechun Shi[2], Fei Lou[1], Lech Wosinski[1], Min Yan[1], Min Qiu[3]
[1] *Royal Institute of Technology (Sweden),* [2] *Nanjing University (China),* [3] *Zhejiang University (China)*

Here we demonstrated the all-optical switching in a cascade of two silicon microdisk resonators integrated with metal-insulator-metal (MIM) absorbers. The tuning of the individual silicon microdisk is induced by the localized heat generation in the continuous-wave (CW) laser pumped MIM absorber. Such a design requires no buffer layer and enables localized heat injection on the selected device, which provides a promising route to the densely integrated micro-resonator switch array with fast temporal response and low switching power.

12:10 : Invited talk

Hybrid plasmonic waveguide for nonlinear four-wave mixing generation and enhancement

Stefano Palomba[1], Fernando Diaz[1], Boris Kuhlmey[1], Taiki Hatakeyama[2], Xiang Zhang[2]
[1] *University of Sydney (Australia),* [2] *University of California (USA)*

We report the first experimental demonstration of a nonlinear four-wave mixing signal generated in a hybrid plasmonic waveguide (HPWG), constituted by a nonlinear dielectric material (Si3N4), sandwiched between a metallic layer (gold) and a Si nanowire. We observe an enhanced nonlinear signal compared to the bare Si nanowire in case of a high order TM mode excitation.

10:30 - 12:30 — NAC 1/201

Session 2A10

Nano-apertures and applications I

Organized by: Sang-Hyun Oh and Reuven Gordon

Chaired by: Sang-Hyun Oh and Reuven Gordon

10:30 : Invited talk

Single photon transport by atom through nanohole

Anton Afanasiev, Pavel Melentiev, Artur Kuzin, Alexandr Kalatskiy, Victor Balykin
Russian Academy of Sciences (Russia)

We have investigated a single photon transport by atom through nanohole. A single Rb atom absorbs a photon of laser radiation before nanohole, passes the photon through nanohole and then emits it after nanohole by way of spontaneous decay. Our measurements showed a high transfer efficiency 1 percent of single photon transport through nanohole for nanoholes of 400 nm diameter.

10:50 : Invited talk

Nano-optical spectroscopic imaging of monolayer MoS2

Wei Bao[1], Nicholas Borys[1], Changhyun Ko[2], Sefaattin Tongay[2], Wen Fan[2], D. Ogletree[1], Paul Ashby[1], Miquel Salmeron[1], Junqiao Wu[2], P. James Schuck[1]
[1] *Lawrence Berkeley National Laboratory (USA),* [2] *U. C. Berkeley (USA)*

We describe the first nano-optical investigation of 2D transition metal dichalcogenides (TMDCs). Establishing a solution to the nanospectroscopy imaging problem for these materials, we cross the boundary from insufficient to sufficient resolution, mapping critical optoelectronic properties at their native length scales. In doing so, we uncover new optoelectronic regions and spatially-varying features in MoS2 that were hidden in prior optical studies.

11:10 : Invited talk

Nanopore Plasmonic Sensing

C. Crick, P. Albella, B. Ng, A. Ivanov, T. Roschuk, M. P. Cecchini, F. Bresme, S. Maier, Joshua Edel
Imperial College London (United Kingdom)

The work presented within details precise temperature control at a plasmonic nanopore. The solid-state devices are made up of a silicon nitride membrane, and gold layer patterned with a well-defined bullseye structure

surrounding a nanopore. The design is optimised, through simulation and experiment, to act as nanoantenna with maximum enhancement at the centre of the pore.

11:30 : Invited talk
Elliptical gold nanohole as optical trap for plasmon-enhanced chiral analysis
Zhan-Hong Lin, Jer-Shing Huang
National Tsing Hua University (Taiwan)

We present a simple design of plasmonic optical trap that enables simultaneous enhanced trapping and chiral analysis. By making the nanoholes elliptical, we introduce 90 degree phase shift between the orthogonal field components. The holes then serve as a nanosized quarter wave plate upon excitation of linearly polarized light. The enhanced circularly polarized near field simultaneously enhance the chiroptical response and trap the targets in the active zone. Our design might find applications in chiral analysis of single proteins.

11:50 : Invited talk
Giant Optical Nonlinearity of a Single Nanohole: from Intense Harmonics Generation to a Broadband Photoluminescence
Pavel Melentiev[1], Anton Afanasiev[1], Artur Kuzin[1], Alex Zablotskiy[1], Victor Balykin[2]
[1] *Russian Academy of Sciences (Russia),* [2] *Moscow Institute of Physics and Technology (Russia)*

We present results of experimental research of a strong nonlinearity of a single plasmonic nanohole: (1) generation of harmonics in UV and visible spectral ranges, (2) multi-photon induced luminescence, (3) the practical application of the giant optical nonlinearity of plasmonic nanoholes to implement (i) all-optical display , (ii) nanolocalized and femtosecond laser sources , (iii) optical nanoscale multi-order auto correlator.

12:10 : Invited talk
Metasurfaces for advanced plasmonic functionalities: fabrication, fundamentals and applications
Ruggero Verre, Mikael Svedendahl, Kunli Xiong, Andreas B. Dahlin, Tomasz Antosiewicz, Timur Shegai, Mikael Kall
Chalmers University of Technology (Sweden)

We report on recent advances in the area in terms of nanofabrication, characterization and applications, with particular emphasis on refractometric based sensing.

Lunch and Exhibit Inspection

12:30 - 14:00

14:00 - 15:35 — Aronow Theater

Session 2A11

Symposium 1: Functional Metastructures and Nanomaterials: Properties, Fabrication and Modeling V

Organized by: Alexander Govorov and Hilmi Volkan Demir

Chaired by: Brendan DeLacy and Jerome Plain

14:00 : Invited talk
Developing semiconductor and plasmonic nanostructures for photovoltaic and photocatalytic applications
Dongling Ma
Institut National de la Recherche Scientifique (Canada)

The synthesis of near infrared (NIR) PbS and PbS@CdS core-shell quantum dots (QDs), and Au and Ag plasmonic nanostructures and their interesting optical properties will be presented first. Their hybridization with other nanomaterials or integration into different devices will also be introduced, which has led to enhanced power conversion efficiency of solar cells or improved catalytic activity in photocatalysis.

14:20 : Invited talk
Plasmon-Enhanced Solar Energy Conversion by Semiconductor-Metal Heterojunctions
Nianqiang Wu
West Virginia University (USA)

This talk will give a brief introduction to the history of plasmon-enhanced solar energy harvesting. This presentation will discuss the underlying mechanisms of plasmon-enhanced charge separation in the semiconductor. Also, this talk will demonstrate the plasmonic metal-semiconductor heterojunction for solar energy conversion.

14:40 : Invited talk
Prolonged Hot Electron Dynamics in Plasmonic-Metal/Semiconductor (Au/TiO2) Heterostructures with Implications for Solar Photocatalysis
Wei David Wei
University of Florida (USA)

Here we demonstrate the merits of augmenting traditional photoelectrochemical cells with plasmonic nanoparticles to satisfy these daunting photocatalytic requirements. Electrochemical techniques were employed to elucidate the mechanics of plasmon-mediated electron transfer within Au/TiO2 heterostructures under visible light irradiation in solution. Significantly, we discovered that these transferred electrons displayed excited-state lifetimes two orders of magnitude longer than those of electrons photogenerated directly within TiO2 via UV excitation. These long-lived electrons further enable visible-light-driven H2 evolution from water.

15:00 : Hot Plasmonic Electrons, Heat Generation and Transparency Windows in Hybrid Nanostructures
Alexander Govorov
Ohio University (USA)

We investigate the effects of generation of heat and hot plasmonic carriers in metal nanostructures. The problem of heat release from optically-excited plasmonic nanocrystals is treated classically whereas the hot electron problem is calculated using the quantum mechanical approach based on the equation of motion for the density matrix. The energy distribution of optically-excited plasmonic carriers is very different in metal nanocrystals with large and small sizes.

15:15 : Invited talk
Electronic read-out of color centers via non-radiative energy transfer
Alexander Holleitner
Technische Universitat Munchen (Germany)

On the nanometer scale, non-radiative energy transfers have an efficiency close to unity. We describe how such a transfer can be used to electronically read-out color centers such as nitrogen vacancy centres in diamond. The read-out is achieved by a graphene layer located only a few nanometers away from the diamond. Via the non-radiative energy transfer, additional charge carriers are generated in the graphene, which are detected as an ultrafast current signal.

14:00 - 16:10 — NAC 0/201

Session 2A12

Topological photonics in synthetic electromagnetic media I

Organized by: Alexander Khanikaev

Chaired by: Alexander Khanikaev

14:00 : Invited talk
Novel Topological States in Photonics
Marin Soljacic
MIT (USA)

Certain novel, topologically non-trivial, photonic states will be presented. Their properties and potential appli-

cations will be discussed.

14:20 : Invited talk
Waveguide-network-based realization of effective magnetic field for photons
Qian Lin, Shanhui Fan
Stanford University (USA)

We propose to create an effective magnetic field for photons in a two-dimensional waveguide network with strong scattering at waveguide junctions. The effective magnetic field is realized by a directional phase on waveguide links, which can be produced by dynamic modulation or magneto-optical effect. Compared to previous proposals, this scheme is resonator-free, thus greatly reduce the experimental complexity.

14:40 : Keynote talk
Photonic Topological Insulators and Topological Anderson Insulators
M. Segev[1], M. C. Rechtsman[2], S. Stutzer[3], Y. Plotnik[1], Y. Lumer[1], M. A. Bandres[4], J. M. Zeuner[5], Alexander Szameit[3]
[1] *Technion (Israel),* [2] *The Pennsylvania State University (USA),* [3] *Friedrich Schiller Universitat Jena (Germany),* [4] *Technion (Israel),* [5] *Friedrich-Schiller Universitat (Germany)*

The Topological Anderson Insulator is a state of matter that enters a topological phase upon the addition of disorder. Here, we show the theoretical proposal for and experimental demonstration of this effect in a two-dimensional photonic system, this effect has not been realized in the solid state- indeed, this is the first realization thereof in any system.

15:10 : Invited talk
Topologically protected elastic waves in phononic metamaterials
Hossein Mousavi[1], Alexander Khanikaev[2], Zheng Wang[1]
[1] *University of Texas at Austin (USA),* [2] *Queens College of The City University of New York (USA)*

In this work we demonstrate that judicious engineering of solid structures can give rise to unusual topological systems supporting disorder-immune helical edge states for phonons. This approach opens up possibilities to realize novel topological phononic materials in both static and time-dependent regimes.

15:30 : Invited talk
Measuring topological invariants in photonic system
S. Mittal, S. Ganeshan, A. Vaezi, Mohammad Hafezi
Joint Quantum Institute (USA)

Electronic transport is localized in low-dimensional disordered media. The addition of gauge fields to disordered media leads to fundamental changes in the transport properties. We implement a synthetic gauge field for photons using silicon-on-insulator technology. We measure corresponding topological invariants and investigate the chiral gauge anomaly in the context of Chern-Simon theory. Our system provides a new platform for investigating the transport properties of photons in the presence of synthetic gauge fields.

15:50 : Invited talk
Quantum spin Hall effect and topological insulators for light
Konstantin Bliokh, Franco Nori
CEMS - RIKEN (Japan)

Free-space light has intrinsic quantum spin-Hall effect (QSHE) properties. These are characterized by a non-zero spin Chern number, and manifest themselves as evanescent modes of Maxwell equations. The recently-discovered transverse spin of evanescent modes demonstrates strong spin-momentum locking. As a result, any interface between vacuum and a medium supporting surface modes exhibits QSHE of light with opposite transverse spins propagating in opposite directions. Usual metals with surface-plasmon-polariton modes represent natural 3D topological insulators for light.

14:00 - 14:55 — NAC Ballroom

Session 2A13

Nonlinear and Reconfigurable Plasmonics and Metamaterials II

Organized by: Christos Argyropoulos and Pai-Yen Chen

Chaired by: Christos Argyropoulos and Pai-Yen Chen

14:00 : Invited talk
Integrated impedance-matched photonic Dirac-cone metamaterials
Yang Li, Shota Kita, Philip Munoz, Orad Reshef, Daryl I. Vulis, Marko Loncar, Eric Mazur
Harvard University (USA)

We design and fabricate an on-chip Dirac-cone metamaterial with impedance-matched zero index in optical regime. Our metamaterial consists of low-aspect-ratio silicon pillar arrays in an SU-8 matrix clad above and below by gold thin films. This design can serve as an on-chip platform to implement applications of Dirac-cone metamaterials in integrated photonics.

14:20 : Invited talk
Integrated super-couplers based on zero-index metamaterials
Daryl Vulis, Orad Reshef, Philip Munoz, Shota Kita, Yang Li, Marko Loncar, Eric Mazur
Harvard University (USA)

Zero-refractive-index metamaterials have been proposed as candidates for super-coupling applications, where light is confined to sub-diffraction limited length scales on-chip. Such a device allows for efficient coupling between disparate modes and compact 90 degree bends, which are challenging to achieve using dielectric waveguides. We discuss the simulation and fabrication results of all-dielectric on-chip zero-index metamaterial-based couplers. We observe transmission normal to all faces, regardless of the structure's shape, highlighting an unexplored feature of zero index metamaterials for integrated photonics.

14:40 : Tunable Transmission with Hybrid Graphene/All-Dielectric Metamaterials
Christos Argyropoulos
University of Nebraska-Lincoln (USA)

Periodically arranged pairs of asymmetric silicon nanobars can sustain trapped magnetic resonances with a sharp Fano-type transmission or reflection signature. In this work, we theoretically present a hybrid graphene/all-dielectric metamaterial device constituted by periodic silicon nanobars placed over a silica substrate. One-atom-thick graphene monolayer is sandwiched between the dielectric nanobars and substrate. Tunable transmission is obtained at near-infrared (near-IR) wavelengths as the doping level of graphene is increased.

14:55 - 15:55 — NAC Ballroom

Session 2A14

Plasmonics and nanophotonics III

Chaired by: Michael Eggleston

14:55 : Evolution of plasmon modes in the effective permittivity of polygonal arrays
Matthew D. Arnold, Angelo Garruzzo, Michael B. Cortie
University of Technology Sydney (Australia)

We investigate the effective permittivity of arrays of columns with polygonal cross-section, including regular tessellations of triangles, squares and hexagons. The evolution of the resonant positions and strengths is determined as a function of the fill factor. Complicated mode interactions at moderate fill factor are observed, and we explore the possibilities of manipulating the modes by additional variations to the shape variations.

15:10 : Giant ultrafast hot electron response in plasmonic nanostructures
Hayk Harutyunyan[1], Alex B. F. Martinson[2], Larousse K. Khorashad[3], Alexander O. Govorov[3], Gary P.

Wiederrecht[2]
[1] *Emory University (USA),* [2] *Argonne National Laboratory (USA),* [3] *Ohio University (USA)*

The strong dependence of the optical properties of nanoparticles on size and shape is a foundation of nanophotonics. In this paper we show how the time-resolved optical responses of hybrid plasmonic nanostructures can be controlled and modified in an unprecedented manner.

15:25 : Polaritonics: Optical diodes and photonic circuits
Tania Espinosa Ortega[1], **Ivan Shelykh**[2], **Timothy Liew**[1]
[1] *Nanyang Technological University (Singapore),* [2] *University of Iceland (Iceland)*

We present theoretically three devices based in exciton polaritons, namely, an optical diode, a complete photonic logic gate architecture and an implementation for hardware neural networks: a perceptron.

15:40 : Novel plasmonic near-field transducer and coupling arrangement for heat-assisted magnetic recording
Jacek Gosciniak[1], **Marcus Mooney**[2], **Mark Gubbins**[2], **Brian Corbett**[1]
[1] *Tyndall National Institute (Ireland),* [2] *Springtown Industrial Estate (Ireland)*

The efficiency of novel near-field plasmonic transducer designs, as can be used in heat-assisted magnetic recording systems, are analyzed with simulations performed using the finite-element method (FEM). The investigated transducer shows a five-fold improvement in terms of the electric field enhancement while achieving a spot size of 20-30nm and a ratio between the hotspot and side-lobe which exceed 36 which is at least 8 times higher compared to the lollipop transducer.

14:00 - 15:45 — NAC 1/202

Session 2A15

Geometrical techniques for controlling electromagnetic waves II

Organized by: Simon Horsley and Oscar Quevedo-Teruel

Chaired by: Simon Horsley and Oscar Quevedo-Teruel

14:00 : Invited talk
Modeling Artificial Structures Through Accelerated Multilayered Periodic Potentials
Guido Valerio[1], **Ferhat Turker Celepcikay**[2], **Donald R. Wilton**[3], **David R. Jackson**[3], **Alessandro Galli**[4]
[1] *UPMC University (France),* [2] *Turgut Ozal University (Turkey),* [3] *University of Houston (USA),* [4] *Sapienza University (Italy)*

In this paper we describe the acceleration of series expressing the potentials due to periodic vertical currents in layered media. This computation is relevant to the numerical study of periodic structures for synthesizing artificial materials or surfaces. Asymptotic extractions are performed, leading to faster-converging expressions. These extracted terms are then efficiently computed through a modified Ewald summation method, thus achieving Gaussian convergence.

14:20 : Invited talk
Geometries, Rays, and Waves
Paul Kinsler, Martin W. McCall
Imperial College London (United Kingdom)

The use of a generalized and orientation dependent refractive index allows us to model the entirety of possible ray-based transformation devices, including cloaks and carpets. We show here how such ray devices generate constitutive parameters that match full wave theories design to a remarkable extent, notably for both electromagnetism and pressure acoustics. However, comparative full wave FDTD simulations reveal that boundary impedance matching as in e.g. the original invisibility cloak is not sufficient to achieve perfect invisibility.

14:40 : Invited talk

Omnidirectional Concentrators and Absorbers: Trapping Light at any Angle
Alexander Kildishev, Ludmila Prokopeva
Purdue University (USA)

We present a general approach for ray tracing in 3D omnidirectional concentrators with the refractive index distribution being conformally scaled from the exterior boundary up to the absorbing core. We illustrate our theory with examples of trapping the obliquely incident light in cylindrical, spherical, and spheroidal concentrators. The proposed approach can be used for modeling conformally scaled graded index lenses for arbitrary incidence angles, the method is essential for non-imaging optics applications in IR-sensing, mobile photovoltaics, and microwave focusing.

15:00 : Exact analysis of a Veselago Lens using eigenstates of Maxwell's equations
David J. Bergman, Asaf Farhi
Tel Aviv University (Israel)

A new approach is applied to the discussion of perfect imaging by a Veselago Lens. This is based upon the eigenstates of Maxwell's equations. Sub-wavelength resolution is obtained, but not at the geometric optics foci.

15:15 : Perfect light absorption and plasmonic sensing from self-assembled optical metasurfaces
Fumin Huang[1], Matthew Millyard[1], Stacey Drakeley[1], Antony Murphy[1], Richard White[2], Elisabetta Spigone[2], Jani Kivioja[2], Jeremy Baumberg[3]
[1]*Queen's University Belfast (United Kingdom),* [2]*Nokia Research Centre (United Kingdom),* [3]*University of Cambridge (United Kingdom)*

We present experimental results about a new class of optical metasurfaces which exhibit omnidirectional near-zero reflectance in the optical frequency region. The zero reflectance film shows optimal plasmonic sensing performance, exhibiting the largest spectral shift per unit refractive index. These metasurfaces can be manufactured at large scales through cost-effective self-assembly methods, making them potential candidates for widespread applications.

15:30 : Controlling Light in Transformation Optical Waveguides through an enhanced thermo-optic effect
Hui Liu[1], Chong Sheng[1], Shining Zhu[1], Dentcho Genov[2]
[1]*Nanjing University (China),* [2]*Louisiana Tech University (USA)*

A controlling laser produces inhomogeneous refractive index inside a waveguide through the photothermal effect. The trajectory of waveguide beam is continuously tuned. This work provides an approach toward optical control of transformation optical devices.

14:00 - 16:00 — ASRC Conference Room

Session 2A16

A bottom-up approach towards metamaterials and plasmonics V

Organized by: Dorota Pawlak and Wounjhang Park

Chaired by: Alexandre Dmitriev and George Chumanov

14:00 : Invited talk
Multiscale conformal patterns transfer for nano-, meta-, micro- and beyond
Kristof Lodewijks, Vladimir Miljkovic, Ines Massiot, Addis Mekonnen, Ruggero Verre, Eva Olsson, Alexandre Dmitriev
Chalmers University of Technology (Sweden)

Here we establish the method for seamless transfer of principally any lithographic top-down or bottom-up pattern of potentially high complexity from a parent flat substrate onto essentially any kind of surface. We will demonstrate how nano- or microscale patterns, occupying macroscopic surface areas, can be transferred with extremely high conformity onto a large variety of surfaces: commercial and research-grade glass, polymers,

plastic, paper or polycrystalline silicon.

14:20 : Invited talk

Plasmonics enabled by DNA Nanotechnology

Anton Kuzyk[1], Robert Schreiber[2], Tim Liedl[3], Alexander Govorov[4], Na Liu[5]
[1]MPI for Intelligent Systems (Germany), [2]Clarendon Laboratory-University of Oxford (United Kingdom), [3]Ludwig Maximilians Universitat (Germany), [4]Ohio University (USA), [5]Max Planck Institute for Intelligent Systems (Germany)

With the invention of the DNA origami technique in 2006 DNA Nanotechnology has reached a new level of sophistication. DNA can now be used to arrange molecules and other nanoscale components, e.g., protein and nanoparticles, with nanometer precision into almost arbitrary geometries. Moreover, dynamic DNA Nanotechnology allows making such assemblies reconfigurable and dynamically controlled in time. Here we demonstrate how DNA nanotechnology can be used for self-assembly of plasmonic nanostructures with chemically or light regulated optical responses.

14:40 : Invited talk

Nonmetallic Metamaterial: Gyroidal Titanium Nitride

Srujana Prayakarao[1], S. Robbins[2], N. Kinsey[3], A. Boltasseva[3], V. M. Shalaev[3], U. B. Wiesner[2], C. E. Bonner[1], R. Hussain[1], N. Noginova[1], M. A. Noginov[1]
[1]Norfolk State University (USA), [2]Cornell University (USA), [3]Purdue University (USA)

We have synthesized gyroidal TiN metamaterials, studied their optical properties, compared them with the optical properties of the TiN thin films. The plasma frequency, w p, and the corresponding free carrier concentration, N, in the gyroid samples were found to be much lower than those in thin films. This makes the studied TiN gyroid a poor plasmonic material. Nevertheless, TiN gyroidal samples have demonstrated bright rainbow pattern in the optical microscopy reflectance, attributed to different orientations of the gyroid domains.

15:00 : Invited talk

3D Optical Metamaterials by Microfluidic Evaporation

Alexandre Baron[1], Antonio Iazzolino[2], Kevin Ehrhardt[2], Jean-Baptiste Salmon[2], Ashod Aradian[2], Vasyl Kravets[3], Alexander Grigorenko[3], Jacques Leng[2], Aurelie Le Beulze[2], Mona Treguer-Delapierre[2], Miguel Correa-Duarte[4], Philippe Barois[2]
[1]Duke University (USA), [2]University of Bordeaux (France), [3]University of Manchester (United Kingdom), [4]Universidad de Vigo (Spain)

We present homogeneous optical metamaterials assembled via a microfluidic evaporation technique which enables a high degree of bulkiness with a depth-to-particle-size ratio that exceeds 600, thus surpassing state-of-the-art realizations by one order of magnitude.

15:20 : Invited talk

Photovoltaic applications of optical haze and perfect absorbers made by self-aggregated nanowire structures

Kyuyoung Bae, Gumin Kang, Kyoungsik Kim
Yonsei University (Korea)

We fabricated the nanostructured film which is composed of self-aggregated nanowires. Since the film has high transmission haze and transparency, it was applied to photovoltaic device for controlling the light-propagation in the active layer. Overall efficiency of the device with the haze film was improved by 5 percent compared to the bare device. We also fabricated the perfect absorbers by depositing Au on self-aggregated nanowires. The perfect absorbers exhibit a reflectivity of 1 percent over a visible range.

15:40 : Invited talk

Cage template synthesis and cage directed assembly of gold nanoparticles

Wei Zhang, Won Park
University of Colorado (USA)

We present template synthesis of gold nanoparticles (AuNPs) using cage molecules and also the directed assembly of AuNPs by cage molecules. Shape persistent cage molecules with internal functional groups serve as effective template for highly monodispersed AuNP synthesis. Cage molecules further functionalized on the outside are then used to direct the assembly of AuNPs into predetermined geometry. Cage-AuNP complex offers an excellent platform for programmable self-assembly.

14:00 - 15:00 — NAC 1/203

Session 2A17

Chiral and Nonlinear Metamaterials: Properties, Fabrication, and Applications II

Organized by: Ventsislav K. Valev and Nicolae C. Panoiu

Chaired by: Ventsislav K. Valev and Nicolae C. Panoiu

14:00 : Invited talk
Electronic energy transfer in chiral media and metamaterials
David Andrews, Kayn Forbes
University of East Anglia (United Kingdom)

The photonic mechanism for local electronic excitation transfer in condensed media is generally understood in terms of coupling electric dipole transitions. By considering additional magnetic effects, chiral aspects emerge, relating to the distinctive character of electromagnetic propagation in a non-symmetric environment. These relate to chiral physics that is also involved in optical electrostriction and circular dichroism. Entirely different photonic behaviour is anticipated when electronic energy transfer occurs in a negative-index medium, even when associated with purely electric dipole coupling.

14:20 : Invited talk
Second-harmonic generation from metasurfaces - more than resonance enhancement
Robert Czaplicki[1], Jouni Makitalo[1], Roope Siikanen[1], Hannu Husu[1], Joonas Lehtolahti[2], Markku Kuittinen[2], Martti Kauranen[1]
[1] *Tampere University of Technology (Finland),* [2] *University of Eastern Finland (Finland)*

We probe metasurfaces of L- and T-shaped gold nanoparticles by second-harmonic generation. The nonlinear radiation from such samples can be boosted through several mechanisms. Furthermore, for certain geometries, the detuning of the incident field polarization from the resonant direction can enhance the overall second-harmonic response.

14:40 : Invited talk
Plasmonic meta-molecules in the quantum tunneling regime
A. Garcia-Etxarri[1], J. Scholl[2], G. Aguirregabiria[1], R. Esteban[1], H. Alaeian[2], T. Narayan[2], J. A. Dionne[2], J. Aizpurua[1]
[1] *Donostia International Physics Center- CSIC-UPV/EHU (Spain),* [2] *Stanford University (USA)*

Closely spaced plasmonic nanoparticles exhibit highly tunable hybridized resonances based on nanoparticle geometry, spacing, and arrangement. Such resonances have allowed for applications ranging from nanoantennas to chiral metamaterials. Here, we explore the quantum-influenced modes of a plasmonic trimer using scanning transmission electron microscopy and electron energy-loss spectroscopy. Our combined experimental and theoretical work provides the first complete evolution of magnetic and dark modes in the classical and quantum tunneling regime, and may enable new quantum plasmonic meta-molecules and metamaterials.

15:00 - 15:45 — NAC 1/203

Session 2A18

Chiral and bianisotropic materials

Chaired by: David L. Andrews

15:00 : Optical diode with topological insulators and chiral media
Filipa Prudencio[1], Mario Silveirinha[2]
[1] *Instituto Superior Tecnico-Instituto de Telecomunicaoes (Portugal),* [2] *Universidade de Coimbra-Instituto de Telecomunicaoes (Portugal)*

An asymmetric light flow requires a broken time-reversal symmetry , and is traditionally achieved with the help of either an external magnetic field or with nonlinear elements. Here, we explore the opportunities offered by materials with a spontaneous nonreciprocal response in the one-way propagation of light. We theoretically demonstrate a new paradigm for optical isolation using antiferromagnet topological insulators, combined with chiral media.

15:15 : Reducing the complexity: Strong single-handed chiral near-fields in diagonal slits
Martin Schaferling[1], Nader Engheta[2], Thomas Weiss[1], Harald Giessen[1]
[1] *University of Stuttgart (Germany),* [2] *University of Pennsylvania (USA)*

We demonstrate a novel plasmonic design to generate near-fields with strong optical chirality for enantiomer sensing applications. Our design, which consists of diagonal slits on top of a mirror, features homogeneous chiral near-fields of one handedness that are easy to access. The diagonal-slit structure is simple to fabricate and allows for straightforward tuning of the operating wavelength. We demonstrate its properties and present optimization strategies using numerical simulations. Additionally, we discuss potential applications as a sensor for enantiomer discrimination.

15:30 : Cramer-Rao Bounds for Anisotropic and Bianisotropic Metasurfaces Susceptibilities
Thomas Lepetit, Boubacar Kante
University of California San Diego (USA)

Accurate and robust characterization of metasurfaces in terms of effective parameters is critical to the design of metadevices. We compute the Cramer-Rao lower bounds on the variance of any estimator for the electric, magnetic, and magneto-electric surface susceptibilities. We show that retrieval of such effective properties is inherently difficult around resonances, most notably for low-loss metasurfaces. The present work is relevant to the development of loss-compensated metasurfaces for which noise has to be closely considered for device characterization.

14:00 - 15:55 — NAC 1/211

Session 2A19

Advances in Hybrid Plasmonics II

Organized by: Mohamed Swillam

Chaired by: Mohamed Swillam

14:00 : Invited talk
Controlling absorption with nanophotonics: application to solar energy conversion and plasmon rulers
Vivian Ferry
University of Minnesota (USA)

This talk will discuss our efforts in nanophotonics for enhancement of solar cell performance. The first part will focus on the integration of photonics with narrow band quantum dot light emitters to achieve high concentration ratios in luminescent solar concentrators, which enhance the performance of solar cells under direct and diffuse illumination. The second part will discuss the design of chiral nanoparticle assemblies that exhibit tunable circular dichroism and may be used as nanoscale biological sensors.

14:20 : Invited talk
Nanocavity enhanced light-matter interaction within thin-films and ultra-thin films
Qiaoqiang Gan
University at Buffalo (USA)

While there is great interest in achieving highly absorptive materials exhibiting large broadband absorption using optically thick, micro-structured materials, it is still challenging to realize ultra-compact subwavelength absorber for on-chip optical/thermal energy applications. In this presentation, we will discuss nanocavity enhanced light-matter interaction in thin-films and ultra-thin films with engineered and freely tunable absorption

band. These on-chip absorbers can easily be integrated with other on-chip electronic/optoelectronic devices, which is promising to create new regimes of optical/thermal physics and applications.

14:40 : Invited talk
2D materials within long-range hybrid plasmonic modes in asymmetric structures
Charles Lin, Yiwen Su, Wen Ma, Amr Helmy
University of Toronto (Canada)

A novel approach that enables long range hybrid plasmonic modes to be supported in asymmetric structures will be discussed. The utility of these waveguide designs is demonstrated when combined with 2D materials to realize optoelectronic components such as filters, modulators and switches with record footprint, performance and insertion losses.

15:00 : Invited talk
Simulating metal and graphene based hybrid plasmonic devices
James Pond, Jens Niegemann, Adam Reid, Roberto Armenta
Lumerical Solutions, Inc. (Canada)

We present an overview of the main challenges when simulating metal and graphene based plasmonic devices combined with other materials such as organics and semiconductors. We review the different numerical methods and demonstrate how they can be used to efficiently design and optimize plasmonic devices. Examples include gap SPR waveguides coupled to nanoantennas, graphene-based silicon modulators, and plasmonic enhanced solar cells.

15:20 : Invited talk
Simulating of Surface Plasmonics on Different Applications
Chenglin Xu, Dan Herrmann, Ying Zhou
Synopsys, Inc. (USA)

Different numerical techniques, both time-domain and frequency domain algorithms, for simulating surface plasmonics will be reviewed. Various applications, such as solar cells, bio/chemical sensing, and nonlinear phenomena will be illustrated.

15:40 : Semi-analytical Design Methodology for Large Scale Plasmonic Networks
M. Swillam[1], Amr Helmy[2]
[1] *The American University in Cairo (Egypt),* [2] *University of Toronto (Canada)*

A semi-analytical approach for efficient modelling of large scale networks of plasmonic slot waveguides is proposed, demonstrated and evaluated. A simple impedance-based model for the junctions is utilized. This efficient and accurate model enables full analysis of a large scale network of without the need for any full wave electromagnetic analysis. The approach is computationally efficient and enables fast design and optimization cycles using these networks

14:00 - 16:00 — NAC 1/201

Session 2A20

Metamaterial-based radiating and absorbing structures I

Organized by: Xavier Begaud and Shah Nawaz Burokur

Chaired by: Xavier Begaud and Shah Nawaz Burokur

14:00 : Invited talk
Multiple-band and broadband terahertz absorbers using multi-layered metallic structures
Shuo Liu, Di Bao, Tiejun Cui
Southeast University (China)

We present the simulation and measurement results for a multi-band absorber and broadband absorber at terahertz frequency. The quad-band absorber is composed of four metallic square loops averagely located on

two polymide layers. It experimentally exhibits four absorption peaks with absorptivity over 98.5 percent. The broadband absorber is formed by averagely stacking 12 metallic sticks with varying lengths on three PI layers. The measured absorptivity totally exceeds 95 percent from 0.81 to 1.32 THz and the FWHM is 60 percent.

14:20 : Invited talk
Metamaterials for Antennas and RCS Reduction Structures
Juan Carlos Iriarte, Amagoia Tellechea, Inigo Ederra, Ramon Gonzalo
Public University of Navarra (Spain)

A lot of designs can be found in literature showing metamaterials possibilities and their application. However, the number of designs which comply with specifications of tangible applications have been limited. A review of the designs realized by Antenna Group of UPNa is presented in the paper, focusing in covering specific applications requirements. The designs take advantage of diverse properties of metamaterials (as EBGs and AMC) complying with specifications of real applications showing them as alternatives to conventional technology designs.

14:40 : Invited talk
Mobile phone model with metamaterials to reduce the exposure
Yenny Pinto, Xavier Begaud
ESPCI ParisTech (France)

This paper presents a terminal mobile model where an Inverted F Antenna (IFA) is associated with three different metamaterials: Artificial Magnetic Conductor (AMC), Electromagnetic Band-Gap (EBG) and Resistive High Impedance Surface (RHIS). The objective is to evaluate what is the metamaterial which is the best solution to reduce exposure. The exposure has been evaluated using a simplified phantom model. Results show that a reduction of 7.9 percent in SAR 10g is obtained using a RHIS structure.

15:00 : Invited talk
2-SR-based electrically small antenna for RFID applications
Ferran Paredes, Simone Zuffanelli, Pau Aguila, Gerard Zamora, Ferran Martin, Jordi Bonache
Universitat Autonoma de Barcelona (Spain)

In this work the 2-turns Spiral Resonator (2-SR) is used as an electrically small antenna for passive Radio Frequency IDentification (RFID) tags at the Ultra-High Frequency band (UHF). The radiation properties are analyzed to explore the advantages and limitations of the 2-SR applied to the tag antenna design. As a proof of concept, a passive tag based on the 2-SR was designed, fabricated and the read range was measured, obtaining distances of roughly 5.5 meters.

15:20 : Invited talk
Towards the Analytical Design of Bianisotropic Metasurfaces
Nikolaos Chiotellis, Anthony Grbic
University of Michigan (USA)

In this work, metasurfaces exhibiting bianisotropic responses are synthesized using analytical models. Such metasurfaces can be implemented by cascading patterned metallic claddings and electrically thin dielectric substrates. Simple expressions for the sheet impedance of periodic claddings are found for arbitrarily incident plane waves in the long wavelength regime. Using the derived models, an X-band polarization rotator is designed analytically, and tuned within a full-wave solver to achieve optimal performance.

15:40 : Invited talk
A Multilayer Metasurface Cloak Coating for Monopole Antennas
Zhi Hao Jiang, Douglas Werner
The Pennsylvania State University (USA)

A multilayer metasurface cloak coating is introduced for monopole antennas. It retains the input impedance and radiation parameters of the antenna for its original operational band. At the same time, it also reduces the monopole's scattering signature and the received power for the operational band of another system located in close proximity. The coating, consisting of two layers of concentric anisotropic metasurfaces, is designed by tailoring their dispersive electromagnetic properties.

Coffee Break and Exhibit Inspection

Session 2P2

Poster session IV

16:00 - 16:40

P1: A single-crystalline silver nanoparticle on SiO2 substrate directly fabricated by focused ion beam milling
Tomohiro Mori[1], **Yasuhiro Tanaka**[1], **Yoshifumi Suzaki**[1], **Toshihiro Okamoto**[2], **Kenzo Yamaguchi**[1]
[1] *Kagawa University (Japan),* [2] *The University of Tokushima (Japan)*

A single-crystalline silver nanoparticle was directly fabricated into the (111)-oriented large grain by focused ion beam milling. Electron backscatter diffraction (EBSD) methods elucidate the grain-growth mechanism in deposited silver films and the crystal orientation of the silver nanoparticle. Furthermore, the light intensity of scattering spectrum was obtained for the single-crystalline silver nanoparticle, and observed surface plasmon resonance. These results provide information for direct fabrication of the single-crystalline silver nanoparticle using physical processing methods.

P2: Templated plasmonic nanostructures for use in non-linear chiroptical spectroscopy
Calum Jack, R. Leyman, A. S. Karimullah, R. Tullius, N. Gadegaard, M. Kadodwala
University of Glasgow (United Kingdom)

Many important biological and pharmaceutical molecules are chiral and their chirality is fundamentally linked to their biological function. Sensitivity to this biomolecular chirality is essential in applications such as biomedical diagnostics and pathogen detection. In this talk we demonstrate the potential of high -throughput chiral plasmonic metamaterials as tool for the ultrasensitive detection of a range of biomolecules.

P3: Structurally dark nano-materials: from perfect broadband absorption to monochromatic emission through light condensation
Changxu Liu, J. Huang, S. Masala, E. Alarousu, Y. Han, Andrea Fratalocchi
King Abdullah University of Science and Technology (Saudi Arabia)

We designed a nanostructured absorber that shows an exceptional darkness, with an extremely high absorption >98 percent between 400 nm and 1200 nm. By introducing an optical amplifier to the system, we show how to create a new type of source with the aid of the structural darkness, generating monochromatic emission without the need of any resonance. This behavior is achieved through a process of light condensation, which spontaneously transfer all the available spectral energy into a single frequency.

P4: Modulated Light Transmission through a Subwavelength Slit at Early Stage
Jian-Shiung Hong[1], **Alexander Ewen Chen**[2], **Kuan-Ren Chen**[1]
[1] *National Cheng Kung University (Taiwan),* [2] *The Pennsylvania State University (USA)*

The early dynamics of light transmission through a subwavelength slit in a finite-difference time-domain simulation shows that the amplitude of the transmitted light can be modulated. This underneath physics is studied with a new model. Besides academic importance, this phenomena and its understanding is essential to photonic applications utilizing short temporal pulses in a width of several to tens of light periods.

P5: Application of the Mathieu's equation for an analysis of photonic crystal - supported surface electromagnetic waves
Ekaterina Rostova, Sergey Sekatskii, Giovanni Dietler
Ecole Polytechnique Federale de Lausanne (Switzerland)

Nowadays, unique characteristics of surface electromagnetic waves, particularly, surface plasmons, supported by specially designed photonic crystals find numerous applications. We propose to exploit an evident analogy between such a photonic crystal and a structure with a sine-modulated refraction index. The propagation of light inside the latter is described by the famous Mathieu's differential equation. This application of the Mathieu's equation can be useful for a design of multilayered structures, also for fundamental understanding of electromagnetic phenomena in inhomogeneous media.

P6: Fabrication of plasmonic nanoantennas by femtosecond direct laser writing lithography for surface-enhanced infrared absorption

Shahin Bagheri, Ksenia Weber, Timo Gissibl, Thomas Weiss, Frank Neubrech, Harald Giessen
University of Stuttgart (Germany)

We demonstrate the use of femtosecond direct laser writing combined with argon ion beam etching to prepare homogenous and large-area nanoantenna arrays with feature sizes below the diffraction limit of the laser light. Such nanoantennas provide tunable and high quality plasmon resonances in the mid-infrared spectral range which are well-suited for surface-enhanced infrared absorption (SEIRA). We demonstrate that and experimentally investigate the influence of plasmonic coupling between neighboring nanoantennas on the SEIRA enhancement effect.

P7: Tuning the Resonance Frequency and Polarization of Plasmonic Nanorods through Geometry, Material, and Substrate Changes

Andrew Lawson[1], Chase Ellis[2], Joseph Tischler[2], Oded Rabin[1]
[1] *University of Maryland (USA),* [2] *U.S. Naval Research Laboratory (USA)*

The tunability of the frequency and polarization of surface plasmon resonances of nanostructures is crucial for their implementation in nanophotonics applications. We report FTIR spectroscopic data of gold and aluminum plasmonic nanorods with resonance frequencies spanning the mid-infrared regime (2-10 microns). The effect of the nanorod material and dimensions as well as substrate material is investigated. Bending of the nanorods results in additional resonances with polarizations not observed in straight nanorods.

P8: An algorithmic approach to plasmonic filter design with applications to 3D directional light sensors

Matthew Davis[1], Jay Lee[1], Amit Agrawal[2], Henri Lezec[2]
[1] *Syracuse University (USA),* [2] *Center for Nanoscale Science and Technology (USA)*

In this work we have developed an efficient analytical method for the design of plasmonic filters. We demonstrate the usefulness of this model by designing a plasmonic 3D directional light sensor based on the bulls-eye structure.

P9: Surface Plasmon excitation via a finite number of sub-l defects at a metallic interface

Raul Garcia-Llamas[1], Sandra Gastelum-Acuna[2], Aldo Ramirez-Duverger[1]
[1] *Universidad de Sonora (Mexico),* [2] *Universidad de Sonora CONACYT (Mexico)*

An experimental and theoretical study of the surface plasmon excitation via a finite number of sub-l defects at a metallic interface when it is illuminated for a Gaussian transverse magnetic polarized beam, is presented. The defects are grooves, for the case of gratings, or wells for the case of bi-gratings. The samples are fabricated by exposing photo-sensible films in the region of interferences of two beams. The maximum coupling strength is measured with the minimum of the specular reflection.

P10: Extreme confinement of low-loss hybrid plasmonic modes in deep nano-scale layered structure

Reyad Mehfuz, Paul Dawson
Queen's University Belfast (United Kingdom)

We propose a tri-layer planar structure to realize photonic waveguiding in deep nano-scale. The structure consists of silver, and silicon, which are separated by an ultra-thin layer of magnesium-oxide (MgO). With proper selection of materials and corresponding geometries, we show that sub-10 nm thick MgO layer can sustain a low-loss hybrid plasmonic mode. It enhances the energy density in the layer and provides extreme confinement with a mode area, which is 100 times smaller than a diffraction-limited waveguide.

P11: Enhanced light emission of ZnO/Ag nanogratings: surface plasmon polariton and resonance mode excitation

Minji Gwon, Dong-Wook Kim
Ewha Womans University (Korea)

We observed significant enhancement of the photoluminescence (PL) intensity from ZnO/Ag nanogratings. Polarization dependence of the PL and angle-resolved reflectance spectra showed that the cavity resonance in the gratings as well as grating-coupled surface plasmon polariton (SPP) excitation played crucial roles in the optical characteristics. The SPP and resonance mode excitation caused strong optical field confinement in the ZnO layers, resulting in distinct surface photovoltage behaviors depending on the incident light polarization.

P12: Excitation of plasmonic nanoantennas with electron tunneling. Comparison of resonant and nonresonant tunneling

Alexander Uskov[1], **Jacob Khurgin**[2], **I. Protsenko**[1]
[1] *Russian Academy of Sciences (Russia),* [2] *Johns Hopkins University (USA)*

Incorporating a resonant tunneling structure inside the gap of plasmonic nanoantennas can lead to manifold increase of the efficiency of electrical excitation of the surface plasmon polaritons, and may enable future electrically-driven nanoplasmonic circuits.

P13: Tunable cavity-coupled plasmonic perfect absorber for ultra-compact thermo-optical switching

Mohsen Bahramipanah, Shourya Dutta-Gupta, Toralf Scharf, Olivier Martin
Swiss Federal Institute of Technology (Switzerland)

A tunable cavity-coupled plasmonic perfect absorber based on liquid crystal is demonstrated.The optical response of the structure can be controlled by applying an external heat source. The physical principles of this phenomenon rely on the interplay between the phase of localized surface plasmon resonances in the nanostructures, the Fabry-Perot modes of the cavity and the thermooptical effect of the liquid crystals. Our experimental results demonstrate a large tuning range of 39 nm in the absorption spectrum of the structure.

P14: Interaction of LSP resonances and Fabry-Perot cavity modes

Mohsen Bahramipanah, Shourya Dutta-Gupta, Banafsheh Abasahl, Olivier Martin
Swiss Federal Institute of Technology (Switzerland)

We experimentally and numerically demonstrate the coupling between Fabry-Perot modes of the microcavities and the localized surface plasmon resonance of metallic nanostructures. Coupling the plasmonic nanostructures to a Fabry-Perot microcavity creates compound modes, which have the characteristics of both Fabry-Perot and the LSPR modes. The special features of the proposed structure and the device concept introduced in this work are applicable in the realization of ultra-high sensitive plasmonic devices for biosensing, optoelectronics, and related technologies.

P15: Self-assembly lithography of Quantum dot nanogap metamaterials

Laxmi N. Tripathi, Taehee Kang Kang, Young-Mi Bahk, Sanghoon Han, Geunchang Choi, Jiyeah Rhie, Jeeyoon Jeong, Dai-Sik Kim
Seoul national university (Korea)

We present a novel self-assembly lithography method to fabricate a large scale cadmium selenide quantum dots-silver nanogap metamaterial. We measured spatially resolved photoluminescence through the nanogap showing the presence of quantum dots inside the gap. This metamaterial will find versatile applications in optical and terahertz technology, for examples, cavity quantum electrodynamics, molecular sensing, Nanogap quantum dot photo detectors etc.

P16: Electrical Tuning of Plasmonic Properties of Transparent Conductive Oxides with a Liquid Electrolyte

Ju-Hyung Kang, Hongtao Yuan, Xiaoge Liu, Junghyun Park, Mark Brongersma
Stanford University (USA)

We demonstrate electrical tuning of the plasma frequency of indium tin oxides by changing the sheet carrier density by electrical gating with an ionic liquid. The significant changes in the optical and electronic properties are quantified using optical reflection, sheet conductivity, and Hall measurements. The transfer matrix method simulation studies successfully reproduce the experimental results. Our observation can therefore offer the capability to develop efficient electro-optic devices.

P17: Optical properties of one-dimensional photonic crystal containing a defect

Jong Bin Yeo, Cheol Jin Park, Heon Kong, Hyun Yong Lee
Chonnam National University (Korea)

Ten-pair TeO2/SiO2 one-dimensional photonic crystal (1D PC) has been investigated. The 1D PC containing a single defect layer of Ta2O5 generated a selective transmittance in photonic band gap (PBG). The 1D PC structure was designed by transfer matrix method (TMM), and fabricated by rf sputtering technique. The samples are exposed by He-Cd laser and He-Ne laser to evaluate the variation of optical properties before and after illuminating light. The fabricated 1D PC structure was measured by UV-VIS-NIR spectrophotometer.

P18: Topologically Protected States in Continuous Systems and Applications to Photonics

Charles L. Fefferman[1], **James P. Lee-Thorp**[2], **Michael I. Weinstein**[2]
[1] *Princeton University (USA),* [2] *Columbia University (USA)*

We outline a rigorous bifurcation theory of topologically protected edge states in 1D dimer structures and 2D honeycomb structures. Our models are continuous Schroedinger operators with potentials consisting of two parts: a bulk periodic potential having Dirac points and a domain wall interpolation between asymptotic periodic structures. We also present a photonic realization of the edge states of dimer structures as highly robust guided wave modes for a class of dielectric structures.

P19: The anomalies of the optical transmission of potash alumoboron glasses with fe2O3 additives induced by gamma radiation

E. M. Ibragimova[1], **O. K. Kuvandikov**[2], **M. K. Salakhitdinova**[2]
[1] *Institute of Nuclear Physics Academy of Science (Uzbekistan),* [2] *Samarkand State University (Uzbekistan)*

As the basic object of investigation have been used the glass which contains Fe2O3 in the form of additives from 0,1 to 3.0 mass.percent over 100percent. The obtained experimental data are explained well enough on the basis of the development of the phenomenological theory of the radiative-induced processes at the thermal and thermoradiating treatments.

P20: Surface Wave Suppression Using Graphene at Microwave Frequencies: Application to Microwave Cancer Treatment

Hulusi Acikgoz[1], **Raj Mittra**[2]
[1] *KTO Karatay University (Turkey),* [2] *The Pennsylvania State University (USA)*

This paper deals with the application of a single layer of graphene as a high impedance surface for reducing backward heating problem caused by surface current generated along the outer conductor of a microwave coaxial slot antenna. By having a graphene layer wrapped on the outer conductor of the coaxial antenna we show that one can suppress the surface current along the antenna.

P21: Hyperbolic-gap-hyperbolic tunable band structure metamaterials

Georgia T. Papadakis, Krishnan Thyagarajan, Harry A. Atwater
CALTECH (USA)

We introduce a motif for active tuning of the effective optical parameters of planar hyperbolic metamaterials. Using the field effect, we gate and electrically modulate the permittivity in transparent conductive oxide (TCO) layers via changes in the carrier density. This enables broadband active modulation of the anisotropy characteristics of metamaterials. We observe opening and closing of omnidirectional band gaps within the visible regime. A sensitivity analysis over the electronic characteristics of TCOs assures experimentally measurable modulation over those parameters.

P22: Ultrasensitive detection of ligand-induced conformational changes in proteins using chiral plasmonic nanostructures.

Ryan Tullius[1], **A. S. Karimullah**[1], **Calum Jack**[1], **M. Rodier**[1], **B. Fitzpatrick**[1], **A. Lapthorn**[1], **G. Cooke**[1], **N. Gadegaard**[1], **V. M. Rotello**[2], **M. Kadodwala**[1]
[1] *University of Glasgow (United Kingdom),* [2] *University of Massachusetts (USA)*

The ability to screen libraries of chemical compounds, or fragments, against a protein target is the basic starting point in the search for a novel therapeutic agent in drug discovery. Here we introduce a new chip based biophysical measurement technology that would be a powerful tool for high throughput screening. We show that gold, plasmonic, substrates imprinted with chiral nanostructures can be used to rapidly detect ligand-induced changes of the protein tertiary and quaternary structure.

P23: Full quantum statistics of plasmon - multi quantum emitter coupling and spasers

Michael Gegg, T. S. Theuerholz, A. Knorr, M. Richter
Technische Universitat Berlin (Germany)

Nanoplasmonic emitters, such as spasers, are needed to supply coherent plasmons and overcome the problem of short lifetimes. In terms of laser theory the spaser is a laser in the bad cavity limit, with extremely high Purcell factors and mesoscopic system sizes - a regime where standard approaches fail. We present a numerically exact, non-perturbative investigation of the full statistical properties of coupled metal nanoparticle/many quantum emitter systems in the spaser limit.

P24: Coupling hyper-sound generated by molecular transducers to plasmonic nanorods

Elena Pavlenko, Steffen Mitzscherling, Wouter Koopman, Matias Bargheer
University of Potsdam (Germany)

We designed and prepared nanolayered composites containing gold nanorods as plasmonic sensors and azobenzene-polyelectrolytes as opto-acoustic transducers. The multilayered structure of Azobenzene-containing polymer is prepared by the layer-by-layer spin coating procedure. A sound wave is triggered by excitation of Azobenzene molecules and then detected by gold nanorods, due to the sensitivity of their plasmon resonance to the surrounding media.

P25: Polarization Controllable THz Stereometamaterial Absorber

Mohammad P. Hokmabadi, Juhyung Kim, Soner Balci, Elmer Rivera, Patrick Kung, Seongsin M. Kim
The University of Alabama (USA)

Spatially different arrangements of identical meta-atoms in a unit cell bring about distinct properties in stereometamaterials. Integrating the stereometamaterial into a perfect metamaterial absorber, we designed, fabricated, characterized a device with single or double band absorption responses and an absorption/reflection switching characteristic dependent upon the polarization of incident THz wave. Despite the rotational symmetry of the rings, non-centricity breaks the reflection symmetry of the FSS, leading to a unique interaction between dipoles on the FSS and their mirror images.

P26: Graphene-Enhanced Near-Field Radiative Transport between a Nanostructured Metamaterial Emitter and a Planar Receiver

Jui-Yung Chang, Yue Yang, Liping Wang
Arizona State University (USA)

It becomes crucial for applications like near-field thermophotovoltaic to achieve strong near-field energy transfer between dissimilar materials, while coupled surface plasmon/phonon polaritons and hyperbolic modes usually require identical materials across nanometer vacuum gaps. In this work, we theoretically study near-field radiative transport between a nanostructured metamaterial emitter and a planar receiver covered by graphene. Strong near-field coupling up to two orders of magnitude enhancement can be achieved. The physical mechanisms are elucidated with fluctuational electrodynamics and dispersion relations.

P27: Theoretical Diffraction and Imaging Assessment of Multi-Layer Metamaterial Microwave Lens Operated Under Fast F/1 Geometries

Steve Kacenjar[1], Tamelia Ali[2], Igor Bendoym[3], Andrii Golovin[2], David Crouse[2]
[1] *Lockheed Martin corporation (USA),* [2] *City University of New York (USA),* [3] *Phoebus Optoelectronics (USA)*

With the advent of lightweight, low cost and spatially stationary metamaterial-based microwave scanning/imaging systems, key questions remain as to their imaging quality effectiveness. Methods such as varactor-controlled metamaterials and metasurfaces provide distinctive approaches in shaping the microwave radiation, yet their robustness to operational bandwidth, loss tangents, and off-axis deployment may limit their utility in various operational setting such as in remote sensing, radar and communication systems. This paper compares the analytic scaling to numerical estimation of such system focusing properties.

P28: Bio-Inspired Hierarchical Acoustic Metamaterials

Marco Miniaci[1], Federico Bosia[2], Nicola Pugno[3]
[1] *Department of Physics - University of Torino (Italy),* [2] *University of Torino (Italy),* [3] *University of Trento (Italy)*

Many biological systems show extremely efficient structural as well as dynamic properties achieved through their structure, which is often hierarchical. In this study, such a hierarchical structure is introduced in ordinary acoustic metamaterials (AMMs) to investigate partial and complete BGs modifications due to increasing structural complexity at different scale levels.

P29: Near-field Energy Extraction with Hyperbolic Metamaterials

Jiawei Shi, Baoan Liu, Pengfei Li, Li Yen Ng, Sheng Shen
Carnegie Mellon University (USA)

Although blackbody radiation described by Planck's law is commonly regarded as the maximum of thermal radiation, thermal energy transfer in the near-field can exceed the blackbody limit due to the contribution from evanescent waves. Here, we demonstrate experimentally a broadband thermal energy extraction device based on hyperbolic metamaterials that can significantly enhance near-field thermal energy transfer.

P30: Exciton-Polariton Laser with Saturable Absorber

I. G. Savenko[1], H. Flayac[2], N. N. Rosanov[3]
[1]*Aalto University (Finland),* [2]*Ecole Polytechnique Federale de Lausanne (Switzerland),* [3]*ITMO University (Russia)*

We consider exciton polaritons in a semiconductor microcavity with a saturable absorber. Such design promotes nonlinear losses of the system with a bistability of the condensate particles number on the intensity of pump. We demonstrate new type of bright spatial dissipative exciton-polariton soliton which spatial extent lies in the sub-micrometer range, much smaller than the typical widths of regular optical dissipative solitons.

P31: Application of the transition semiconductorto semimetal in type II nanostructure superlattice for mid infrared optoelectronics devices.
Abderrazak Boutramine, Abdelhakim Nafidi, Driss Barkissy, Abdelkrim Hannour, Ahmed Saba, Thami El Gouti
LCMP Nano Re-University Ibn Zohr (Morocco)

We report here electronic bands structures in InAs (d1)/GaSb (d2) type II superlattice performed in the envelope function formalism. When d1 (or the offset) increases, the band gap Eg decreases to zero at d1c (or 920 meV) accusing a semiconductor to semimetal transition. The cut-off wavelength situates this sample, with Eg (300K) = 230 meV, as mid-wavelength infrared detector (MWIR). These results agree well with the experimental Eg (T) data reported in literature.

P32: Real space observation of percolation clusters and their evolution in nearly grain-boundary-free VO2/TiO2 thin films
Ahrum Sohn[1], Dong-Wook Kim[1], Teruo Kanki[2], Kotrao Sakai[2], Hidekazu Tanaka[2]
[1]*Ewha Womans University (Korea),* [2]*Osaka University (Japan)*

We investigated the surface work function (WS) of 15-nm-thick nearly grain-boundary-free VO2/TiO2 thin films using Kelvin probe force microscopy (KPFM). WS maps obtained while varying the sample temperature enabled us to observe metallic and insulating domains with distinct WS values, while the sample underwent the metal-insulator transition.

P33: Plasmonic Focus Points for Sensing Chiral Molecules
Luisa Magdalena Kneer[1], Eva-Maria Roller[1], Robert Schreiber[2], Tim Liedl[1]
[1]*Ludwig Maximilans Universitat (Germany),* [2]*University of Oxford (United Kingdom)*

Naturally occurring biomolecules often exhibit strong optical activity in the UV, but usually none in the visible frequency range. Plasmonic nanostructures can transfer the optical activity of the biological molecules to their plasmon resonance frequency. Here we demonstrate a unique approach to pick up the circular dichroism (CD) signal of regular B-DNA in the visible and near infrared by using gold nanoantennas self-assembled on DNA origami structures.

P34: Photo-striction and reversible patterning of polymer-on-metal nanostructures with a plasmonic hologram
Carsten Henkel, J. Jelken, B. Stiller, D. Neher, T. Papke, Nataraja Sekhar Yadavalli, S. Santer
University of Potsdam (Germany)

Surface plasmons in thin metallic films can be excited by nm-scale defects (grooves, pits) and interfere with the incident laser field. We observe this plasmonic hologram with a polymer film containing azo-benzene chromophores that is coated on the metal. It deforms into a surface relief when exposed to plasmons. The azo-benzene units isomerize and re-orient depending on local intensity and polarization. The relief period (plasmon fringes) gives access to the dispersion relation of surface plasmons in the multilayer metal-on-substrate structure.

P35: ZnO/Au-based Surface Plasmon Resonance Device for CO2 Gas Detection
Ratno Nuryadi, R. D. Mayasari, L. Aprilia
Agency for the Assessment and Application of Technology (Indonesia)

We propose surface plasmon resonance (SPR) device using ZnO/Au/prism and study its response to CO2 gas. The SPR device is based on Kretschmann's prism configuration with ZnO/Au layer deposited on the flat surface of the prism. It is found that the absorption of gas molecules on the ZnO sensitive layer produces the shift of SPR angle to higher incident angle. A consistent sensing behavior over repetitive circles indicates that the SPR device works on good reproducibility for gas detection.

P36: Chiroptical Sensing with Plasmonic Metasurfaces
Amr Shaltout, J. Liu, V. M. Shalaev, A. V. Kildishev
Purdue University (USA)

Circular dichroism spectrometers measure the differential absorption spectrum between optical spins (circular polarizations) through taking sequential readings of left and right-handed spins at different wavelengths. This requires complicated hardware to switch the laser source and manage sequential data collections. Instead, we implement a metasurface which utilizes photonic spin Hall effect for spatial separation of left and right-handed spectra. This enables real-time sensing, and eliminates the need for the complicated hardware.

P37: Direct Measurement of Far Field Radiation Patterns of Large Scale Aluminum Nanoantenna Arrays using Fourier Microscopy
Neciah Dorh[1], N. Ahmad[1], S. Nunez-Sanchez[1], M. Lopez-Garcia[1], G. Ternent[2], M. J. Cryan[1]
[1] *University of Bristol (United Kingdom),* [2] *University of Glasgow (United Kingdom)*

In this paper, we present direct measurement of the far field radiation pattern produced by a 62,500 element aluminum nanoantenna array. The 250 x 250 array consists of nanorod/monopole nanoantennas separated by a uniform 409 nm pitch. Using the Fourier Microscopy technique, angle resolved reflectance measurements revealed a 40 percent peak reflectance at the nanoantenna array resonance (710 nm). Using Finite Difference Time Domain (FDTD) modelling of the array, we observe a similar peak of 68 percent near 690 nm.

P38: Dyakonov surface waves in nanoparticle dispersed liquid crystal metamaterials
Tatsunosuke Matsui
Mie University (Japan)

We have investigated existence condition of lossless Dyakonov surface waves (DSWs) on nanoparticle dispersed liquid crystal (NDLC) metamaterials composed of nematic liquid crystal host dispersed with Ag nanoparticle inclusions. Effective dielectric permittivities of NDLCs are obtained by an extended Maxwell-Garnett mixing rule. We have shown that the existence condition for DSWs can be significantly relaxed allowing even air cladding. Our approach may open a new avenue exploring practical application of lossless DSWs with switching capabilities.

P39: Leaky Dyakonov Surface Plasmon Polaritons for Birefringent Crystals
Ardi Loot, Vladimir Hizhnyakov
University of Tartu (Estonia)

The surface waves propagating at the interface of metal and positive birefringent crystal, usually called Dyakonov surface plasmon polaritons (DSPPs), were theoretically investigated. It was shown, that at special conditions the extraordinarily polarized component of DSPPs could become leaky. The properties of such half-leaky waves were theoretically investigated and it was shown that these surface waves could be excited without any prism or grating. This is especially beneficial in the experiments of nonlinear optics where field enhancement is required.

16:40 - 17:50 — Aronow Theater

Session 2A21

Symposium 1: Functional Metastructures and Nanomaterials: Properties, Fabrication and Modeling VI

Organized by: Alexander Govorov and Hilmi Volkan Demir

Chaired by: Wei David Wei and Alexander Holleitner

16:40 : Invited talk
Plasmonic Silver Nanowires as Security Labels for Anti-counterfeiting Applications
Yan Cui[1], Ravi S. Hedge[2], In Yee Phang[3], Hiang Kwee Lee[1], Xing Yi Ling[1]
[1] *Nanyang Technological University (Singapore),* [2] *Institute of High Performance Computing (Singapore),* [3] *A*STAR (Singapore)*

We present a next generation covert plasmonic security labels based on Ag nanowire structures and their polarization dependent surface-enhanced Raman spectroscopy (SERS) imaging. Our plasmonic security labels exhibit very narrow spectral fingerprint vibration, which is more specific than broad-band colorimetry-based systems. The polarization dependent SERS intensity, molecular fingerprint of SERS spectra, and versatile geometrical design by two-photon lithography have made our plasmonic Ag nanowire structures an ideal candidate as an advanced security solutions for anti-counterfeiting application.

17:00 : Ultrasensitive label-free biosensor based on photonic crystal surface waves: a tool to study dynamics of receptor-ligand interactions with living bacteria and cells
Ekaterina Rostova, Sergey Sekatskii, Giovanni Dietler
Ecole Polytechnique Federale de Lausanne (Switzerland)

A label-free biosensor based on photonic crystal surface waves was used to study dynamics of receptor-ligand interactions with living bacteria and cells. We elaborated a chitosan-based protocol of surface modification of the sensor chip enabling to produce sufficiently dense and homogeneous monolayers of live bacteria Escherichia coli. The attached bacteria have been exploited as a target to study binding kinetics of different ligands onto a bacterial surface, including antibacterial drugs and bacterial phages.

17:15 : Photonic nanoarchitectures in butterfly wing scales and butterfly chromaticity diagram as a well-tuned emitter- detector system for optical vapor sensing
Gabor Piszter[1], Krisztian Kertesz[1], Zofia Vertesy[1], Zsolt Balint[2], Laszlo Peter Biro[1]
[1] *Institute of Technical Physics and Materials Science (Hungary),* [2] *Hungarian Natural History Museum (Hungary)*

Butterfly wing scales containing photonic nanoarchitectures act as chemically selective sensors due to their color change when mixing vapors in the atmosphere. Based on butterfly vision we developed the efficient characterization of the spectral changes in different air + vapor mixtures. Almost perfectly coincident results were found using standard principal component analysis and butterfly visual space for seven vapors. The conformal modification of the scale surface by atomic layer deposition significantly altered the optical response and the selectivity.

17:30 : Invited talk
Near Field Properties of Coupled Metallic Nanostructures
Anran Li[1], Sivan Isaacs[2], Chihao Liow[1], Ibrahim Abdulhalim[2], Shuzhou Li[1]
[1] *Nanyang Technological University (Singapore),* [2] *Ben Gurion University (Israel)*

We proposed a new metallic nanostructure that includes two spiky metallic nanoparticles. The spiky metallic nanoparticle dimer could have large electric field enhancement and large hot volume at the same time. The hot spot volume in tip-to-tip dimer is 7 times and 5 times larger than those in the spike dimer and sphere dimer with the same gap size of 2 nm. These results show high potential for enhanced spectroscopic sensing and other optoelectronic application.

16:40 - 17:35 — NAC 0/201

Session 2A22

Advances in Hybrid Plasmonics III

Organized by: Mohamed Swillam

Chaired by: Mohamed Swillam

16:40 : Invited talk
Hybrid electro-optical plasmonic modulators and switches for integrated optical signal processing
Dimitrios Zografopoulos[1], Mohamed Swillam[2], Lamis Shahada[3], Romeo Beccherelli[1]
[1] *Istituto per la Microelettronica e Microsistemi (Italy),* [2] *The American University in Cairo (Egypt),* [3] *Qatar University (Qatar)*

By breaking the diffraction limit, plasmonics enable the miniaturization of integrated optical signal proces-

sing units in a platform compatible with traditional CMOS technology. In such architectures, modulators and switches are essential elements for fast and low-power optical signal processing. This work reviews the state-of-the-art on electro-optical plasmonic integrated components, comprising different propagation length scales and tuning mechanisms. Among these, particular attention is paid to the Pockels effect in non-linear polymers and the electro-optical switching of nematic liquid crystalline materials.

17:00 : Invited talk
Hybrid Plasmonics for Integrated Optics and Sensing Applications
Mo Mojahedi
University of Toronto (Canada)

Hybrid plasmonic waveguides and structures provide a new platform for design and fabrication of integrated optical devices and sensors. By merging the silicon photonics with plasmonics, the hybrid plasmonic promises a new platform which enables the design of extremely compact and efficient integrated devices with notably reduced real-state on the chip. Moreover, the uses of hybrid plasmonic technology in design of sensors will at least double the amount of date gathered during a single sensing event.

17:20 : Brewster mode or how to optically monitor the doping concentration in highly doped semiconductor layers
T. Taliercio[1], L. Cerutti[1], E. Tournie[1], J.-J. Greffet[2]
[1] *University of Montpellier (France),* [2] *Paris Sud University (France)*

We propose a new experimental technique to accurately measure the plasma frequency of metallic layers and notably doped semiconductors. The technique is based on reflectance measurements evidencing a resonant dip near the plasma frequency. Based on Fresnel coefficients in the case of transverse electromagnetic waves, we propose that this resonance is due to the excitation of a leaky electromagnetic mode, the Brewster mode, propagating in the metallic layer deposited on a dielectric material.

16:40 - 18:00 — NAC Ballroom

Session 2A23

Plasmonics and nanophotonics IV

Chaired by: Yuliy Bludov

16:40 : Invited talk
Plasmonics/metamaterials and crystal growth at the crossroads
D. A. Pawlak[1], K. Sadecka[1], P. Osewski[1], M. Gajc[1], K. Korzeb[1], A. Klos[1], E. Petronijevic[2], A. Belardini[2], G. Leahu[2], C. Sibilia[2]
[1] *Institute of Electronic Materials Technology - ITME (Poland),* [2] *University of Warsaw (Poland)*

We report on developments in fabricating nano and micro-structured volumetric plasmonic materials and metamaterials utilizing crystal growth techniques as the micro-pulling down method. Materials developed by directional solidification of eutectic composites and directional solidification of dielectrics directly doped with functional nanoparticles.

17:00 : Plasmon Assisted Thermionic Current Injection in Metal-Insulator-Metal Junctions
Matthias Hensen[1], Dominik Differt[1], Felix Becker[1], Detelf Diesing[2], Walter Pfeiffer[1]
[1] *Bielefeld University (Germany),* [2] *Universitat Duisburg-Essen (Germany)*

Gold nanoparticles deposited on a metal-insulator-metal junction act as optical nanoantennas and locally enhance the absorption of radiation. As a consequence the electron gas in the top electrode is heated and thermionic emission dominates the carrier injection upon excitation with ultrashort laser pulses. The injection current is sufficiently large to allow the detection of single nanoparticles. The optically driven nonlinear carrier injection mechanism demonstrated here opens new perspectives for nanoantenna based photodetectors and ultrafast switching.

17:15 : Plasmo-Photonic Metasurfaces Manipulating Electronic Processes in Fluorescent Molecules

Masanobu Iwanaga, Bongseok Choi, Hideki Miyazaki, Yoshimasa Sugimoto, Akihiro Ohtake, Kazuaki Sakoda
National Institute for Materials Science (Japan)

Plasmo-photonic metasurfaces, which have been very recently introduced, are applied for fluorescence (FL) enhancement experiment. Optimization of the structur and the gap between the outmost interface and FL molecules has enabled us to reach significant FL enhancement factor over 5500 fold, strongly suggesting that desired control of electronic transitions in the FL molecules is realized.

17:30 : Large-area metasurface antireflection coating enabled by randomly dispersed silver nanodiscs
Hideki Yasuda, Ryo Matsuno, Takeharu Tani, Masayuki Naya
Fujifilm Corp. (Japan)

We propose a metasurface anti-reflection coating for visible light using randomly dispersed silver nanodiscs. The effective refractive index of 10nm-thick monolayer of silver nanodiscs is about 0.5 for visible light, which enable strong suppression of reflection from substrate. This structure is easy to fabricate using conventional wet-coating methods and we report successful fabrication of proposed structure in a large area.

17:45 : Study of plasmonic oscillations in composite structures through surface integral equation method
Dimitrios Ch. Tzarouchis, Pasi Yla-Oijala, Ari Sihvola
AALTO University (Finland)

Tailoring the optical response of geometrically complex metal structures and clusters is a highly demanding procedure. In the present work, we demonstrate the usage of the surface integral equation method, for the evaluation of the near fields on metallic scatterers, at the optical regime. In that way, some important physical insights occur, enabling the deduction of useful design guidelines.

16:40 - 18:00 — NAC 1/202

Session 2A24

Thermoplasmonic and near-field heat transfer between metamaterials I

Organized by: Philippe Ben-Abdallah and Svend-Age Biehs

Chaired by: Philippe Ben-Abdallah and Svend-Age Biehs

16:40 : Invited talk
Non-equilibrium quantum manipulation: from quantum thermal machines to quantum transport
Mauro Antezza
Montpellier University (France)

We will discuss the behavior of one or more elementary quantum systems (atoms, molecules, quantum dots, etc) interacting with a stationary, simple and rich electromagnetic environment out of thermal equilibrium. Particular attention will be devoted to the new features that this system offers toward the possibility to manipulate collective atomic states and leading to improved performances in: creation and protection of entanglement, quantum thermal machines, transport of excitations.

17:00 : Invited talk
Exploring and Tailoring Near-Field Thermal Radiation at Extreme Separation
Svetlana V. Boriskina, Vazrik Chiloyan, Poetro L. Sambegoro, Jonathan Tong, Yi Huang, Gang Chen
MIT (USA)

Theoretical and experimental studies of mechanisms of the near-field thermal radiation enhancement and control reveal contributions from surface polariton waves, morphology-dependent trapped optical modes, as well as material and metamaterial phase transitions. A new theoretical approach based on the lattice dynamics and the microscopic Maxwell equations is presented, which enables bridging the theories of conduction and radiation.

17:20 : Invited talk
Thermal self-oscillations in radiative heat exchange
Sergey Dyakov, J. Dai, M. Yan, M. Qiu
KTH Royal Institute of Technology (Sweden)

We report the effect of relaxation-type self-induced temperature oscillations in the system of two parallel plates of SiO-2 and VO2 which exchange heat by thermal radiation in vacuum. The non-linear feedback in the self-oscillating system is provided by metal-insulator transition in VO2 . Using the method of fluctuational electrodynamics we show that under the action of an external laser of a constant power, the temperature of VO2 plate oscillates around its phase transition value.

17:40 : Invited talk
Near-field heat transfer in moving media
Yu Guo, Zubin Jacob
University of Alberta (Canada)

Resonators fold the path of light by reflections leading to a phase balance and thus constructive addition of propagating waves. However, amplitude decrease of these waves due to incomplete reflection or material absorption leads to a finite quality factor of all resonances. Here we report on our discovery that evanescent waves can lead to a perfect phase and amplitude balance causing an ideal Fabry-Perot resonance condition in spite of material absorption and non-ideal reflectivities.

16:40 - 18:05 — ASRC Conference Room

Session 2A25

Nano-apertures and applications II

Organized by: Sang-Hyun Oh and Reuven Gordon

Chaired by: Sang-Hyun Oh and Reuven Gordon

16:40 : Invited talk
Fast modeling of nano-apertures using the hybridizable discontinuous Galerkin method
Ngoc-Cuong Nguyen[1], Jaime Peraire[1], Hyeong-Ryeol Park[2], Xiaoshu Chen[2], Sang-Hyun Oh[2]
[1] *MIT (USA),* [2] *University of Minnesota (USA)*

Accurate computational modeling of electromagnetic wave propagation inside nano-aperatures poses some significant challenge. The enormous mismatch in length scales, up to 6 orders of magnitude between millimeter-scale wavelength and nanometer-scale gap size, is beyond the capabilities of currently available finite-difference time-domain or finite-element methods. To solve this problem, we employ the Hybridizable Discontinuous Galerkin method to calculate full 3D field distributions and transmission spectra for nano-aperature structures in a fast and accurate manner.

17:00 : Invited talk
Nanostructured plasmonic interferometers for ultrasensitive label-free biosensing
Filbert J. Bartoli
Lehigh University (USA)

This presentation will focus on the design, fabrication, and characterization of nanoplasmonic interferometers for label-free biosensing applications.

17:20 : Subwavelength Lattice Optics by Evolutionary Design
Teri Odom
Northwestern University (USA)

A new class of structured optical materials-lattice opto-materials-that can manipulate the flow of visible light into a wide range of three dimensional profiles using evolutionary design principles will be discussed. Lattice opto-materials based on predicted arrangements of nanoscale holes can exhibit simple properties, such as on- and off-axis focusing, and can also concentrate light into multiple, discrete focal spots. Anisotropic unit

cell shapes can achieve polarization-dependent optical responses from the same two-dimensional patterned substrate.

17:35 : Extraordinary light intensity enhancement by hyperfocusing in low Q-factor resonators: the Helmholtz Optical Resonator example.
F. Pardo[1], P. Chevalier[1], P. Bouchon[2], R. Haidar[2], J.-L. Pelouard[1]
[1] *MiNaO Laboratory- LPN-CNRS (France),* [2] *MiNaO Laboratory-ONERA-DOTA (France)*

A slit-box combination (the Optical Helmholtz Resonator) permits to observe the nearly total funneling of a transverse magnetic focused beam, even if the slit is arbitrarly narrow. In this hyperfocusing phenomena, the energy concentration corresponds to a giant enhancement of the electric field intensity, up to 10 5 in the near infrared range. I will discuss the applications for photodetection, SERS, SEIRA, and nonlinear optics, and show in a picturial way the building sequence of the field.

17:50 : Listening to a virus with a double-nanohole optical tweezer
Skylar Wheaton, Ryan Gelfand, Reuven Gordon
University of Victoria (Canada)

Virus vibrations reveal structural properties, allowing for identification and selecting specific virus particles in solution, and these vibrations can be targeted to destroy specific viruses with a unique excitation frequency spectrum. Using extraordinary acoustic Raman spectroscopy (EARS), we measure the vibrational spectra of individual isolated MS2 virus particles in solution.

16:40 - 17:50 — NAC 1/203

Session 2A26

Topological photonics in synthetic electromagnetic media II

Organized by: Alexander Khanikaev

Chaired by: Alexander Khanikaev

16:40 : Invited talk
Bulk and Surface Correspondence through Geometric Phases in Photonic Crystals
M. Xiao, Xueqin Huang, Z. Q. Zhang, C. T. Chan
Hong Kong University of Science and Technology (Hong Kong)

We find a correspondence between the surface impedance and the bulk geometric phase of the bands for photonic crystals. This surface-bulk correspondence actually applies to all one dimensional periodic systems with mirror symmetry. We extend this correspondence to two dimensional systems with C4v symmetry. Such correspondence allows us to use the bulk geometric phase to predict the existence of an interface state between two different photonic crystals.

17:00 : Invited talk
Observation of topological edge states in subwavelength resonant structures
A. E. Miroshnichenko[1], A. N. Poddubny[2], I. S. Sinev[2], I. S. Muhin[2], A. P. Slobozhanyuk[1], K. Samusev[2], P. A. Belov[2], Y. S. Kivshar[1]
[1] *The Australian National University (Australia),* [2] *ITMO University (Russia)*

We suggest a novel type of photonic topological edge states in zigzag arrays of resonant subwavelength particles. We experimentally verify our concept for plasmonic nanodisks in visible and for dielectric spherical particles in microwave ranges. One of the recognized topologically control the subwavelength topologically-protected electromagnetic edge modes by changing the nontrivial phases of electronic matter is associated with the quantum Hall effect when a polarization of the incident wave.

17:20 : Measurement of the Zak phase in photonic systems
Qiang Wang[1], Meng Xiao[1], Hui Liu[1], Fan Zhong[1], Shining Zhu[1], C. T. Chan[2]
[1] *Nanjing University (China),* [2] *Hongkong University of Science and Technology (Hong Kong)*

We propose an experimental method to measure Zak phase in optical system. We can extract the property of each band gap through surface states which exists at the interface of trivial mirrors and nontrivial mirrors. By comparing the properties of two adjacent band gaps, Zak phase of the band sandwiched between them can be directly determined. We can also manipulate the excitation frequency and polarization of surface state by metasurfaces designed.

17:35 : Robust propagation of microwave edge modes in reconfigurable topological crystals
Camille Jouvaud, Xiaojun Cheng, Xujun Ma, Hua Zheng, Azriel Genack, Alexander Khanikaev
Queens College of The City University of New York (USA)

We demonstrate a microwave analogue of topological quantum spin Hall system in a photonic crystal-like system embedded into a parallel plate waveguide. Topologically protected transport of microwave radiation is found along the reconfigurable boundary between two domains of crystals with opposite synthetic gauge field emulating spin-orbital interaction. Waves propagation is controlled in a reconfigurable manner by modifying the domain walls. Protected states are shown to be reciprocal and robust against defects, including abrupt changes in the propagation direction.

16:40 - 18:00 — NAC 1/211

Session 2A27

Metamaterials and negative index materials III

Chaired by: Ajay Nahata

16:40 : Invited talk
Poynting theorem and its implication on the signs of the imaginary parts of the electromagnetic constitutive parameters in passive metamaterial.
O. M. Ramahi, B. Alavikia, A. Kabiri
University of Waterloo (Canada)

Metamaterials have been found experimentally and theoretically to yield negative imaginary permittivity or permeability. This conclusion was deemed impossible or non-physical by many researchers based on fundamental entropy concepts. In this work, we show that basic intuitive assumptions about the positiveness of the imaginary part of passive metamaterial cannot be guaranteed by the Poynting Theorem. In fact, we show that passivity does not necessarily imply negative imaginary parts while maintain consistency with entropy principles.

17:00 : Tunable negative permeability in a three-dimensional superconducting metamaterial
Cihan Kurter[1], T. Lan[2], L. Sarychev[1], S. Anlage[1]
[1] *Missouri University of Science and Technology (USA),* [2] *University of Maryland (USA)*

We demonstrate a highly tunable, 3D metamaterial made of superconducting spiral resonators. The rf transmission of a single element of the metamaterial shows a fundamental resonance peak at 24.95 MHz that shifts to a 25 percent smaller frequency and becomes degenerate when a 3D array of such elements is created. The metamaterial shows an in-situ tunable narrow frequency band in which the real part of the effective permeability is negative over a wide range of temperature.

17:15 : A Phase Diagram and an Order Parameter for the Transitions between Photonic Crystals and All-Dielectric Metamaterials
M. Rybin, D. Filonov, K. Samusev, P. Belov, Yury Kivshar, Mikhail Limonov
ITMO University (Russia)

Photonic crystals and all-dielectric metamaterials can be composed of the same type of structural elements, and they may differ only by material's permittivity and a filling factor. Here we introduce a concept of phase transitions between these two classes of artificial structures, demonstrate its underlying mechanism, and suggest a phase diagram that places both photonic crystals and metamaterials on a common parameter plane. Our theory is confirmed by experiments with a square lattice composed of cylinders.

17:30 : Gate-controlled Circular Dichroism in Graphene Chiral Metamaterials
Teun-Teun Kim[1], Hyeon-Don Kim[2], Hyun-Sung Park[2], Sang Soon Oh[3], Bumki Min[2], Shuang Zhang[1]
[1] *University of Birmingham (United Kingdom),* [2] *Korea Advanced Institute of Science and Technology (Korea),* [3] *Imperial College London (United Kingdom)*

We demonstrate electric control of circular dichroism for terahertz waves by active tuning of the coupling between adjacent chiral metamolecules. By hybridizing gated single-layer graphene with a conjugated double Z metamaterial, we experimentally show that the transmission of left-handed circular polarized light can be effectively controlled without affecting that for the right handed circular polarized wave.

17:45 : Nanoantenna Coupled Quantum Dot Infrared Photodetectors
Giancarlo Cerulo, Yuriy Fedoryshyn, Valeria Liverini, Mattias Beck, Jerome Faist
ETH Zurich (Switzerland)

We present the proof of principle of the enhancement of the responsivity of a quantum dot infrared photodetector (QDIP) by means of complementary split ring resonator(c-SRR) nanoantennae. The nanantennae, coupled to the QDs in the detector, yield an enhancement of the responsivity of almost one order of magnitude.

16:40 - 18:00 — NAC 1/201

Session 2A28

Metamaterial-based radiating and absorbing structures II

Organized by: Xavier Begaud and Shah Nawaz Burokur

Chaired by: Xavier Begaud and Shah Nawaz Burokur

16:40 : Invited talk
Broadband metamaterial absorbers from multilayered polymer-based nanocomposite films
Yann Danlee, Arnaud Delcorte, Sophie Hermans, Luc Piraux, Christian Bailly, Isabelle Huynen
UCL (Belgium)

Broadband absorbers were obtained by a multilayer arrangement of polymer nanocomposites built from alternating dielectric polycarbonate films and conducting layers. The latter are stacked in a gradient of conductivity, and consist of either Nickel nanowires carpets sandwiched between polycarbonate films or Carbon Nanotubes-patterned polycarbonate films. Nickel-based absorbers demonstrate excellent performance thanks to enhanced attenuation provided by magnetic response of Nickel, while anisotropic conductive layers obtained by ink deposition of carbon nanotubes patterns onto polycarbonate films provide polarization-selective absorbers

17:00 : Invited talk
Metamaterial perfect absorbers for electromagnetic wave at low frequencies
YoungPak Lee[1], Y. J. Yoo[1], B. X. Khuyen[1], Y. J. Kim[1], J. Y. Rhee[2], Y. H. Kim[3], K. W. Kim[4]
[1] *Hanyang University (Korea),* [2] *Sungkyunkwan University (Korea),* [3] *Infovion Inc. (Korea),* [4] *Sunmoon University (Korea)*

Using a planar and flexible metamaterial (MM), we obtained the low-frequency perfect absorption even with very small unit-cell size in snake-shape structure. The ratio between periodicity and resonance wavelength (in mm) is close to 1/12 and 1/30 at 2 GHz and 400 MHz, respectively. We also demonstrated a MM perfect absorber in MHz region based on a planar sandwiched structure of metal-dielectric-metal.

17:20 : Invited talk
Broadband metasurfaces for the design of planar lenses
Oscar Quevedo-Teruel[1], Mahsa Ebrahimpouri[2], Malcolm Ng Mou Kehn[3]
[1] *KTH Royal Institute of Technology (Sweden),* [2] *Royal Institute of Technology (Sweden),* [3] *National Chiao Tung University (Taiwan)*

Metasurfaces have demonstrated to be a low cost solution for development of directive antennas at high

frequency. One of the opportunities of metasurfaces is the possibility to produce planar lenses. However, these lenses usually present a narrow band of operation. Those limitations on bandwidth are more restrictive when the required range of refractive index is high. Here, we present a novel implementation of metasurfaces with low dispersion that can be employed for the design of broadband planar lenses.

17:40 : Invited talk

Non-coplanar refraction in microwave region by ultra-thin high efficiency metalens with phase discontinuities in orthogonal directions

Kuang Zhang, Xumin Ding, Qun Wu
Harbin Institute of Technology (China)

An ultrathin flat metalens experimentally realizing three-dimensional microwave manipulation has been demonstrated to be able to approach the theoretical limit of cross-polarization conversion efficiency of the transmission. The helicity-dependent phase change is introduced to the transmission and can be engineered by assembling the spatial orientation of each Pancharatnam-Berry phase element. The proposed metalens has only one single layer as thin as 0.001lambda, which massively reduces the thickness of the microwave lens along the wave propagation direction.

Thursday 6th August, 2015

08:30 - 09:50 — Aronow Theater

Session 3A1

Plenary Session III

Chaired by: Natalia Litchinitser

08:30 : Plenary talk
Using metamaterials for optical switching
Nikolay I. Zheludev
University of Southampton (United Kingdom)

We report on recent results on ultra-compact electro-optical and magneto-optical switching devices of sub-micron thickness for controlling light-with-light that exploit artificial nano-opto-mechanical plasmonic and dielectric metamaterials. We also report recent experiments demonstrating that coherently controlled redistribution of energy at plasmonic metamaterials can underpin various forms of optical switching and show that devices based on coherent control can operate down to single photon level and with a multi-THz modulation bandwidth.

09:10 : Plenary talk
The singularities of light: intensity, phase, polarization
Michael Berry
University of Bristol (United Kingdom)

Light has singularities at different levels. Coarsest is geometrical optics, whose singularities are ray caustics, classified by catastrophe theory. Wave optics decorates these singularities with characteristic interference patterns. Wave optics introduces phase, with its own singularities: optical vortices. These dark singularities are lines in space, or points in the plane. In vector light are polarization singularities: lines of purely circular or linear polarization. These singularities illustrate asymptotically emergent phenomena, and form a hierarchy, predicting new quantum phenomena.

Coffee Break and Exhibit Inspection

Session 3P1

Poster session V

09:50 - 10:30

P1: 1D Nickel Gratings as Solar Absorbers
N. Ahmad, S. Nunez-Sanchez, Martin Cryan
University of Bristol (United Kingdom)

This paper presents measured absorptance results for Focused Ion Beam fabricated 1D nickel gratings optimised for solar spectrum. Results are shown for a grating period of 500nm and for varying etch depths. We obtain absorptance greater than 90 percent for wavelengths 633nm to 714nm and greater than 65 percent from 450nm to 800nm. Angular and spectral is also shown using Fourier Imaging measurements.

P2: Band Structure of Two-Dimensionally Photonic Crystal
Raul Garcia-Llamas[1], **Daniel Valenzuela-Sau**[2]
[1] *Universidad de Sonora (Mexico),* [2] *Universida de Sonora (Mexico)*

We calculate the photonic band structure and the electromagnetic modes of a photonic crystal, a rectangular array of cylinders of elliptical cross section, for TE and TM polarizations. A full band gap for both polarizations

was found, and the band structure was compared with that presented in ref. [17]. We plan to calculate the band structure and modes considering oblique electromagnetic propagation according to the homogeneous axis of the system.

P3: The localized surface plasmon resonance enhanced electron tunneling in gold nanoparticles array
Yusheng Zhai, Qilong Wang, Zhiyang Qi, Ji Xu, Xiaohua Li
Southeast University (China)

In this paper, we use a low-cost and simple method to fabricate Au nanoparticles(NPs) arrays and then investigate its plasmons enhanced electron tunneling characteristic when illuminated by light of different wavelengths. The self-assembly and secondary growth method is used to fabricate the Au NPs arrays with controlled size and spacing on the insulate glass substrate. We find that the photo-induced current strongly dependent on the wavelength of illuminated light.

P4: Plasmonic probes for nanoscale Raman and topography mapping.
Francesco Tantussi, Andrea Jacassi, Rajeshkumar Mupparapu, Francesco De Angelis
Istituto Italiano di Tecnologia (Italy)

Nanostructured AFM cantilevers with gold nanocone plasmonic tip are promising tools for nanoscale mapping Raman signals and topography at the same time. Different from the standard TERS illumination, our approach is based on a backside illuminations with radial polarization focused on the cone base. Thanks to the appropriate polarization, Surface Plasmon Polaritons are launched from the cone base toward the nanoscale cone apex where the E field enhanced is generated.

P5: Temperature dependence of band gap ratio and Q-factor defect mode in a semiconductor quaternary alloy hexagonal photonic-crystal hole slab
Robert Sanchez Cano[1], **Nelson Porras Montenegro**[2]
[1] *Universidad Autonoma de Occidente (Colombia),* [2] *Universidad del Valle (Colombia)*

We present numerical predictions for the photonic TE-like band gap ratio and the quality factors of symmetric localized defect as a function of the thickness-slab and temperature by the use of plane wave expansion and the finite-difference time-domain methods. The photoniccrystal hole slab is composed of a 2D-hexagonal array of identical air holes of circular cross-section, embedded in a non-dispersive III-V semiconductor quaternary alloy slab, which has a high value of dielectric function in the near-infrared region.

P6: Study on magneto-optic three dimensional display composed of magnetophotonic crystal
Kazuki Nakamura, H. Takagi, T. Goto, P. Lim, M. Inoue
Toyohashi University of Technology (Japan)

We have developed magneto-optic three-dimensional displays (3D-MOSLMs) with submicron scaled magnetic pixels to apply wide-viewing holographic display. The 3D-MOSLMs modulated light polarization with magneto-optic (MO) effect to represent holographic 3D images. The magnetophotonic crystals (MPCs) enhance magneto-optic (MO) effect by microcavity composed of magnetic garnet as defect layer. In this paper, we focused on the magnetophotonic crystals (MPCs) for magnetic media of 3D-MOSLMs. Using the MPC increased diffraction efficiency and reduced power consumption for thermomagnetic recording.

P7: Photonic crystal simulation of two co-existing SSH models with a topological phase difference
Momchil Minkov, Vincenzo Savona
EPFL Lausanne (Switzerland)

We fine-tune photonic crystal cavities supporting two orthogonally polarized modes such that when arranged in a 1D chain, each polarization is dimerized, but a strong bond in one comes with a weak bond in the other. We demonstrate the correspondence of the system to two co-existing, off-phase SSH models, and show the expected orthogonal, zero-frequency edge modes which are robust to some particular types of disorder.

P8: Exploitation of Fano resonance in periodic nanodome arrays for surface enhanced Raman scattering
M. Hardy[1], **Ryan McCarron**[1], **M. D. Doherty**[1], **R. J. Winfield**[2], **P. Dawson**[1]
[1] *Queen's University Belfast (United Kingdom),* [2] *University College Cork (Ireland)*

We demonstrate the fabrication and analysis of a large-array SERS substrate which uses Fano resonances generated from the scatterer-Bloch mode interaction to create absorption-emission split peaks tailored to the Raman shifts for specific SERS scattering events in analyte molecules. Using standard polymer-based imprint

patterning techniques which avoid the need for nanoscale roughness these substrates exhibit enhancement factors.

P9: Arbitrary bending the unidirectional electromagnetic waves using nonreciprocal materials
Qing-Bo Li, Zhen Li, Yin Poo, Ruixin Wu
Nanjing University (China)

Based on the nonreciprocal photonic crystal (PC) with simultaneously the parity (P) and time-reversal (T) symmetries broken, unidirectional waveguides with arbitrary bending have been designed by the optical transformation. The numerical results show the incident waves can pass through the waveguide without any reflections in one direction, but totally reflected in the opposite direction. We expect this design could be applied to improving the nonreciprocal performance of electromagnetic devices.

P10: Angular selection based on Dirac points in Two-Dimensional Photonic Crystals
ChangQing Xu, Yun Lai
Soochow University (China)

We demonstrate how to achieve angular selection of electromagnetic waves based on Dirac points in two dimensional photonic crystals. The transmittance for s-polarization wave can reach unity at the incident angle and frequency corresponding to the Dirac point. Away from the Dirac point, the transmittance will decrease sharply. By modifying the photonic crystal structure, the wave vector and frequency of the Dirac point can be tuned, leading to the function of tunable angular selection..

P11: Study of transmission properties in a finite magnetized plasma photonic crystal
Chien-Jang Wu[1], Tzu-Chyang King[2], Chih-Chiang Yang[2]
[1]*National Taiwan Normal University (Taiwan),* [2]*National Pingtung University (Taiwan)*

We study the transmission properties in a one-dimensional finite magnetized plasma photonic crystal of (1/2)N, where 1 is a dielectric layer, 2 is a plasma layer, and N is the number of periods. When B = 0, the structure behaves as a multichannel filter with a channel number of N-1. The positions of channels are shifted as the static magnetic field is applied. The blue-shift or red-shift depends on the orientation of the applied magnetic field.

P12: Wave manipulation by coupled cavities in structured metallic surface
Qiang Zhang[1], Zhenzhen Liu[1], Hong Xiang[2], Dezhuan Han[2], Junjun Xiao[1]
[1]*Harbin Institute of Technology (China),* [2]*Chongqing University (China)*

Spoof surface plasmon polaritons (SSPPs) were proposed and realized by structured metallic surfaces consisting of coupled cavities. We utilize the temporal coupled mode theory (TCMT) to describe their properties, including both the dispersion and transmission of the SSPPs. Based on the TCMT we can carefully design the resonance properties of the cavities to manipulate the propagation of the SSPPs, and further to achieve some interesting coherence phenomena. The predictions of the theory are verified by simulations and microwave experiments.

P13: Use of single-negative material as a tunable defect in a dielectric photonic crystal heterostructure
Tsung-Wen Chang, Chih-Jen Cheng, Chien-Jang Wu
National Taiwan Normal University (Taiwan)

The defect mode in a dielectric photonic crystal heterostructure of (1/2)N(2/1)N can be tuned by a single-negative layer D, namely, (1/2)ND(2/1)N. It is shown that, when D is a mu-negative (mu <0)) medium, the defect frequency is red-shifted as a function of the thickness of D as well as the static permittivity. When D is epsilon-negative (eps <0) medium, the defect frequency is blue-shifted as the thickness increases, but it is independent of the static permeability.

P14: Magnetic tunable elastic metamaterials beam
Wei Qian[1], Xiaole Wang[2], Yun Lai[3], Benjamin B. Yellen[4]
[1]*University of Michigan-Shanghai Jiao Tong University (China),* [2]*Shanghai Jiao Tong University (China),* [3]*Soochow University (China),* [4]*Duke University (USA)*

In this paper, by using 1-D beam composed of membrane-type or bulk-type elastic metamaterial with magnets, we experimentally demonstrate the possibility to tune the bandgap frequency of elastic metamaterial by external magnetic force. The experimental results is well matched with theoretical analysis and numerical simulations.Our work demonstrates a unique noncontact way to tune the properties of elastic metamaterials

with a very high efficiency.

P15: Plasmonic enhancement of Chiroptical effects: the role of surface plasmon polaritons
M. H. Alizadeh, B. M. Reinhard
Boston University (USA)

The most pronounced of chiral light-matter interactions occur in the ultraviolet (UV) range of the electromagnetic spectrum, which is difficult to access with conventional localized plasmon resonance based sensors. Although Surface Plasmon Polaritons (SPPs) on noble metal films can sustain resonances in the desired spectral range, their transverse magnetic nature has been an obstacle for enhancing chiroptical effects. Here we demonstrate, both analytically and numerically, that SPPs excited by near-field sources can exhibit rich and non-trivial chiral characteristics.

P16: Mie Scattering from a uniaxial sphere with single-negative
Youlin Geng, Zhiqun Cheng, Tao Zhou
Hangzhou Dianzi University (China)

Based on the spherical vector wave functions (SVWFs) in source-free uniaxial anisotropic medium, the electromagnetic fields in a uniaxial sphere with single-negative can be obtained. Applying the continuity in boundary conditions on the surface of uniaxial anisotropic sphere with single-negative. The EM scattering by a uniaxial sphere with single-negative can be characterized. Numerical results between this paper and Mie theory are obtained, and some new numerical results of scattering by a uniaxial sphere with single-negative are illustrated.

P17: Terahertz quantum plasmoncis of copper-graphene-copper hybrid structures
Young-Mi Bahk[1], Bong Joo Kang[2], Yong Seung Kim[3], Joon-Yeon Kim[1], Won Tae Kim[2], Tae Yun Kim[1], Jiyeah Rhie[1], Sanghoon Han[1], Cheol-Hwan Park[1], Fabian Rotermund[2], Dai-Sik Kim[1]
[1] *Seoul National University (Korea),* [2] *Ajou University (Korea),* [3] *Sejong University (Korea)*

We observed a ninety-seven percent decrease of terahertz transmittance in five-millimeter long, angstrom-sized optical gaps of copper-graphene-copper hybrid structure when irradiated with intense terahertz pulses. The giant nonlinearity was induced by terahertz funneling through the gap, across which a large transient potential difference facilitates electron tunneling.

P18: Experimental investigation of loss compensation of surface plasmon polaritons using quantum-well medium under electrical injection
Ting Mei[1], Y. Li[2], H. Zhang[3]
[1] *Northwestern Polytechnical University (China),* [2] *Nanyang Technological University (Singapore),* [3] *South China Normal University (China)*

Compensation of propagation loss of Surface Plasmon Polaritons (SPP) in Au film waveguides was experimentally investigated using InGaAsP/InP multiple quantum well (MQW) gain medium under electrical injection. In the asymmetric guide, while the long-range SPP mode was inert, the short-range SPP mode propagation was elongated upon electrical injection. By engineering the guide structure with a cladding layer of amorphous silicon to make the guide symmetric, the long-range mode was made active and became more sensitive to the electrical gain.

P19: Functional double layer scaffold fabricated in single step
Soonmo Choi[1], Deepti Singh[2], Sungsoo Han[1]
[1] *Yeungnam University (Korea),* [2] *Yale University School of Medicine (India)*

Most techniques entail several stages to create multi-layered and result in layers which have uneven thickness and morphology. The aim of this study is to develop a double layer scaffold for skin tissue engineering through single step process. We have fabricated gelatin bilayer scaffold with two kinds of layer using phase separation at certain temperature and concentration. The morphology of two layers (a dense layer and macroporous layer) was assessed by scanning electron microscopy (SEM) and micro-computed tomography.

P20: Interaction of Porous Silicon based 1D Photonic Crystals and Plasmonic Structures Fabricated by Nanosphere Lithography
Martin Franzl, Stefan Moras, Dietrich R. T. Zahn
Chemnitz University of Technology (Germany)

We investigated the interaction of one-dimensional porous silicon photonic crystals and plasmonic structures.

For this purpose we placed ordered metallic nanostructures on top of a one-dimensional photonic crystal structure. We adjusted the properties of both structures so that the plasmonic resonance is located in the photonic band gap. The work includes the fabrication, measurements as well as the simulation of these structures.

P21: Near-infrared thermal emission by metal-insulator-metal cavity structure
Manohar Chirumamilla[1], Alexander S. Roberts[2], Sergey I. Bozhevolnyi[2], Kjeld Pedersen[1]
[1] *Aalborg University (Denmark),* [2] *University of Southern Denmark (Denmark)*

A Metal-insulator-metal structure forming a Fabry-Perot cavity resonator is investigated for tailoring cavity resonances ranging from visible to near-infrared, and for generating thermal emission in the near-infrared.

P22: Plasmon-mediated control of entanglement between a pair of two level atoms
Andrei Nemilentsau[1], Seyyed Ali Hassani[1], George Hanson[1], Steve Hughes[2]
[1] *University of Wisconsin-Milwaukee (USA),* [2] *Queens University (Canada)*

Entanglement between two two-level atoms mediated by surface plasmons metallic nano- waveguides and graphene is studied theoretically. Dynamics of the emitters are described using a rigorous quantum master equation, where the plasmonic reservoir is accounted for through the classical electric field Green dyadic. We demonstrate that entanglement depends crucially on the geometry of metallic waveguides. Moreover, when the emitters are placed above graphene, entanglement can be controlled on-the-spot by biasing graphene with a static electric field.

P23: Compact and tunable MNM by figure of eight resonator and its application to microwave isolator
Shouta Komatsu, Toshiro Kodera
Meisei University (Japan)

Magnet-less non-reciprocal metamaterial (MNM) provides magnetic material free magnetic gyrotropy at microwave and higher frequency range, nevertheless its requirement of active unilateral components in each resonator particle is still a drawback compared to natural magnetic material. A new MNM structure by a varactor inserted figure of eight resonator is introduced, which enables reduction of active components by half and even smaller footprint to the original simple ring resonator structure in addition to frequency tunability keeping better performance.

P24: Visible-frequency hyperbolic metasurface
Robert C. Devlin[1], Alexander A. High[1], Alan Dibos[1], Mark Polking[1], Dominik S. Wild[1], Janos Perczel[2], Nathalie P. de Leon[1], Mikhail D. Lukin[1], Hongkun Park[1]
[1] *Harvard University (USA),* [2] *MIT (USA)*

We report the first experimental realization of a hyperbolic metasurface. The HMS exhibits broadband negative refraction and diffraction-free propagation of surface plasmon polaritons, while displaying 100x improvement over bulk hyperbolic metamaterials in terms of losses. Moreover, we observe a strong spin-orbit coupling where the direction of the propagating SPPs depends on both the helicity of light. Thus, the HMS enables polarization and wavelength-dependent routing of SPPs.

P25: Reconfigurable Antenna using Capacitive Tuning Metamaterial of Artificial Magnetic Conductor
R. Dewan, M. K. A. Rahim, M. R. Hamid, H. A. Majid, M. F. M. Yusoff, M. E. Jalil
Universiti Teknologi Malaysia (Malaysia)

A metamaterial of dual band Artificial Magnetic Conductor (AMC) with capacitive tuning of reflection phase at lower band frequency is proposed. The AMC operate at fixed upper band frequency at 5.8 GHz while the lower band reconfigurable frequency from 2.43 GHz up to 3.46 GHz.The reconfigurable frequencies are 2.43 GHz, 2.48 GHz, 2.67 GHz, 3.10 GHz and 3.46 GHz. The effects of AMC capacitive tuning to antenna performance is studied in terms of frequency reconfigurability, gain, and radiation patterns.

P26: Textile Artificial Magnetic Conductor Jacket for Transmission Enhancement between Antennas under Bending and Wetness Measurements
Kamilia Kamardin[1], Mohamad Kamal A. Rahim[1], Peter S. Hall[2], Noor A. Samsuri[1]
[1] *Universiti Teknologi Malaysia (Malaysia),* [2] *University of Birmingham (Malaysia)*

Textile Artificial Magnetic Conductor (AMC) sheet for transmission enhancement between antennas is proposed. Transmission characteristics between antennas with different orientations and placements are studied. Significant transmission enhancement is observed for all tested positions. Bending and wetness measure-

ments are also conducted. Bending does not give significant effect to the performance, while wetness yields severe performance distortion. However, the original performance is retrieved once the antennas and AMC dried.

P27: Whispering Gallery Modes Sensors Using Spherical Slot Channel Configurations
M. Alzahrani, R. Gauthier
Carleton University (Canada)

A theoretical study of whispering gallery mode of a slot channel running the equator of the sphere for sensing application is presented. The calculations are accomplished using numerical technique based on the spherical basis functions (BLF technique). The existence of intense electric field within the channel enhances the sensing of the external ambient medium.

P28: Modification of PV behavior using dissipative MTM
H. J. El-Khozondar, Dena Alamassi, Mohammed Shabat
Islamic University of Gaza (Palestine)

In this work, double layer photovoltaic cell (PV) is introduced in which the materials for the two layer are different. They are antireflection coating (ARC) layer covered by metamaterial (MTM) bounded by glass substrate and covered by air. The reflectance of the solar cell is studied. The effect of the MTM parameters on reflectance is studied. Results showed that the reflectance can be controlled by changing the reflectance index of MTM.

P29: Experimental demonstration of reduced light absorption by intracavity metallic layers in Tamm plasmon-based microcavity
M. A. Kaliteevski[1], A. A. Lazarenko[1], N. D. Il'inskaya[2], Yu. M. Zadiranov[2], M. E. Sasin[2], D. Zaitsev[2], V. A. Mazlin[1], A. R. Gubaydullin[1], P. N. Brunkov[2], S. I. Pavlov[2], A. Yu. Egorov[1]
[1] *St. Petersburg Academic University (Russia),* [2] *Russian Academy of Sciences (Russia)*

We demonstrate experimentally a microcavity based on SiO2/TiO2 with two gold layers directly attached to the central base of the microcavity. The design of optical modes based on the peculiarities of Tamm plasmons provides reduced absorption due to the fixing of the node of the electric field of optical mode to metallic layers. Experimentally measured reflection and transmission spectra exhibits three features, corresponding to three hybrid modes of the microcavity.

P30: Optical Broadband High Pass Transmission Property of Thin Film Hyperbolic Metamaterial
Ying Tang[1], Xu Man[2], Aurele Adam[1], Paul Urbach[1]
[1] *Delft University of Technology (Netherlands),* [2] *The Netherlands Organization for Applied Scientific Research (Netherlands)*

Here we report the modeling, fabrication and measurement of a type II Hyperbolic Metamaterial (HMM) consisting of 10 pairs Ag/Al2O3 subwavelength layers to demonstrate the high pass filter property of type II HMM. The HMM is deposited on the hypotenuse side of a TiO2 prism and covered with a fluorescent dye doped PMMA layer. The excitation of fluorescent dye is observed only with large incident angle throughout the optical frequency and infrared, which is in accordance with theoretical calculation.

P31: Control of the Optical Polarizability of Plasmonic Nanorod near Metallic Reflecting Surfaces
Xingxing Chen[1], Yuanqing Yang[1], Yu-Hui Chen[2], Min Qiu[1], Richard J. Blaikie[2], Boyang Ding[2]
[1] *Zhejiang University (China),* [2] *University of Otago (New Zealand)*

The polarized optical properties of short gold nanorods (length less than 100nm) nanoscopically coupled to a metallic surface has been examined using dark-field microscopy. Specifically, the polarizability of scattered light from nanorods shows significant spectral dependence and can be modified as the distance between nanorods and metallic surfaces varies. This is because the scattered light arises from the hybridized excitation of differently oriented surface plasmon resonances, whose contributions to global scattering are highly dependent on the nanorod-surface distance.

P32: Infrared Frequency Selective Surface with Silver Nanoparticles
Taehwan Kim[1], Jae Baek Han[2], Hwanseong Lee[1], Beom Seok Kim[1], Hyoung Hee Cho[1]
[1] *Yonsei University (Korea),* [2] *Republic of Korea Air Force (Korea)*

Micro and nano-structured FSS with silver nanoparticles works as double FSS in IR region. Because most of incident light is absorbed or scattered by nanowire forest and silver nanoparticles, silver particles embedded

nanowire cannot play the role as IR FSS by itself. With micro structured island pattern, silver nanoparticles embedded FSS can operate as a micro structured FSS and a plasmonic light confiner. The band stop FSS at infrared range is possible by these strategy without increase of reflectance.

P33: Fabrication of infrared resonating structures using microlens projection lithography method
Hwanseong Lee, Taehwan Kim, Taeil Kim, Geehong Choi, Hyung Hee Cho
Yonsei University (Korea)

The microlens projection lithography method could be effective to fabricating Infrared resonating structure, which have sub-one micron size patterns. To control the structure size, we fabricate microlens array using UV nanoimprint method and microlens mold master is fabricated using isotropic etching of silicon. With this method, a few hundreds of nanometer resolution element with microns pitched periodic array patterns are easily achieved.

P34: Topologically protected one-way edge mode in networks of acoustic resonators with circulating air flow
Xu Ni, Cheng He, Xiao-Chen Sun, Ming-Hui Lu, Yan-Feng Chen
Nanjing University (China)

We have realized topologically protected one-way acoustic edge states by utilizing a sonic crystal containing circulating air flow. The introduction of air flow breaks the time-reversal symmetry of the sonic crystal, and induces nontrivial topological properties of acoustic bands. The Chern numbers of the associated acoustic bands are verified to be nonzero by our tight-binding model, and the simulated field distributions demonstrate that the one-way edge states are robust to various kinds of defects on the boundaries.

P35: Characterization of the electrodynamic response of plasmonic nano-particles
Dimitrios Ch. Tzarouchis, Pasi Yla-Oijala, Ari Sihvola, Tapio Ala-Nissila
Aalto University (Finland)

Characterizing the electrodynamic response of arbitrary shaped, metallic nano-particles offers new important insights on the plasmonic design and engineering process. A robust and reliable numerical method towards that direction is the surface integral equation method (SIE). As a result, the response of several non-analytically solved metallic nano-particles is presented.

P36: Nanocrystal based meta-materials by direct nanoimprinting
Sung-Hoon Hong, In-Kyu You
Electronics and Telecommunications Research Institute (Korea)

In this study, we demonstrate the Ag nanocrystal based metamaterial using direct nanoimprinting. The Ag nanocrystal was coupled with short conducting ligand building block. The various nanocrystal based nanostructures of nano-pillar, nano-rods, nano-mesh structures were successfully fabricated.

P37: Doping effect of silver ions on the photoconductivity of novel vanadate pentoxide based bulk material
H. Algarni, I. M. Ashraf, H. H. Hegazy, E. Yousef
King Khalid University (Saudi Arabia)

The bulk glassy based on V2O5 oxide have been prepared by a melting technique. Herein the photoconductivity measurement of prepared material as a function of intensity of light and temperature and Raman of the glass was occurred. The photoconductivity value of prepared glasses largest than compared with other glasses systems reported in the literature. Increase and decay of photocurrent at different temperatures and intensities obtain that photocurrent increase monotonically to the steady state value.

P38: Double negative meta-composites built upon ferromagnetic microwires
Faxiang Qin[1], Hua-Xin Peng[1], Yang Luo[2], Mihail Ipatov[3], Arcady Zhukov[3]
[1] *Zhejiang University (China),* [2] *Bristol University (United Kingdom),* [3] *Universidad del Pais Vasco (Spain)*

Metacomposites have been fabricated by embedding Fe-based and hybrid Fe-based and Co-based microwires into aerospace-grade E-glass epoxy prepregs using a conventional lay-up technique for engineering composites manufacture. Double negative characteristics have been realized owing to the natural ferromagnetic resonance of Fe-based microwire and the plasmonic behaviour of the parallel wires. Field-tuneable DNG , dual-band DNG and DNG/band-stop features are successfully realized in the metacomposites containing both Co and Fe-based wires.

P39: Plasmon Enhanced Photocurrent in Observed in Nanostructure Based Heterojunction Solar Cell
Gen Long, Levine Ching, Huizhong Xu, Mostafa Sadoqi
St. John's University (USA)

In this poster, we report a first hand study of plasmon enhanced photocurrent observed in nanostructure based heterojunction solar cell. The heterojunction solar cell was fabricated using home-made narrow gap semiconductor, IV-VI group nanoparticles(PbS, PbSe), wide gap semiconductor ZnO nanowires, and gold nanoparticles, by spin-coating in ambient conditions (25C, 1atm). Different architectures of heterojunction were fabricated to study the effects on solar cell performance.

P40: Near-and Mid-Infrared Fluorescence Enhancement in Terbium-Yttrium Polytantalate
Jarrett Vella[1], John Goldsmith[1], Nicholaos Limberopolous[2], Validmir Vasilyev[2]
[1] *Air Force Research Laboratory/Wyle (USA),* [2] *Air Force Research Laboratory (USA)*

A unique study examining the fluorescence enhancement of Tb3+ doped yttrium polytantalate, Tb0.15Y0.85Ta7O19, in the 1000-5000 nm region will be described. After sputtering onto films of plasmonic gold nanoparticles, thickness dependent, infrared fluorescence enhancement factors were found to be 0.64-6-fold relative to the same thickness film without gold particles. The large Tb0.15Y0.85Ta7O19 film thickness dependence on the fluorescence enhancement factor will be described within the context of electromagnetic theory.

10:30 - 12:30 — Aronow Theater

Session 3A2

Symposium 1: Functional Metastructures and Nanomaterials: Properties, Fabrication and Modeling VII

Organized by: Alexander Govorov and Hilmi Volkan Demir

Chaired by: Stephen K. Gray and Jessica Rodriguez-Fernandez

10:30 : Invited talk
Second Harmonic Generation (SHG) chiroptical effects in plasmonic nanostructures
Ventsislav K. Valev
University of Bath (United Kingdom)

Strong SHG chiroptical effects result from the interaction of light with chiral plasmonic nanostructures. Due to the favorable power-law scaling of near-field enhancements, the nonlinear optical properties of chiral plasmonic nano- and metasurfaces are of prime fundamental and practical interest. Recently, these optical properties have attracted considerable interest. Numerous examples of SHG chiroptical interactions will be demonstrated and the relationship to superchiral light will be discussed.

10:50 : Invited talk
Chiral nanomaterials and their applications
Yurii K. Gun'ko[1], Finn-Purcell Milton[1], Joseph E. Govan[1], Valerie A. Gerard[1], Alexander Loudon[1], Olan Cleary[1], Maria Mukhina[2], Alexander Baranov[2], Anatoly Fedorov[2]
[1] *Trinity College Dublin (Ireland),* [2] *ITMO University (Russia)*

The main aim of our work is to develop new types of technologically important inorganic nanoparticulate materials possessing optical activity and chirality and explore their applications.Here we report development of new chiral nanomateriarials including chiral quantum dots and chiral nanoparticles of technologically important titanium and manganese oxides. We demonstrate potential applications of chiral quantum dots for chiral recognition and luminescent chemo- and bio- sensing, while titanium and manganese oxides exhibit promising catalytic properties in oxidation reactions.

11:10 : Invited talk
Biosensing with a Twist: Detection and Characterization of Biomaterials with Sculpted EM Fields
Nadia A. Abdulrahman, Christopher D. Syme, Calum Jack, A. S. Karimullah, Laurence D. Barron, N. Gadegaard, Malcolm Kadodwala

University of Glasgow (United Kingdom)

The application of new, high throughput, chiral plasmonic metamaterial for biophysical / biosensing application will be discussed. The use of these substrates for both linear and non-linear measurements will be illustrated.

11:30 : Invited talk
Chiral Nanoparticles and Their Self-Organization: Why, What, and How
Nicholas Kotov[1], B. Yeom[1], J. Yeom[1], W. Ma[2], C. Xu[2], A. Govorov[3], P. Kral[4], A. Rogach[5], S. Link[6]
[1] *University of Michigan (USA),* [2] *Jiangnan University (China),* [3] *Ohio University (USA),* [4] *University of Illinois in Chicago (USA),* [5] *City University of Hong Kong (Hong Kong),* [6] *Rice University (USA)*

In this presentation we shall address the latest development in chemistry and physics of chiral semiconductor and metallic nanostructures.

11:50 : Invited talk
Detecting, Visualizing, and Measuring the Chirality of Chiral Ligand-Capped Gold Nanoparticles using Nematic Liquid Crystal Phases
Anshul Sharma[1], Taizo Mori[2], Bergquist Leah[1], Huey-Charn Lee[3], Matthew Worden[1], Eric Bidwell[1], Torsten Hegmann[1]
[1] *Kent State University (USA),* [2] *Japan Society for the Promotion of Science (Japan),* [3] *University of Manitoba (Canada)*

We used the induction of bulk chiral nematic liquid crystal phases to image, measure, and compare the chirality and chirality transfer ability of chiral ligand-capped gold nanoparticles. Characteristic defect textures and helical pitch measurements in the induced chiral nematic phase reveal clear tends with respect to nanoparticle size and synthesis method.

12:10 : Invited talk
Chiroptically active intrinsically chiral and achiral inorganic nanostructures
Gil Markovich, Assaf Ben Moshe
Tel Aviv University (Israel)

Optical activity in inorganic nanostructures can be more intense than in chiral molecules. We show that it is possible to perform an enantioselective synthesis of inorganic nanostructures made of intrinsically chiral crystals, such as alpha-HgS, Te and Se. These nanocrystals, belonging to the P3121 chiral space group, were grown in the presence of thiolated chiral molecules, such as cysteine or glutathione. This led to the growth of the nanocrystals with a particular handedness and consequent strong optical activity.

10:30 - 12:30 — NAC 0/201

Session 3A3

PT-symmetry in photonics, metamaterials and plasmonic systems I

Organized by: Anatole Lupu and Henri Benisty

Chaired by: Anatole Lupu and Henri Benisty

10:30 : Keynote talk
PT symmetry and the taming of instabilities
Carl M. Bender
Washington University (USA)

Physically unacceptable theories that suffer from instabilities may be reinterpreted as PT-symmetric theories in the complex plane. The advantage of doing so is that in the complex plane these theories become stable and thus physically realistic.

11:00 : Invited talk
Bloch Oscillations in Lattices with local PT-symmetry
Nicholas Bender, Huanan Li, Tsampikos Kottos

Wesleyan University (USA)

We investigate a new type of Bloch Oscillations which are supported in lattices with local PT-symmetry. Interestingly enough we find that these lattices can be interpreted as the Floquet lattices describing periodically driven PT-symmetric dimers.

11:20 : Parity-Time symmetric Plasmonic Materials and Metamaterials
H. Alaeian, J. A. Dionne
Stanford University (USA)

Parity-Time (PT) symmetric photonic structures are constructed with balanced amounts of gain and loss positioned in a geometrically symmetric layout. Here, we describe PT plasmonic materials and devices constructed from deeply subwavelength components. We investigate planar and coaxial plasmonic PT waveguides and metamaterials, exploring optical mode coalescence, unidirectional scattering, dipolar spontaneous emission control and optical enantiomer selection. Our results may enable new nanoscale PT materials and metamaterials that exhibit optical asymmetry and, with incorporation of nonlinearities, unidirectionality.

11:35 : Invited talk
Interaction of soliton with an exceptional point in a PT-symmetric coupler with a coupling defect
Yuliy Bludov[1], Chao Hang[2], Guoxiang Huang[2], Vladimir Konotop[3]
[1] *Universidade do Minho (Portugal),* [2] *East China Normal University (China),* [3] *Universidade de Lisboa (Portugal)*

We study interaction of a soliton in a parity-time symmetric coupler which has local perturbation of the coupling constant. Such a defect does not change the PT-symmetry of the system, but locally can achieve the exceptional point. We found several scenarios of the symmetric and antisymmetric soliton-defect interactions (transformation into breather, broadening, splitting, blowup). All the effects are preserved when the coupling strength in the center of the defect deviates from the exceptional point.

11:55 : Evolution of energy conservative states in a non-uniform system of coupled waveguides with local parity-time symmetry
Anatole Lupu[1], Vladimir V. Konotop[2], Henri Benisty[1]
[1] *Paris Sud University (France),* [2] *Universidade de Lisboa (Portugal)*

We address the problematic of energy conservative states in PT-symmetric system of coupled waveguides. It is demonstrated that energy conservative states satisfying requirements for a switching operation can be also obtained in PT-symmetric couplers with non-uniform coupling or gain-loss profiles. We also provide evidence for energy conservative states corresponding to polarization rotation. This opens new prospects for functional applications of PT-symmetric devices in photonics.

12:10 : Invited talk
Parity-Time Anti-Symmetric Parametric Amplifier
Diana Antonosyan, Alexander Solntsev, Andrey Sukhorukov
Australian National University (Australia)

We predict that directional coupler of quadratically nonlinear and lossy waveguides can perform ultrafast signal switching and parametric amplification, using the pump-controlled breaking of the parity-time anti-symmetry associated with nonlinear wave mixing.

10:30 - 12:30 — NAC Ballroom

Session 3A4

Interactions between structured light and matter at the nano-scale I

Organized by: Luat Vuong and Gabriel Molina-Terriza

Chaired by: Luat Vuong and Gabriel Molina-Terriza

10:30 : Invited talk

Structured surface plasmon polaritons with metasurfaces

Federico Capasso
Harvard University (USA)

Metasurfaces have become a powerful tool to shape surface plasmon polaritons (SPPs) beams. I will present new experiments on imaging SPP that have revealed the formation of Cherenkov SPP wakes and demonstrated polarization sensitive light couplers that control the directionality of SPP and lenses which demultiplex focused SPP beams depending on their wavelength and polarization.

10:50 : Invited talk

Infinite anisotropy: An approach to manipulating deep sub-wavelength optical beams

Peter B. Catrysse, Shanhui Fan
Stanford University (USA)

Media with extreme electromagnetic parameters have created significant fundamental and applied interest recently. I discuss our work on infinite anisotropy. I point out opportunities for controlling light at the nano-scale with infinitely anisotropic metamaterials. I show diffraction-free propagation of deep-subwavelength beams. I demonstrate interfaces that are impedance-matched for deep-subwavelength beams and enable reflection-free routing with zero bend radius without diffraction. These behaviors indicate an unprecedented possibility to manipulate deep-subwavelength beams and images using infinite anisotropy.

11:10 : Invited talk

In-situ visualization of intercalation-driven nanoparticle phase transitions using plasmon-EELS

Jennifer A. Dionne
Stanford University (USA)

We observe and measure atomic dipole forces for nanodiamonds (NDs) containing many NV centres, in a liquid environment. While holding the NDs (150 nm in size) at the focus of classical optical tweezers in liquid, we employ a second laser beam slightly detuned from the dipole transition of the target colour centres and measure dispersive variations in the trap stiffness, due to the resonant forces, of 10 percent.

11:30 : Invited talk

Tuning the optical response using ultranarrow flat plasmonic gaps.

Ruben Esteban, Javier Aizpurua
Donostia International Physics center DIPC (Spain)

We study theoretically the rich optical response of gap plasmonic antennas supporting both cavity and longitudinal antenna modes. We show how small changes in the exact configuration of the gap can allow to tune the near and far field almost independently, as well as to track subtle morphological changes. We also discuss quantum effects due to tunneling, and the possibility to tune the plasmonic modes of flat-gap chains over a very large spectral range.

11:50 : Invited talk

Interaction of Light with Structured Graphene and other Atomic-Scale Materials

Javier Garcia de Abajo
ICFO (Spain)

The emergence of graphene plasmonics has triggered the search for resonant optical phenomena in other materials that are structured down to the atomic scale, and in particular, alternative 2D crsystals, noble-metal monolayers, and polycyclic aromatic hydrocarbons, which can be regarded as molecular versions of graphene. We will review recent progress made in the achievement of strong optical tunability in the vis-NIR using plasmons of atomic-scale materials, as well as their potential application for quantum optics, light manipulation, and sensing.

12:10 : Invited talk

Structured light and chiral plasmons

Yuri Gorodetski[1], Aurelien Drezet[2], Konstantin Bliokh[3], Benedikt Stein[4], Nir Shitrit[5], Vladimir Kleiner[5], Erez Hasman[5], Cyriaque Genet[4], Thomas Ebbesen[4]
[1] *Ariel University (Israel),* [2] *Joseph Fourier University (France),* [3] *RIKEN (Japan),* [4] *Strasbourg University (France),* [5] *Technion (Israel)*

We examine, both experimentally and theoretically, an interaction of chiral light with helical nanostructures, milled on both sides of a suspended golden membrane. We analyze the plasmonic near-field distribution and

demonstrate the beaming of singular optical mode to the far-field. We show how the interaction of the chiral light with a simple slit may induce unexpected near-field symmetry breaking of plasmonic field and regard it as a plasmonic weak measurement.

10:30 - 12:30 — NAC 1/202

Session 3A5

Metamaterials based on novel symmetries I

Organized by: Jensen Li and Minghui Lu

Chaired by: Jensen Li and Minghui Lu

10:30 : Invited talk
Tunable Light-matter Interaction With Quantum Spillover and 2D materials
Dafei Jin, Anshuman Kumar, Qing Hu, Yingyi Yang, Eunnie Lee, Nicholas Fang
MIT (USA)

Recently, exciting new physics of plasmonics has inspired a series of key explorations to manipulate, store and control the flow of information and energy at unprecedented dimensions. In this talk I will report our recent efforts on controlling light absorption and emission process through quantum effects in sub-20nm scale coatings.

10:50 : Invited talk
Observation of non-Hermitian degeneracies in quantum exciton-polariton billiards
Tingge Gao[1], Eliezer Estrecho[1], Michael Fraser[2], Sebastian Brodbeck[3], Martin Kamp[3], Christian Schneider[3], Sven Hofling[3], Yuri Kivshar[1], Andrew Truscott[1], Konstantin Bliokh[2], Robert Dall[1], Elena Ostrovskaya[1]
[1] *The Australian National University (Australia),* [2] *Center for Emergent Matter Science, RIKEN (Japan),* [3] *Universitat Wurzburg (Germany)*

We demonstrate that exciton-polariton quantum billiards, optically induced in semiconductor microcavities, represent a new experimental platform for studies of non-Hermitian physics with matter waves. By engineering a Sinai billiard for Bose-condensed microcavity polaritons, we show that the open-dissipative nature of the system enables experimental observation of non-Hermitian degeneracies in this macroscopic quantum system.

11:10 : Invited talk
Observation of nonreciprocal surface wave and space wave in the chain of gyromagnetic rods
Ruixin Wu, Zhen Li, Qing-Bo Li, Yin Poo
Nanjing University (China)

Nonreciprocal surface wave and space wave are observed in one-dimensional magnetic photonic crystal made of a chain of gyromagnetic rods. These nonreciprocal waves are associated with the time reversal symmetry breaking of the gyromagnetic rods, but exhibit different behaviors. The underline mechanisms of the nonreciprocal waves are discussed. Base on the nonreciprocal wave phenomenon, some example devices which can guide the surface wave or space wave unidirectional transmission are given.

11:30 : Invited talk
Nonlinear optics in zero-index materials
Haim Suchowski[1], Kevin O'Brien[2], Zi-Jing Wong[2], Alessandro Salandrino[2], Xiaobo Yin[2], Xiang Zhang[2]
[1] *Tel Aviv University (Israel),* [2] *University of California (USA)*

Phase-matching is critical for coherent nonlinear optical processes, allowing nonlinear sources to combine constructively, resulting in efficient emission. We experimentally demonstrate phase mismatch-free nonlinear propagation in a bulk zero index metamaterial that allow symmetric nonlinear emission to both forward and backward directions. We also discuss transverse phase matching, utilizing the in-plane zero index modes of metamaterials, which will allow coherent broadside emission.

11:50 : Invited talk
Single Negative Metamaterials take on Negative Indices owing to Multiple Scattering: Demonstration with an Acoustic Super-lens
Nadege Kaina, Fabrice Lemoult, Mathias Fink, Geoffroy Lerosey
ESPCI ParisTech (France)

We evidence that single negative metamaterials can turn into double negative ones, hence leading to a negative band solely by breaking the symmetry. We explain this phenomenon from multiple scattering effects and give an analogy with the phonon optical branch. We experimentally demonstrate a negative index acoustic super-lens using a soda can hexagonal array with a focal spot 15 times smaller than the wavelength.

12:10 : Invited talk
Amplification and absorption in topological photonic systems
Henning Schomerus
Lancaster University (United Kingdom)

Topological photonic systems generate robust modes whose properties are well controlled. A difference to the original electronic context, from which these concepts are borrowed, are photon creation and annihilation processes, which induce a new class of exploitable symmetries but also serve as an extra source of noise.

10:30 - 12:30 — ASRC Conference Room

Session 3A6

Chiral and Nonlinear Metamaterials: Properties, Fabrication, and Applications III

Organized by: Ventsislav K. Valev and Nicolae C. Panoiu

Chaired by: Ventsislav K. Valev and Nicolae C. Panoiu

10:30 : Invited talk
Chiral Nanostructures with Plasmon and Exciton Resonances
Alexander Govorov
Ohio University (USA)

Bio-assembled and lithographic nanostructures incorporating metal and semiconductor nanocrystals exhibit strong optical absorption associated with exciton and plasmon resonances. When a system includes chiral molecules, the Coulomb and electromagnetic interactions between excitons and plasmons are able to alter and enhance circular dichroism (CD) of chiral molecular dipoles. Strong CD signals can also appear in purely plasmonic systems with a chiral geometry and a strong particle-particle interaction.

10:50 : Invited talk
Topologically nontrivial photonics of bianisotropic metamaterials
Alexander Khanikaev
Queens College of the City University of New York (USA)

Topologically nontrivial photonic states have been first shown to exist in photonic systems with broken time-reversal symmetry, such as magnetic photonic crystals. Here we demonstrate that topological order for light can also be found in crystals made of Tellegen medium, a special class of bianisotropic response violating time-reversal symmetry. Theoretical simulations of Tellegen crystals reveal existence of topologically robust edge transport insensitive to structural imperfections and defects.

11:10 : Invited talk
Metasurfaces with continuously engineered phase of nonlinearity
Guixin Li[1], Shumei Chen[1], Nitipat Pholchai[2], Polis W. H. Wong[3], Edwin Y. B. Pun[3], KokWai Cheah[4], Thomas Zentgraf[2], Shuang Zhang[1]
[1] University of Birmingham (United Kingdom), [2] University of Paderborn (Germany), [3] City University of Hong Kong (Hong Kong), [4] Hong Kong Baptist University (Hong Kong)

Based on the concept of spin rotation coupling, we propose and realize a novel nonlinear metasurface with

homogeneous linear optical properties but continuously controllable phase of the local effective nonlinear polarizability. The continuous phase engineering of the effective nonlinear polarizability enables complete control of the propagation of harmonic generation signals, and therefore, it seamlessly combines the generation and manipulation of the harmonic waves for highly compact nonlinear nanophotonic devices.

11:30 : Invited talk
Nonlinear Metasurface with Magnetic Response
D. N. Neshev
The Australian National University (Australia)

The nonlinear properties of optical metasurfaces can be dramatically enhanced in the vicinity of their magnetic resonances. Here we present our recent studies on enhancement of the nonlinear frequency conversion of plasmonic and all-dielectric metasurfaces with magnetic resonant properties. We characterize the nonlinearity enhancement and the origin of the nonlinear frequency conversion.

11:50 : Invited talk
Nonlinearities in 2D and 2D-3D Heteromaterials
Richard Osgood, Xiang Meng, Hsu-Cheng Huang, Jerry Dadap, Nick Bierket, Sung-Young Hong
Columbia University (USA)

This invited talk discusses the use of optical nonlinearities in a variety of 2D materials, including harmonic frequency generation, nano optical sources, and guided-wave devices.

12:10 : Invited talk
Three-Dimensional Nanohelices for Chiral Photonics
Vittorianna Tasco[1], Marco Esposito[1], Francesco Todisco[1], Alessio Benedetti[2], Massimo Cuscuna[1], Daniele Sanvitto[1], Adriana Passaseo[1]
[1] *National Nanotechnology Laboratory (Italy),* [2] *Universita di Roma La Sapienza (Italy)*

We discuss the tailoring of linear chiroptical effects in three-dimensional plasmonic nanohelices by means of challenging technological nanoscaling approaches, allowing the operation of this metamaterial in the optical frequency range. The growth dynamics involved in focused ion and electron beam induced deposition have been extensively studied and targeted to the realization of complex 3D structures where intrinsic chirality and spatial anisotropy can be controlled at the nanoscale level, towards miniaturized chiral photonics for application in optoelectronics and biological detection.

10:30 - 12:35 — NAC 1/203

Session 3A7

Thermoplasmonic and near-field heat transfer between metamaterials II

Organized by: Philippe Ben-Abdallah and Svend-Age Biehs

Chaired by: Philippe Ben-Abdallah and Svend-Age Biehs

10:30 : Invited talk
Understanding and reducing electromagnetic heat transfer
Carsten Henkel
University of Potsdam (Germany)

We discuss strategies to reduce electromagnetic heat transfer in the context of traps for ultra-cold atoms based on nanostructures. The basic processes of fluctuation-induced friction forces and path decoherence are discussed with the help of a microscopic model using the toolbox of quantum field theory.

10:50 : Invited talk
Giant Radiative Heat Flux at the Nanometer Scale Measured with our Calibrated Near Field Scanning Thermal Microscope
Achim Kittel, K. Kloppstech, N. Konne, Svend-Age Biehs, L. Worbes, D. Hellman

Physics Institute University of Oldenburg (Germany)

We perform quantitative measurements of the heat flux between a gold near-field scanning thermal microscope tip and a planar gold sample at nanometer distances across a vacuum gap. We find an extraordinary large heat flux which is more than five orders of magnitude larger than black-body radiation and three orders of magnitude larger than the values predicted by conventional. The findings demand modified, or even new models to describe the heat transfer across a vacuum gap at nanometer distances.

11:10 : Invited talk
Near-field thermal radiation of thin metamaterials
Xianglei Liu, Zhuomin Zhang
Georgia Institute of Technology (USA)

Based on exact approaches, we demonstrated that patterning thin films into 1D and 2D nanostructures can improve its near-field heat transfer performance by more than one order of magnitude. The underlying mechanism lies in the excitation of hyperbolic modes supporting high LDOS for broad frequency and k-space regimes.

11:30 : Invited talk
Fluctuating volume–current formulation of electromagnetic fluctuations in inhomogeneous media
Athanasios G. Polimeridis[1], M. T. H. Reid[2], Weiliang Jin[3], Steven G. Johnson[2], Jacob K. White[2], Alejandro W. Rodriguez[3]
[1]*Skolkovo Institute of Science and Technology (Russia),* [2]*Massachusetts Institute of Technology (USA),* [3]*Princeton University (USA)*

We present a framework for the general-purpose calculation of many different incandescence and luminescence processes, including fluorescence, thermal radiation and heat transfer, that is based on the volume-integral equation formulation of electromagnetic scattering and that expands the range and validity of current methods to situations involving inhomogeneous media. We demonstrate the flexibility and utility of these techniques via new predictions of highly directional thermal emission from inhomogeneous objects subject to temperature gradients.

11:50 : Radiative heat transfer in 2D Dirac materials
Diego Dalvit[1], Pablo Rodriguez-Lopez[2], Wang-Kong Tse[1]
[1]*Los Alamos National Laboratory (USA),* [2]*Paris Sud University (France)*

We compute the radiative heat transfer between two sheets of 2D Dirac materials, including topological Chern insulators and graphene, within the local optics approximation. We derive both numerically and analytically the short-distance asymptotics of the near-field heat transfer in these systems, and show that it scales as the inverse of the distance between the two sheets. We discuss the limitations to the validity of this scaling law imposed by spatial dispersion in 2D Dirac materials.

12:05 : Hyperbolic blackbody
Slawa Lang[1], Alexander Petrov[1], Manfred Eich[1], Philippe Ben-Abdallah[2], Svend-Age Biehs[3]
[1]*Hamburg University of Technology (Germany),* [2]*Paris Sud University (France),* [3]*Institut fur Physik-Carl von Ossietzky Universitat (Germany)*

We adapt the blackbody theory to analyze the thermal radiative properties of lossless, nonmagnetic uniaxial media. In case of hyperbolic media, the spectral energy density and spectral heat flux show fundamentally different behavior compared to the classical blackbody. The thermal energy is shifted to lower frequencies making hyperbolic media appear colder. Besides, both energy density and heat flux in hyperbolic media can be much larger than in vacuum or in a dielectric medium.

12:20 : Photo-thermal effect within plasmonic absorption metamaterials in infrared region
Yongqian Li, Chenglin Zhang, Xiaolun Xu
Northwestern Polytechnical University (China)

The energy-conversion process and photo-thermal effect within plasmonic absorber metamaterials (PAM) were investigated theoretically using Poynting theorem. Ohmic loss and dielectric loss were calculated to estimate the amount of heat energy produced. From the microscopic details, heat-generation owing to the electric current accounts for the majority of the energy conversion, while the magnetic resonance plays a negligible role. The field confinement and redistribution within PAMs guides the design for subsequent thermal-detection.

10:30 - 12:40 — NAC 1/211

Session 3A8

Optically engineered emission: from the weak to the strong coupling regime I

Organized by: Stéphane Kena-Cohen

Chaired by: Stéphane Kena-Cohen

10:30 : Invited talk
Quantum manipulation of polariton fluids with structured light
Alberto Bramati
UPMC (France)

Polaritons behave as a quantum fluid and can exhibit superfluidity. In this regime, we observed the formation of a lattice of vortex-antivortex pairs due to colliding flows of polaritons and the appearance of same-sign quantized vortex chain in an ensemble of polaritons with an orbital angular momentum (OAM), injected by a Laguerre-Gauss beam. The formation of a vortex chain is a consequence of the quantization of the total angular momentum transferred to the superfluid.

10:50 : Information processing with topologically protected vortex memories in exciton-polariton condensates
H. Sigurdsson[1], O. E. Egorov[2], X. Ma[2], I. A. Shelykh[1], T. C. H. Liew[1]
[1] *Nanyang Technological University (Singapore),* [2] *Friedrich Schiller Universitat Jena (Germany)*

We show theoretically that in a non-equilibrium system of an exciton-polariton condensate, where polaritons are generated from incoherent pumping, a ring-shaped pump allows for stationary vortex memory elements of singular topological charge. Using simple potential guides we can choose whether to copy the same charge or invert it onto another spatially separate ring pump. Such manipulation of binary information opens the possibility of a new type of processing using vortices as topologically protected memory components.

11:05 : Invited talk
Polaritons from micro to nano scale
Giovanni Lerario[1], Francesco Todisco[1], Dario Ballarini[1], Milena De Giorgi[1], Marco Esposito[1], Luisa De Marco[2], Alessandro Cannavale[2], Federica Mangione[1], Salvatore Gambino[1], Massimo Cuscuna[1], Giuseppe Gigli[1], Daniele Sanvitto[1]
[1] *Istituto Nanoscienze (Italy),* [2] *Istituto Italiano di Tecnologia (Italy)*

Strong coupling between light and matter is at the forefront of research both for the observation of new phenomenologies and the development of technologies based on interacting fluid of light. Here we show organic polaritons in different optical systems. First we see Bloch surface wave mode dressed with excitons showing ultrafast propagation of hundreds of microns at half the speed of light. Then we shift to polaritons in plasmonic systems demonstrating ultra strong coupled excitons with nanometer-scale plasmonic disks.

11:25 : Scattering and amplification of directed polariton beams mediated by interactions with background carriers
Johannes Schmutzler[1], Dominik Niemietz[1], Przemyslaw Lewandowski[2], Marc Abmann[1], Stefan Schumacher[2], Karol Winkler[3], Martin Kamp[3], Christian Schneider[3], Sven Hofling[3], Manfred Bayer[1]
[1] *Technische Universitat Dortmund (Germany),* [2] *University of Paderborn (Germany),* [3] *Universitat Wurzburg (Germany)*

In analogy to particle collision experiments in high energy physics, a scattering experiment of a condensed polariton beam is presented. Here, the trajectories of the scattered quasi-particles can be immediately observed allowing for the determination of interaction parameters between polaritons and background carriers. Besides guiding of polariton beams, background carriers are also considered as a gain medium. Using an attractive potential environment provided by polariton traps, a significant amplification of polariton beams is achieved without beam distortion.

11:40 : Invited talk
Transport and harvesting of excitons mediated by strong coupling

Johannes Feist, Carlos Gonzalez-Ballestero, Esteban Moreno, Francisco Garcia-Vidal
Universidad Autonoma de Madrid (Spain)

Exciton conductance in organic materials can be enhanced by several orders of magnitude under strong coupling to an electromagnetic mode. Using a 1D model system, we show how the formation of a collective polaritonic mode allows excitons to bypass the disordered molecule array and jump directly from one end of the structure to the other. We furthermore demonstrate that by tailoring the electromagnetic mode, excitons can be harvested from a specific spot and funneled to another one.

12:00 : Invited talk
Strong coupling of plasmons to dye molecules: Tailoring dispersion and emission
Thejaswi Tumkur, Guohua Zhu, Mikhail Noginov
Norfolk State University (USA)

We report on the strong coupling of surface plasmon polaritons to dye molecules in reflection, excitation, and emission experiments and demonstrated modification of the corresponding dispersion curves. We have also observed a nontrivial dispersion curve from angle-resolved spontaneous measurements, presumably resulting from a strong coupling of SPPs and spontaneously emitting dye molecules. Finally, we demonstrate the strong coupling of localized plasmons of silver islands (deposited on the top of glass, or hyperbolic metamaterials) and R6G dye molecules.

12:20 : Invited talk
Large Purcell Enhancement Using Plasmonic Nanopatch Antennas
Gleb Akselrod[1], Christos Argyropoulos[2], Thang Hoang[1], Cristian Ciraci[3], Chao Fang[1], Jiani Huang[1], David Smith[1], Maiken Mikkelsen[1]
[1] *Duke University (USA),* [2] *University of Nebraska-Lincoln (USA),* [3] *Istituto Italiano di Tecnologia (Italy)*

We demonstrate a plasmonic nanoantenna based on a film-coupled nanocube with a sub-10 nm gap embedded with emitters. Fluorescence lifetime measurements on ensembles of emitters shows Purcell factors exceeding 1000 while maintaining high quantum efficiency (>0.5) and directional emission. Using angle-resolved fluorescence measurements, we first determine the orientations of emission dipoles in the nanoscale gap. Incorporating this information along with the three-dimensional spatial distribution of dipoles into full-wave simulations predicts the time-resolved emission dynamics, in excellent agreement with experiments.

10:30 - 11:50 — NAC 1/201

Session 3A9

Transformation Electromagnetics concepts and applications

Organized by: André de Lustrac and Shah Nawaz Burokur

Chaired by: André de Lustrac and Shah Nawaz Burokur

10:30 : Invited talk
Engineering of electromagnetic emissions through Transformation Electromagnetics
S. N. Burokur, Paul-Henri Tichit, Jianjia Yi, Andre de Lustrac
Paris Sud University (France)

Transformation Electromagnetics (TE) is an innovative concept that allows realizing electromagnetic devices in a novel way. It offers an unprecedented control of the routes of electromagnetic waves by properly designing artificial metamaterials for desired material parameters. We present the design of transformation media based devices able to tailor electromagnetic emissions in a unique way. The performances are validated numerically and experimentally.

10:50 : Invited talk
Transformation optics with spatially dispersive media
Jie Luo[1], Yuting Yang[1], Zhihong Hang[1], C. T. Chan[2], Yun Lai[1]
[1] *Soochow University (China),* [2] *Hong Kong University of Science and Technology (Hong Kong)*

By designing pure dielectric photonic crystals with a shifted elliptical dispersion, we achieved ultra-transparent spatially dispersive media with the ability of forming ideal virtual images without aberrations. The ultra-transparency effect is experimentally demonstrated in microwave frequency regime. We further provide transformation optics examples based on such media. Our work provides a theory for realization of ultra-transparency with spatially dispersive media, opening new possibilities in optical designs such as wide-angle super-polarizer and transformation optics devices.

11:10 : Invited talk
Surface Wave Manipulation Design
Luigi La Spada, Yang Hao
Queen Mary University of London (United Kingdom)

In this paper a new design for surface waves manipulation is presented. A rotationally symmetric graded index media above a ground plane is used. First of all an analytical approach is developed to design the proposed structure. Then, the device is manufactured and measured in the range 8-10 GHz. The proposed approach is a useful tool for telecommunications and radar applications, paving the way for the design of conformal surface wave-based antenna devices in a broad frequency range.

11:30 : Invited talk
Anti-Reflective Coatings for Gradient Index Lenses
Kenneth L. Morgan, Donovan H. Brocker, Xiande Wang, Douglas H. Werner, Pingjuan L. Werner
The Pennsylvania State University (USA)

Anti-reflective coating designs for conventional lens systems are well-documented. However, the recent development of transformation optics has piqued interest in designing gradient index, particularly flattened, lenses. Previous works have not yet considered the application of anti-reflective coatings to such systems. Here, we present several anti-reflective coating designs developed for gradient index systems. Conventional design techniques are leveraged in conjunction with transformation optics to produce coatings that reduce reflections of a flat gradient-index lens.

11:50 - 12:20 — NAC 1/201

Session 3A10

Advances in Hybrid Plasmonics IV

Organized by: Mohamed Swillam

Chaired by: Mohamed Swillam

11:50 : Hybrid plasmonic electro-optical modulator
Aya Zaki[1], Khalid Kirah[2], M. Swillam[1]
[1] *American University (Egypt),* [2] *Ain Shams University (Egypt)*

Integration of electronic and photonic circuitries entails the design of on-chip ultra-compact electro-optical modulators. Here we introduce the design of a high performance electro-optical modulator structure based on an asymmetric hybrid plasmonic waveguide (AHPW) on a silicon-on-insulator (SOI) platform. The insertion loss and extinction ratio have been numerically verified by finite-difference time-domain simulations. The insertion loss is minimized for a 5 um modulator.

12:05 : Ultra-broadband plasmonic super absorbers for universal surface enhanced Raman spectroscopy substrate
Nan Zhang, Kai Liu, Haomin Song, Xie Zeng, Dengxin Ji, Qiaoqiang Gan
The State University of New York at Buffalo (USA)

We developed an ultra-broadband super-absorbing metasurface substrate for SERS sensing. In contrast to conventional substrates working for limited excitation wavelengths, this structure can work for almost all available laser lines from 450 nm to 1000 nm.

Lunch and Exhibit Inspection

12:30 - 14:00

14:00 - 16:15 — Aronow Theater

Session 3A11

Symposium 1: Functional Metastructures and Nanomaterials: Properties, Fabrication and Modeling VIII

Organized by: Alexander Govorov and Hilmi Volkan Demir

Chaired by: Malcolm Kadodwala and Yurii K. Gun'ko

14:00 : Keynote talk
Single Photons and Atoms at Meta Surfaces
Girish S. Agarwal
Oklahoma State University (USA)

We report several radiative effects involving exchange of single photons at meta surfaces. Quantum interferences at such surfaces can induce intra atomic interaction. We discuss the possibility of strong entanglement between artificial atoms on meta surfaces as well as two photon Hong-Ou-Mandel interference.

14:30 : Invited talk
Optically-Induced Entanglement in Hybrid Quantum Dot/Plasmonic Systems
Matthew Otten[1], Raman A. Shah[2], Norbert F. Scherer[2], Misun Min[3], Matthew Pelton[4], Stephen K. Gray[5]
[1] Cornell University (USA), [2] The University of Chicago (USA), [3] Mathematics and Computer Science Division-Argonne National Laboratory (USA), [4] University of Maryland (USA), [5] Argonne National Laboratory (USA)

Quantum dynamics calculations are carried out on model Hamiltonians corresponding two and three quantum dot systems interacting with a dissipative, plasmonic system that is subjected to ultrafast laser pulses. We show how the pulses can be used to create significant entanglement among the dots from an initially cold system.

14:50 : Plasmonic Optical Interferences in Self-Assembled Multiscale Metamaterials
Virginie Ponsinet, Johann Toudert, Xuan Wang, Clemence Tallet, Ashod Aradian, Philippe Barois
University of Bordeaux (France)

We investigate the phase changes of visible light upon interaction with self-assembled polymer-gold nanocomposites, with a spectral response reflecting the interplay between plasmonic and optical interference effects. Thanks to a detailed study of the films by spectroscopic ellipsometry, which gives access to amplitude and phase information, their plasmonic and interferential spectral features are correlated with their nanostructure. We explore the potential of coupling plasmonic and photonic modes for multiscale metamaterial-based phase-sensitive environmental detection at the nanoscale.

15:05 : Invited talk
Theoretical and computational analysis of quantum plasmons in graphene nanostructures
Nicolae C. Panoiu, Wei Wu
University College London (United Kingdom)

We present some recent results regarding physical properties of optical spectra of single and coupled graphene nano-flakes, determined using the time-dependent density functional theory. The time evolution of the charge density has been calculated as well and used to identify the nature of the observed spectral resonances. For small graphene nano-flakes edge plasmons are dominant, whereas for larger ones the edge plasmons are accompanied by multipolar collective charge oscillations that can be identified as core plasmons.

15:25 : UHF Metamaterial Enhanced Vivaldi antenna

Ada-Simona Popescu[1], **Igor Bendoym**[2], **Taulant Rexhepi**[1], **Andrii B. Golovin**[1], **David T. Crouse**[1]
[1] *City College of New York (USA),* [2] *Phoebus Optoelectronics (USA)*

In this work, a UHF Vivaldi antenna is designed and uses metamaterials to improve its performance. The metamaterial in the antenna improves the directivity and gain enhancement and belong to the larger class of anisotropic zero index metamaterials. A technique for lowering dimensions of the metamaterial unit cell is presented and applied. An antenna with the integrated metamaterials is designed. Simulation results for antenna and metamaterials are presented.

15:40 : Weak measurement of optical spin Hall effect in phase-discontinuity metasurface
Yeon Ui Lee, Jeong Weon Wu
Ewha Womans University (Korea)

Recently it has been demonstrated that a rapid phase-change at a phase-discontinuity metasurface (PDM) leads to an additional momentum gradient enabling a direct observation of optical spin Hall (OSH) shift. We show that that the helicity-dependent OSH shift depends on incidence and refraction angles at PDM, and construct a weak value measurement to control OSH shift by a variable phase retardance in the post-selection.

15:55 : Invited talk
Integrated nanowire plasmonics
K. Goodfellow[1], **C. Chakraborty**[1], **R. Beams**[1], **L. Novotny**[2], **A. N. Vamivakas**[1]
[1] *University of Rochester (USA),* [2] *ETH-Photonics Laboratory (Switzerland)*

Atomically thin materials, such as graphene and transition metal dichalcogenides, offer an interesting platform to tailor nanoscale light-matter interaction. The ease with which these materials can be incorporated into optoelectronic devices has given rise to the emerging area of nano-optoelectronics. In this talk I will discuss some recent results on merging plasmonics and atomically thin materials as well as the possibility of exploiting atomically thin semiconductors for integrated quantum photonics applications.

14:00 - 15:10 — NAC 0/201

Session 3A12

Chiral and Nonlinear Metamaterials: Properties, Fabrication, and Applications IV

Organized by: Ventsislav K. Valev and Nicolae C. Panoiu

Chaired by: Ventsislav K. Valev and Nicolae C. Panoiu

14:00 : Invited talk
Linear and nonlinear optical effects in hybrid self-assembled layers of nanoparticles
Thierry Verbiest, Ward Brullot
University of Leuven (Belgium)

We show that hybrid nano materials composed of several different types of nano particles show exciting new linear and nonlinear optical effects. Furthermore, we will address the role of chiral inclusions in these layers on the optical properties.

14:20 : Invited talk
Free-standing terahertz metamaterial fabricated via injection molding
Jinqi Wang, Shuchang Liu, Sivaraman Guruswamy, Ajay Nahata
The University of Utah (USA)

We demonstrate a technique of fabricating free-standing all-metal two-dimensional (2D) and three-dimensional (3D) terahertz metamaterials through injection molding of gallium, a metal that melts at temperatures slightly above room temperature. To obtain free-standing metamaterials, two polydimethylsiloxance (PDMS) molds are created using conventional soft lithography and then peeled away after gallium is injected and solidified. We demonstrate three different approaches for creating 3D metamaterials: a multilayer stack, a manually folded structure and a directly injection molded 3D structure.

14:40 : Wafer-scale fabrication of plasmonic chiral metamaterials with tunable chiro-optical response.
Greshma Nair, Haobijam Singh, Ambarish Ghosh
Indian Institute of Science (India)

Chiral metamaterials have been promising candidates for applications such as broadband polarizers, negative refractive index. One of the ways to achieve large Circular Dichroism (CD) response is by arranging metallic nanoparticles in chiral geometries.We report wafer-scale fabrication of plasmonic chiral nanostructures, which exhibited large chiro-optical response in the visible. Also, we have demonstrated the tunability of the CD response, by changing the distance between the nanoparticles on a helix and by varying the refractive index of the dielectric template.

14:55 : A Far-Field Interpretation of Optical Chirality in Analogy to Poynting's Theorem
L. V. Poulikakos[1], P. Gutsche[2], K. M. McPeak[1], S. Burger[2], J. Niegemann[1], Ch. Hafner[1], D. J. Norris[1]
[1] *ETH Zurich (Switzerland),* [2] *Zuse-Institut (Germany)*

The optical chirality density is a valuable tool in locally characterizing chiral electromagnetic near-fields. However, how this quantity could translate into the far-field is not well understood. Here, we formulate a far-field interpretation of optical chirality by investigating its conservation law in isotropic media in analogy to Poynting's Theorem. We define the global chirality and find that lossy materials, in particular plasmonic nanostructures, can act as chirality generators. This can enable chiral sensing applications at the single molecule level.

15:10 - 16:25 — NAC 0/201

Session 3A13

Metamaterials and negative index materials IV

Chaired by: Mikhail Belkin

15:10 : Keynote talk
How to deal with the loss in Plasmonics and Metamaterials
Jacob B. Khurgin
Johns Hopkins University (USA)

Recent years have seen staggering growth of interest in using nanostructured metals in optical range with the goal of enhancing linear and nonlinear optical properties or even engineering novel optical properties unknown in Nature - usually this burgeoning field is referred to as Plasmonics and Metamaterials. After the initial years of excitement the community is slowly beginning to recognize that loss in the metal is an important factor that might impede practical application of plasmonic devices, be it in signal processing, sensing, imaging or more esoteric applications like cloaking.

15:40 : Apex angle-dependent resonances in triangular split-ring resonators
Max Burnett, Michael Fiddy
University of North Carolina at Charlotte (USA)

Along with other frequency selective structures (circles and squares), triangular split-ring resonators (TSRRs) only allow frequencies near the center resonant frequency to propagate. Further, TSRRs are attractive due to their small surface area, comparatively, and large quality (Q) factors. Beyond frequency selection, TSRRs are capable of left-handedness and negative permittivities. Here we examine the effects of varying the apex angle on the resonant frequency and the Q factor within the GHz frequency regime.

15:55 : Co-Designed Meso-Photonic Broadband Solar Absorber
Abul Azad[1], Milan Sykora[1], Nina Weisse-Bernstein[1], Ting Luk[2], Diego Dalvit[1], Hou-Tong Chen[1], Antoinette Taylor[1]
[1] *Los Alamos National Laboratory (USA),* [2] *Sandia National Laboratory (USA)*

We demonstrate an ultra-thin, ultra-wideband meso-photonic material capable of absorbing over entire solar spectrum. The co-designed approach enables selective absorption of solar radiation for any desired spectral window.

16:10 : Ellipsometry characterization of semiconductor hyperbolic metamaterials
T. S. Luk, T. Tiwald, S. Campione, J. F. Klem, T. Beechem, A. Benz, M. B. Sinclair
Sandia National Laboratories (USA)

We report on an ellipsometry characterization method for semiconductor hyperbolic metamaterials not as a single effective medium layer but as a multilayer of alternating doped and undoped layers. Our results show that the doped layers should be modeled as uniaxial materials to accurately recover measured ellipsometry data. This anisotropic effective medium theory provides a more reliable out-of-plane dielectric function than the single effective medium method. This multilayer method enables accurate characterization of semiconductor hyperbolic metamaterials for light-matter interaction research.

14:00 - 15:40 — NAC Ballroom

Session 3A14

Interactions between structured light and matter at the nano-scale II

Organized by: Luat Vuong and Gabriel Molina-Terriza

Chaired by: Luat Vuong and Gabriel Molina-Terriza

14:00 : Invited talk
Shaping the topology of light with metallic nanostructures
H. Magallanes[1], D. Hakobyan[1], G. Gervinskas[2], G. Seniutinas[2], S. Juodkazis[2], E. Brasselet[1]
[1] *University of Bordeaux (France),* [2] *Swinburne University of Technology (Australia)*

Structured metallic nanolayers allow spin-controlled shaping of the topological features of light. We present several options relying on geometrical properties of the metallic design. Experimental demonstration is made in the visible domain using ion-beam milled gold films with typical thickness of the order of 100nm.

14:20 : Invited talk
Control of nanostructures by exploiting the symmteries of the light-matter interaction
Gabriel Molina-Terriza, Xavier Zambrana-Puyalto, Ivan Fernandez-Corbaton, Nora Tischler, Mathieu L. Juan, Xavier Vidal
Macquarie University (Australia)

We have developed techniques to control the scattering and probe the properties of nanostructures with light. We show how the angular momentum and the helicity of light fields can be used to retrieve information from nano and micro particles which is typically hidden to the usual optical characterization techniques. In particular, we show applications to position sensing, enhancement of the optical activity of molecular samples and design of metamaterials for transformation optics.

14:40 : Invited talk
Nanoplasmonics for control over localized emission and heat generation
Stefan Maier
Imperial College London (United Kingdom)

Metallic nanostructures allow for the generation of spatially structured optical near-fields and near-field gradients, and have been heavily employed in surface-enhanced sensing and spectroscopies. Here we will present two new studies, namely control over quantum dot emission in extended hot spots of ring nanocavities, and the controlled heating of a solid state nanopore for molecular translocation studies.

15:00 : Invited talk
Spin-polarization Properties of Optical Metasurfaces: Control of Light Transmission and Emission
D. N. Neshev
The Australian National University (Australia)

The symmetry of the meta-atoms and their arrangement of optical metasurfaces can dramatically influence their response to spin polarized light. In particular we review our recent studies on control of circular dichroism by metasurfaces of different rotational symmetries as well as the control of spin of photons from emitters

coupled to the meta-atoms.

15:20 : Invited talk
Chiral interaction of light and matter in confined geometries
Arno Rauschenbeutel
Vienna University of Technology (Austria)

Light with strong intensity gradients at the wavelength scale exhibits a significant polarization component along its direction of propagation. The interaction of quantum emitters with such light fields leads to new and surprising effects. Making use of these findings, we experimentally demonstrate first examples of a new class of nonreciprocal nanophotonic devices which exploit the chiral interaction between quantum emitters and transversally confined photons.

15:40 - 16:25 — AC Ballroom

Session 3A15

Modeling and Computational Techniques I

Chaired by: Thomas Koschny

15:40 : Temporal photonic crystals and a genuine k-gap
Jose Roberto Reyes-Ayona, Peter Halevi
Instituto Nacional de Astrofisica, Optica y Electronica (Mexico)

We consider a temporal photonic crystal (TPC) with periodically modulated permittivity. We prove that for long wavelengths a TPC is accurately mimicked by a dynamic transmission line (TL). Employing a dynamic TL in the microwave region, we measured the photonic band structure, which results to display a genuine wave vector- or k-gap, in very good agreement with our theoretical model. This seems to be the first such experimental observation.

15:55 : Geometrical tradeoffs in designing deep subwavelength graphene based metamaterials
Sara Arezoomandan, Berardi Sensale Rodriguez
The University of Utah (USA)

Graphene based metamaterials have been the subject of much recent attention for multiple terahertz (THz) applications. Here we report on the geometrical tradeoffs when designing the unit-cells in metamaterials for THz beam shaping applications.

16:10 : Triggered single-photon emitters based on stimulated parametric scattering in weakly nonlinear systems
Timothy Liew[1], Oleksandr Kyriienko[2]
[1] *Nanyang Technological University (Singapore),* [2] *University of Copenhagen (Denmark)*

We introduce a scheme of single-photon emission based on four-wave mixing in a three mode system with weak Kerr-type nonlinearity. A highly populated lower energy mode results in strong stimulated scattering of particle pairs out of the central mode, which consequently limits the central mode occupation. Using the master equation approach we show strong antibunching. Under pulsed excitation we demonstrate theoretically a triggered single-photon emitter in a weakly nonlinear system with 33 percent emission probability.

14:00 - 16:15 — NAC 1/202

Session 3A16

Metamaterials based on novel symmetries II

Organized by: Jensen Li and Minghui Lu

Chaired by: Jensen Li and Minghui Lu

14:00 : Invited talk
Exotic spectral singularities in parity-time symmetric cavities
Xiang Zhang, Hamidreza Ramezani
University of California (USA)

We show that the presence of parity-time symmetry, a hallmark of structures with a delicate balance of gain and loss mechanisms, leads to novel lasing schemes with exotic and controllable features. Specifically, in a microring laser, existence of rotational parity-time symmetry leads to intrinsic single-mode lasing regardless of the gain spectral bandwidth. Moreover, an interplay between the Fano resonances and parity-time symmetry in coupled ring cavities with balanced amplification and absorption results in lasing modes with unidirectional emission.

14:20 : Invited talk
Experimental demonstration of Mie-resonance-based transition metamaterials
Natalia Litchinitser[1], Jingbo Sun[1], Zhaxylyk Kudyshev[1], Xiaoming Liu[2], Ji Zhou[2]
[1] *The State University of New York (USA),* [2] *Tsinghua University (China)*

Inhomogeneous metamaterials with materials parameters gradually changing from positive to negative values - so-called transition metamaterials - are of significant interest from both fundamental science and applications viewpoints. This interest is motivated by anomalous field behavior in the vicinity of the transition point, where refractive index, dielectric permittivity and/or magnetic permeability is equal to zero. We report the first experimental demonstration of the predicted field enhancement effect in all-dielectric metamaterials made of high-refractive index dielectric blocks.

14:40 : Invited talk
Loss-induced topological transition of dispersion from a closed elliptic curve to an open hyperbolic curve
Kun Yu, Haitao Jiang, Hong Chen
Tongji University (China)

Topological transitions of dispersion from a closed elliptic curve to an open hyperbolic curve have been realized in dispersive metamaterials by changing the frequency. In this work, we use intrinsic loss in low-permeability medium to induce the topological transition of dispersion at a fixed frequency. By gradually increasing the loss, we study the evolution process of the topological transition.

15:00 : Invited talk
Experimental realization of Bloch oscillations in a Parity-Time synthetic silicon photonic lattice
Xiaoping Liu[1], Yelong Xu[1], William Fegadolli[2], Lin Gan[3], Minghui Lu[1], Liang Feng[4], Axel Scherer[2], Zhiyuan Li[3], Yanfeng Chen[1]
[1] *Nanjing University (China),* [2] *California Institute of Technology (USA),* [3] *Chinese Academy of Sciences (China),* [4] *The State University of New York at Buffalo (USA)*

As a phenomenon originally discovered for electrons subjected into a periodic potential, Bloch oscillations (BO) have been studied in many other Hermitian physical systems for quantum particles exhibiting wave nature. Here by exploiting the emerging concept of parity-time synthetic photonic system, we experimentally realize for the first time Bloch oscillation in a non-Hermitian silicon photonic lattice consisting of periodic dissipative elements and show that such system gives rise to abundant physics.

15:20 : Invited talk
Spin-Orbit Coupling in Polariton Graphene: Optical Spin Hall Effect and Z Topological Insulator
Dmitry Solnyshkov, Anton Nalitov, Hugo Terças, Guillaume Malpuech
University Blaise Pascal (France)

We show that the TE-TM splitting of planar cavities leads to a special type of spin-orbit coupling for polariton

graphene, a honeycomb superstructure formed by pillar microcavities, transforming into an emergent field with Dresselhaus symmetry at the Dirac points of the Brillouin zone. This transformation can be evidenced by the Optical Spin Hall effect. Under an applied magnetic field, polariton graphene behaves as a Z topological insulator with chiral surface states, which can be evidenced by direct resonant excitation.

15:40 : Invited talk
On-Chip Optical Isolator and Circulator Using Active Microcavities without Magneto-Optical (Faraday) Effect
Xiaoshun Jiang[1], Jianming Wen[2], Liang Jiang[2], Min Xiao[3]
[1] *Nanjing University (China),* [2] *Yale University (USA),* [3] *Nanjing University (USA)*

Traditional approach on realizing optical isolators and circulators rely mainly on the magneto-optical effect to break time-reversal symmetry. Yet, this approach has difficulty with conventional complementary metal-oxide-semiconductor (CMOS) technology. By exploring gain-saturation induced nonlinearity in active high-Q microtoroid resonators, we here report two of our recent experiments towards the realizations of on-chip optical isolation and circulation. Not only compatible with the existing CMOS technique, our devices also show unprecedented performances even for signal power down to few nanowatts.

16:00 : Fabrication and ferromagnetic resonance of cobalt chiral meta-molecule arrays
Toshiyuki Kodama, Satoshi Tomita, Nobuyoshi Hosoito, Hisao Yanagi
Nara Institute of Science and Technology (Japan)

We fabricated arrays of micrometer-sized, three-dimensional chiral meta-molecule (CMM) of cobalt (Co) by using a strain-driven self-coiling technique. In the arrays, the Co CMMs were fixed on a silicon substrate and aligned in the same direction. We investigated the ferromagnetic resonance of the arrays with varying angles of external dc magnetic field. The Co CMM arrays show a resonance signal at a much lower field than the Kittel mode.

14:00 - 15:55 — Hoffman Atrium

Session 3A17

PT-symmetry in photonics, metamaterials and plasmonic systems II

Organized by: Anatole Lupu and Henri Benisty

Chaired by: Anatole Lupu and Henri Benisty

14:00 : Invited talk
Parity-Time Symmetry Breaking beyond One Dimension: the Role of Degeneracy
Li Ge[1], A. Stone[2]
[1] *The Graduate Center City University of New York (USA),* [2] *Yale University (USA)*

We consider the role of degeneracy in Parity-Time (PT) and Rotation-Time symmetry breaking for non-hermitian wave equations beyond one dimension. We show that the non-hermicity of the system eigenmodes can either onset abruptly as in typical PT-symmetric systems or be a linear function of the gain/loss parameter. These results are illustrated by using different T-breaking perturbations of a uniform dielectric disk and sphere, and a group theoretical analysis is given in the disk case.

14:20 : Invited talk
Surprises in systems with oscillating gain and loss: infinite ladder of PT transitions and the PT Rabi problem
Yogesh N. Joglekar
Indiana University Purdue University Indianapolis (USA)

I will discuss a PT system in the presence of oscillatory gain and loss. I will show that the PT symmetry breaking occurs at arbitrarily small gain if the frequency of its modulation is at resonance with the coupling. I will also show that in the neighborhood of the static PT-transition point, PT symmetry is repeatedly broken and restored in the low frequency regime, this result is a significant departure from the standard adiabatic

theorem or Berry-phase considerations.

14:40 : Invited talk
Spatially nonreciprocal Bragg gratings based on surface plasmons
Elham Keshmarzi[1], Niall Tait[1], Pierre Berini[2]
[1] *Carleton University (Canada),* [2] *University of Ottawa (Canada)*

The concept of spatial non-reciprocity in surface plasmon based Bragg gratings is introduced. It is shown that balanced modulation of index and gain/loss with quarter pitch spatial shift cause a nearly perfect unidirectional coupling between contra-propagating modes in a long range surface plasmon polariton Bragg grating. Such a Bragg grating operates at the breaking threshold of parity-time symmetry.

15:00 : Invited talk
Optical properties of PT-symmetric periodic stacks of the layers
Oksana V. Shramkova, Giorgos P. Tsironis
University of Crete (Greece)

The scattering properties of PT-symmetric periodic stack of binary dielectric layers characterised by balances loss and gain are explored. It is shown that resonant phenomena are connected with surface mode excitation at internal boundaries of the stack. The effects of structure parameters and direction of incidence on resonant phenomena and spontaneous symmetry breaking transition are determined. It is shown that structure periodicity significantly increase the number of resonant phenomena, especially in stacks with high dielectric permittivity of layers.

15:20 : Matched Quarter Stacks with Balanced Loss/Gain
Josue Ramirez-Hernandez, Felix Izrailev, Nykolay Makarov
Benemerita Universidad Autonoma de Puebla (Mexico)

With the transfer matrix approach, we study the spectral and transport properties for an array of PT-symmetric bilayers. The number of spectral bands turns out finite and depends on the loss/gain parameter. The transmittance T exhibits the Fabry-Perrot resonances with T=1, however, between them T can be either larger or less than unity. We have found a new kind of specific frequencies inside every spectral band, which separate the regions with T>1 from those with T.

15:35 : Invited talk
Parity-Time Symmetric Optics in Compound Microtoroid Cavities
Jianming Wen[1], Liang Jiang[1], Xiaoshun Jiang[2], Yanhong Xiao[3], Min Xiao[4]
[1] *Yale University (USA),* [2] *Nanjing University (China),* [3] *Fudan University (China),* [4] *University of Arkansas (USA)*

Parity-time (PT) symmetric optics has recently attracted great attention, partly due to the theoretical discovery that non-Hermitian Hamiltonians may possess entirely real spectra by satisfying PT symmetry. Another major driving force comes from the facts that synthesized PT-symmetric materials allow observing novel optical phenomena which would be difficult in conventional media. Here, we report our recent experimental realizations of on-chip PT-symmetric optics using two directly active-passive-coupled microtoroid cavities at the telecom band.

14:00 - 14:45 — NAC 1/203

Session 3A18

Thermoplasmonic and near-field heat transfer between metamaterials III

Organized by: Philippe Ben-Abdallah and Svend-Age Biehs

Chaired by: Philippe Ben-Abdallah and Svend-Age Biehs

14:00 : Optical Resonator Modulated Super-Plankian Monochromatic Thermal Radiation in Near-field
Baoan Liu, Sheng Shen
Carnegie Mellon University (USA)

We propose a general methodology to achieve the super-Planckian monochromatic thermal radiation by designing the emitter-absorber optical resonator. The monochromatism can thus be controlled by the resonance mode, rather than the material intrinsic properties. A general theory based on the quasinormal modes of the resonator is derived to qualitatively guide the design of the emitter-absorber resonator.

14:15 : Metamaterial-enhanced Near-field Thermophotovoltaic Conversion by Excitation of Magnetic Polariton
Yue Yang, Hao Wang, Liping Wang
Arizona State University (USA)

We study a near-field thermophotovoltaic system made of an InGaSb cell and a tungsten grating metamaterial emitter, in which magnetic polariton is excited to spectrally enhance near-field radiative transfer. Fluctuational electrodynamics incorporated with scattering matrix method and rigorous coupled-wave analysis is used to exactly calculate the spectral heat flux. The preliminary results show improved conversion efficiency and almost doubled total electrical power output over that with plain tungsten emitters at a vacuum gap distance of 100 nm.

14:30 : Thermoplasmonic optimization of nanostructured metals
Adrien Lalisse[1], G. Tessier[1], G. Baffou[2], J. Plain[3]
[1] *University Paris Descartes (France),* [2] *Institut Fresnel (France),* [3] *University of Technology of Troyes (France)*

We investigate new materials for plasmonic metal nanostructures, to serve both as near-field enhancers and heat nanosources. Numerical simulations highlight the influence of morphology and composition on the nanoparticles absorption and temperature.

14:45 - 16:00 — NAC 1/203

Session 3A19

Large-scale metamaterial assemblies I

Organized by: Jake Fontana

Chaired by: Jake Fontana

14:45 : Large-scale full-wave simulation of metamaterials through boundary element methods
Diego Martinez Solis[1], Jose Manuel Taboada Varela[2], Fernando Obelleiro Basteiro[1], Luis Manuel Liz Marzan[3], Francisco Javier Garcia de Abajo[4]
[1] *University of Vigo (Spain),* [2] *University of Extremadura (Spain),* [3] *Bionanoplasmonics Laboratory-CIC bioma-GUNE (Spain),* [4] *ICFO-The Institute of Photonic Sciences (Spain)*

Electromagnetic simulation tools play an important role in the fields of nanoplasmonics and metamaterials, where breakthroughs are frequently slowed down by the limited power of these tools when addressing real-life problems. We herein show that boundary element variational methods, along with the hierarchical spectral compression of the multilevel fast multipole algorithm (MLFMA), can effectively model the interaction of light with large nanoplasmonic metamaterial assemblies, raising the standard of full-wave simulations in the field of nanoplasmonics to an unprecedented level.

15:00 : Invited talk
Large Area Printed Three-Dimensional Optical Metamaterials
Debashis Chanda
University of Central Florida (USA)

We developed two complementary printing techniques based on nanotransfer printing and imprinting that are directly applicable to fabrication of 3D metamaterials with excellent optical characteristics, in ways that are scalable to arbitrarily large areas and compatible with manufacturing.

15:20 : Invited talk
Programmable Nanoparticle Assembly

Oleg Gang
Brookhaven National Laboratory (USA)

The structural plasticity and interaction encoding provided by DNA offer enormous opportunities for directing the nano-objects into precisely structured architectures. Such architectures might coordinate nanoparticles of multiple types in the designed manner, and they might be transformed on demand. Toward these goals, we have developed a range of methods for assembly of well-defined nanoparticle clusters and arrays using the DNA-assembly platform, explored how the structures can be manipulated, and applied these approaches for the fabrication of optically active systems.

15:40 : Invited talk
Building Metamaterials Using Scalable Self-Assembly Techniques
Andrea Tao
University of California (USA)

I will present our recent work on the synthesis and self-assembly of nanocrystals for plasmonic metamaterials. We show the organization of polymer-grafted metal nanocrystals into nanojunction arrays that possess intense hot spots due to electromagnetic field localization. We also demonstrate doped semiconductor nanocrystals as a new class of plasmonic building blocks, where shape and carrier density can be actively tuned to engineer plasmon resonances. We are utilizing these self-assembled metamaterials in applications such as near-field spectroscopy, biosensing, and optoelectronics.

14:00 - 16:05 — NAC 1/211

Session 3A20

Optically engineered emission: from the weak to the strong coupling regime II

Organized by: Stéphane Kena-Cohen

Chaired by: Stéphane Kena-Cohen

14:00 : Invited talk
Plasmonic, dielectric, and hyperbolic platforms for surface-enhanced spectroscopies
Stefan Maier
Imperial College London (United Kingdom)

Plasmonic nanostructures serve as the main backbone of surface enhanced sensing methodologies, yet the associated optical losses lead to localized heating as well as quenching of molecules, complicating their use for enhancement of fluorescent emission. Additionally, conventional plasmonic materials are limited to operation in the visible part of the spectrum. We will elucidate how nanostructures consisting of conventional and polar dielectrics can be employed as a highly promising alternative platform.

14:20 : Invited talk
Super-Coulombic Energy Transfer: Engineering Dipole-Dipole Interactions with Metamaterials
Ward Newman, Cristian Cortes, David Purschke, Amir Afshar, Zhijiang Chen, Glenda De Los Reyes, Frank Hegmann, Ken Cadien, Robert Fedosejevs, Zubin Jacob
University of Alberta (Canada)

We demonstrate experimentally that hyperbolic metamaterials fundamentally alter dipole-dipole interactions conventionally limited to the near-field. The effect is captured in long-range energy transfer and lifetime reduction of donor emitters due to acceptors placed 100 nm away.

14:40 : Invited talk
Quantum nanophotonics
Jelena Vuckovic
Ginzton Laboratory (USA)

By embedding a single quantum emitter inside a nanoresonator that strongly localizes optical field, it is possible to achieve a very strong light -matter interaction. The strength of this interaction is characterized by the

coherent emitter-field coupling strength (g), which increases with reduction in the optical mode volume and which also sets the limit on the operational speed of such a system.

15:00 : Invited talk
Nanophotonic design for bright single-photon sources based on single quantum dots
Marcelo Davanco[1], Jin Liu[1], Luca Sapienza[2], Antonio Badolato[3], Kartik Srinivasan[1]
[1] *Center for Nanoscale Science and Technology National (USA),* [2] *University of Southampton (United Kingdom),* [3] *University of Rochester (USA)*

We describe the design and performance of bright single-photon sources based on individual epitaxially grown InAs quantum dots embedded in GaAs-based nanophotonic geometries. Two geometries will be discussed which can be produced via standard III-V fabrication processes, provide a moderate enhancement of spontaneous emission rate and allow spectrally broad and efficient single-photon extraction and coupling into different types of collection optics.

15:20 : Tailoring the Purcell effect with magnetic fields in graphene
W. J. M. Kort-Kamp[1], Bruno Amorim[2], G. Bastos[1], F. A. Pinheiro[1], F. S. S. Rosa[1], N. M. R. Peres[3], C. Farina[1]
[1] *Universidade Federal do Rio de Janeiro (Brazil),* [2] *Instituto de Ciencia de Materiales de Madrid (Spain),* [3] *University of Minho (Portugal)*

We investigate analytically the spontaneous emission (SE) of a two-level quantum emitter near a graphene-coated substrate under the influence of a magnetic field B. We demonstrate that in the near-field regime the application of B can induce in the decay rate a variation as large as 99 percent if compared to the case where B = 0. We show that the magnetic field allows us to manipulate the different decay channels of the system.

15:35 : Chiral Purcell effect in negative-index metamaterials
SeokJae Yoo, Q-Han Park
Korea University (Korea)

We present a theory of the chiral Purcell effect, describing the polarization dependent spontaneous decay rate of chiral molecules coupled to optical resonators. The chiral Purcell factor is introduced as a figure of merit for the cavity-modified differential decay rate of left and right circularly polarized modes. We also demonstrate the double fishnet structure, a class of negative-index metamaterials, possesses the high chiral Purcell factor and thus it paves the way towards a chiroptical spectroscopy in ultra-small molecular quantity.

15:50 : Transient spectroscopic study of upconversion energy transfer processes coupled with Plasmonic field
Dawei Lu, Chenchen Mao, Sungmo Ahn, Suehyun Cho, Wounjhang Park
University of Colorado at Boulder (USA)

Large enhancement of upconverted luminescence by plasmonic field has been widely reported but most studies considered steady state only. Here we report the theoretical and experimental study on the transient behavior of plasmon enhanced upconverted luminescence. We observed 23-fold faster rise of upconverted luminescence with the presence of plasmonic field. The dependence of rise time on plasmonic field is theoretically predicted and verified by experiments.

14:00 - 16:30 — NAC 1/201

Session 3A21

Plasmonics and nanophotonics V

Chaired by: Alexander Kildishev and Laurens Kuipers

14:00 : SHG in Non-Centrosymmetric Nanostructured Metamaterials
W. Luis Mochan[1], Bernardo S. Mendoza[2], Guillermo Ortiz[3]
[1] *Universidad Nacional Autonoma de Mexico (Mexico),* [2] *Centro de Investigaciones en Optica (Mexico),* [3] *Universidad Nacional del Nordeste (Argentina)*

The surface of the nanoparticles in a composite metamaterial may be a source of strong SH radiation, but only if their geometry is itself non- centrosymmetric. We present an efficient scheme for its calculation.

14:15 : Plasmonic Couplers in Refractory Metals as Heat Generators for High Temperature Applications
Sara Nunez Sanchez, Hugo Andrade, C. Harwood, Ian Bickerton, Neil Fox, Martin Cryan
University of Bristol (United Kingdom)

Plasmonic gratings have been fabricated using laser scribing in a refractory metal (molybdenum) for high temperature applications. The molybdenum micro-structures have been designed to generate heat from plasmon excitation in the mid-infrared (10.6um). Real time temperature measurements have been done achieving an increase of temperature of more than 150 percent when compared to flat molybdenum. The heat generation from light absorption will be analyzed in detail as a function of the plasmon excitation efficiency and temperature.

14:30 : Strong Light-Matter Interactions in Dielectric-Metallic Hybrid Nanostructures
Huanjun Chen, Zhang-Kai Zhou, Hao Wang
Sun Yat-sen University (China)

By coating the Au nanospheres with dielectric shells, Fano resonances can be induced without symmetry breaking. Dimer structures composed of Au and silicon nanospheres can exhibit interesting unidirectional light scattering behaviors in the visible range. On the other hand, exotic avalanche multiphoton emission properties can be observed from the hybrid dielectric and plasmonic nanostructures based on anodic aluminum oxide (AAO). Such hybrid structures can further be used for tailoring the light emission spectra of the quantum dots.

14:45 : Tuning and Enhancement of the Magneto-Dielectric Behavior of Semiconductor Nanoparticles
Braulio Garcia-Camara, J. F. Algorri, V. Urruchi, J. M. Sanchez-Pena, R. Vergaz
Carlos III University of Madrid (Spain)

Magneto-dielectric response of semiconductor nanoparticles has been recently shown as a useful phenomenon for several applications, e.g. sensors. The enhancement and spectral tuning of this behavior is a keynote aspect for some of these approaches. In this work, we show that the Mie resonances of nanoparticles composed of AlxGa1-xAs can be enhanced and tuning in a fine way by controlling the relation between the particle size and the concentration of Al atoms (x).

15:00 : Control of near-field focused photoemission by plasmonic nanohole arrays in gold thin films
Yu Gong, Alan G. Joly, Patrick Z. El-Khoury, Wayne P. Hess
Pacific Northwest National Laboratory (USA)

Plasmonic nanohole arrays are unique constructs. Under laser excitation, the incident electric fields can be strongly amplified and spatially guided when resonantly coupled to array plasmon modes. Nanohole arrays can be exploited to manipulate highly localized electric fields on the nanoscale, which has applications in development of plasmonic-assisted photovoltaic devices, optical devices and integrated nano-circuits.

15:15 : Active mid-IR plasmonic metadevices
Xinghui Yin[1], Andreas Tittl[1], Martin Schaferling[1], Ann-Katrin Michel[2], Matthias Wuttig[2], Frank Neubrech[1], Thomas Taubner[2], Harald Giessen[1]
[1] *University of Stuttgart (Germany),* [2] *RWTH Aachen University (Germany)*

We present experimental realizations of two active mid-IR plasmonic metadevices that are based on the integration of the phase change material Ge3Sb2Te6: a wavelength tunable, plasmonic perfect absorber with multispectral thermal imaging capability and a wavelength-tunable and handedness-switchable chiral metamaterial.

15:30 : Fano Coil-type Resonances: a Plasmonic Route Towards Magnetic Field Enhancement
Simone Panaro, Adnan Nazir, Remo Proietti Zaccaria, Carlo Liberale, Francesco De Angelis, Andrea Toma
Istituto Italiano di Tecnologia (Italy)

The possibility to develop nano-architectures with appreciable magnetic response at optical frequencies has been matter of intense study in the last few years. Here we introduce matrices of nanodisk trimers as a viable platform for the generation of extremely intense and localized magnetic hot-spots. Exploiting the Fano resonance condition, the optical magnetic fields can be squeezed in strongly sub-wavelength regions, opening

promising scenarios for spin-wave engineering.

15:45 : SPASER as a complex system: femtosecond dynamics traced by ab-initio simulations
Juan S. Totero Gongora[1], Andrey E. Miroshnichenko[2], Yuri S. Kivshar[2], Andrea Fratalocchi[1]
[1]King Abdullah University of Science and Technology (Saudi Arabia), [2]Australian National University (Australia)

We study the temporal and spatial dynamics of the spaser emission by means of ab-initio simulations at the femtosecond scale. We reveal that the spaser's dynamics demonstrates different operating regimes which range from multipolar pulsed emission to coherent emission with rotational dynamics. These complex dynamics are explained by exploiting a novel quantum-mechanical approach which describes the spaser emission in terms of a dynamically-disordered magnetic system.

16:00 : Engineering the band gap and the indirect-direct gap transition in type I nanostructure superlattice for near infrared detection
Driss Barkissy, Abdelhakim Nafidi, Abderrazak Boutramine, Hicham Charifi, Abdellatif Elanique, Ali Khalal
LCMP Nano Re-University Ibn Zohr (Morocco)

We report here electronic bands of GaAs(d1)/AlAs(d2) superlattice near infrared detector performed in the envelope function formalism as a function of the thickness d1, d1/d2, the temperature T and the offset. The transition indirect to direct band gap, of (GaAs)m/(AlAs)4, takes place at m=5. When the offset increases, Eg increases to a maximum and decreases. For each d1, Eg increases with d2/d1. When T and d1 increases, the direct Eg (m=9) of the GaAs(2.52nm)/AlAs(1.16nm) decreases in agreement with literature.

16:15 : Remote Control of Perfect Absorption in Plasmonic Metamaterial with Entangled Photons
C. Altuzarra[1], S. Vezzoli[1], J. Valente[2], W. Gao[1], C. Soci[1], D. Faccio[3], C. Couteau[1], N. Zheludev[1]
[1]Nanyang Technological University (Singapore), [2]University of Southampton (UK), [3]Heriot-Watt University (UK)

We provide the first experimental demonstration of coherent perfect absorption that can be controlled nonlocally. Recently, we demonstrated coherent absorption of single photons in a deeply subwavelength plasmonic absorber. We showed that while the absorption of photons from a travelling wave is probabilistic, standing wave absorption can be observed deterministically, with nearly unitary probability of coupling a photon into the plasmonic resonant mode of the metamaterial.

Coffee Break and Exhibit Inspection

Session 3P2

Poster session VI

16:00 - 16:40

P1: Broadband asymmetric transmission in ultrathin chiral metamaterial
J. H. Shi, Z. P. Li, Y. X. Li
Harbin Engineering University (China)

We theoretically and experimentally demonstrate broadband artificial chirality in an ultrathin metamaterial constructed by an array of asymmetrically split ring apertures (ASRA). The anisotropic bilayered metamaterial with chirality exhibits a broadband asymmetric transmission of linearly polarized waves with totally suppressed co-polarization transmission.

P2: Photoconductivity and Structure of Cu(In,Ga)Se2 for Thin Film Solar Sell Application
Hosameldin Helmy Hegazy, Ashraf Ibrahim Abou Alhasan, Fatimah Said Al Juman
King Khalid University (Egypt)

Samples of polycrystalline Cu(In0.65, Ga0.35)Se2 bulk as well as thin films have been prepared. The crystal structure of prepared material identified as chalcopyrite structure using x-ray diffraction. Surface analysis was performed using scanning electron microscope and atomic force microscope. The optical energy gap is determined and has the value of 1.35 eV. The steady state and transient photoconductivity measurements

illustrated the photosensitivity, recombination processes and the differential lifetime of the generated photo-carriers in the films under investigation.

P3: Amplitude and Phase Controlled THz Metasurface using Silver and Carbon Ink-Jet Printing
Andrew Paulsen[1], **Ajay Nahata**[2]
[1] *Univeristy of Utah (USA),* [2] *University of Utah (USA)*

Controlling the amplitude and phase response of an optical device was once thought to be constrained by the bulk material properties of that device. Demonstrations of metasurfaces have shifted this paradigm. We show that the amplitude and phase of a transmitted THz signal through an array of V-shaped antennas can be controlled by varying the conductivity and geometry of the V-shaped structures. These structures are created using conductive silver and resistive carbon ink deposited by a consumer ink-jet printer.

P4: Surface Plasmon in Monolayer Graphene with Liquid Crystal Layer
Victor Y. Reshetnyak[1], **Timothy J. Bunning**[2], **Dean R. Evans**[2]
[1] *Taras Shevchenko National University (Ukraine),* [2] *Air Force Research Laboratory (USA)*

Surface plasmon frequency in monolayer graphene placed between two dielectric layers depends on dielectric constant of layers, Fermi energy, and relief grating period. We suggest using liquid crystal (LC) as one of dielectrics to control surface plasmon in graphene. LC is uniaxial medium with optical axis given by director. Director orientation can be controlled by applied voltage. We find plasmon resonance shift about 70cm-1 for graphene on top of silicon grating with period of 200nm, when director is reoriented.

P5: SOI Forked Grating Coupler for Integrated Optics: Fabrication Tolerances and Efficiency Improvements for Coupling into a Single Mode Fiber
Derek Kosciolek[1], **Chris Nadovich**[2], **David Crouse**[1], **William Jemison**[2]
[1] *City College New York (USA),* [2] *Clarkson University (USA)*

A novel, low-profile, tunable device capable of detection or emission of optical vortex light beams of specific topological charge is presented. The proposed forked grating design couples a planar dielectric waveguide mode into a free-space propagating beam with orbital angular momentum. To promote coupling into a single mode fiber, methods to diminish power loss across the spatial profile of an emitted beam, as well as enable perfectly vertical coupling, are explored and analyzed.

P6: Probing semiconductor confined excitons decay into Surface Plasmon Polaritons
Fernando de Alencar Sobreira[1], **Marcio Teodoro**[2], **Rodrigo Pereira**[1], **Euclydes Marega Jr.**[1]
[1] *Universidade de Sao Paulo (Brazil),* [2] *Universidade Federal de Sao Carlos (Brazil)*

The interaction of Surface Plasmon Polaritons with quantum emitters has become very important in the last few years. The ability to design optical devices as well as investigate the physics of strongly interacting systems are some of its applications. In the presentation we show some results on the decay of excitons confined in a semiconductor matrix into SPPs confined in a metallic thin film, an important step toward the investigation of the basic features of SPP-exciton interaction.

P7: Room-temperature Microdisk Microlsers of Perovskites Self-Assembled from Solution
Qing Liao[1], **Xue Jin**[2], **Ke Hu**[2], **Hongbing Fu**[1]
[1] *Chinese Academy of Sciences (China),* [2] *Capital Normal University (China)*

We report for the first time single-crystalline square microdisks (MDs) of perovskite CH3NH3PbBr3 prepared by using a solution self-assembly method. Single and multiple mode lasing had been achieved in single MDs with different sizes at room temperature. By partial replacement of Br with Cl in mixed perovskites CH3NH3PbClxBr3-x, lasing wavelengths of our WGM MDLs have been tuned from 525 to 557 nm with decreasing x = 1 to x = 0.

P8: Numerical Analysis of Multilayered Structures Composed of Metallic Nanoparticles
Joaquim Junior Isidio de Lima, Vitaly Felix Rodriguez-Esquerre
Federal University of Bahia (Brazil)

The absorption and the reflection properties of multilayered plasmonic structures with subwavelength sizes are analyzed in details by using an efficient frequency domain finite element method. The multilayered structures are composed by several layers of metallic nanoparticles of Silver and Gold embedded in dielectric such as amorphous silicon. Peaks of reflection or absorption larger than 80 percent were obtained and their performance over the near infrared can be improved by adequately tuning their geometrical parameters and

thickness of the layers.

P9: Standing wave plasmon modes interact in an antenna-coupled nanowire
Jared Day[1], Nicolas Large[2], Peter Nordlander[3], Naomi Halas[3]
[1] *City College of New York (USA),* [2] *Northwestern University (USA),* [3] *Rice University (USA)*

We demonstrate the coupling between standing wave plasmonic modes and observe mode-pulling features only previously seen in macroscopic laser cavities. By positioning our Fabry-Perot resonator (nanowire) within the gap of a plasmonic nanoantenna we introduce a passive, hybridization-based coupling between the standing-wave nanowire plasmons themselves through interaction with the antenna structure. Frequency pushing and pulling, and the enhancement and suppression of specific plasmon modes, can be controlled and manipulated by nanoantenna position and shape.

P10: Localized Surface Plasmon Resonance in the IR Regime
Neha Sardana[1], Frank Heyroth[2], Joerg Schilling[3]
[1] *Institute of Nano Science and Technology (India),* [2] *Interdisciplinary center of material science (Germany),* [3] *Martin Luther University (Germany)*

Different sizes of disk shaped gold nanoantenna arrays which support extinction spectra in IR are prepared by e-beam lithography, which show localized surface plasmon resonance and Rayleigh anomalies in the range from 1000-1400nm. Embedded quantum dots surrounding the nanoantennas show up to 4-fold photoluminescence enhancement due to the coupling to the surface plasmon lattice resonances for larger disk diameters.

P11: Infrared Thermal Emission by Multipolar Nanoantennas
Marco Centini, Alessio Benedetti, Maria Cristina Larciprete, Alessandro Belardini, Roberto Li Voti, Mario Bertolotti, Concita Sibilia
Universita di Roma La Sapienza (Italy)

We studied the far field thermal emission pattern of multipolar nanoantennas of arbitray shapes at a given equilibrium temperature. The numerical investigation was performed by using a method based on the fluctuational electrodynamics approach and on the discretization of the resulting volume integral equation. Our calculations suggest that coherent emission and high directionality can be obtained by taking advantage of multipolar contributions.

P12: Metallic oriented nanowires films for infrared radiation manipulation
Maria Cristina Larciprete, Marco Centini, Roberto Li Voti, Mario Bertolotti, Concita Sibilia
Sapienza Universita di Roma (Italy)

We developed a numerical method to model the infrared spectral properties of metal nanowires on a substrate. The combination of homogenization techniques and the transfer matrix method for birefringent layered materials allows to obtain a tool for optimizing the infrared properties of the resulting system. Different in-plane orientations are investigated, while the model also allows the introduction of an off-plane tilt of the nanowires axes. Possible applications such as infrared polarizers, polarizing beam splitter and polarization rotators are discussed.

P13: Radially Inhomogeneous and Anisotropic Nanoporous Anodic Alumina Microtubes as Metamaterial Optical Fibers
Dheeraj Pratap, Subramaniam Ramakrishna
Indian Institute of Technology Kanpur (India)

The acid anodization of a cylindrically symmetric micro-aluminium wire yields a cylindrical nanoporous alumina microtube where the nanopores are radially oriented towards the cylindrical axis. The nanopore diameter decreases linearly towards the axis along with the periodicty of the nanopores along the azimuthal direction while the periodicity along z-axis remains constant. Thus, a cylindrical waveguide that is radially inhomogeneous and anisotropic results in which light at visible and NIR frequencies can be guided.

P14: Saturable absorption by surface plasmon resonance effects in zinc nanoparticles onto the core of an optical fiber
Placido Zaca[1], Jose G. Ortega[2], Fenando Chavez[1], Gerardo F. Perez[1], Luz C. Gomez[1]
[1] *Benemerita Universidad Autonoma de Puebla (Mexico),* [2] *Universidad Politecnica de Tulancingo (Mexico)*

The presense of saturable absorption (SA) in zinc nanoparticles photodeposited onto the core of an optical

fiber by a coherent source is reported. An analysis based on Mie theory was carried out to demonstrate the interaction of the absorption coefficient with the particles sizes in the proximity of surface plasmon resonance in the infrared region. This work opens a new scheme for the implementation of photonic devices.

P15: Highly confined elastic energy in pinned plates through pillar-based defects
Younes Achaoui, Andre Diatta, Stefan Enoch, Sebastien Guenneau
Institut Fresnel (France)

We investigate the propagation of elastic bending waves in pinned platonic plates. We first recall and summarize the most conclusive results in the literature, especially regarding the analytical and numerical aspects. We explain afterwards in detail through the calculation of the band diagram, transmission loss and group delay how to perform highly confined long flexural waves within sub-wavelength interspacing between nails (screws). Long-waves frequency demultiplexing is highlighted as a potential application.

P16: Modelling photonic crystals by high-frequency homogenization of Maxwell's equations
Ben Maling, Daniel Colquitt, Richard Craster
Imperial College London (United Kingdom)

We present an asymptotic method for studying the behaviour of electromagnetic waves in 3D periodic structures. The efficacy of the method is demonstrated via comparison with full numerical simulations, providing insight into effects associated with both propagating and evanescent modes. We specialise to the case of photonic crystal fibers, for which our method gives quantitative predictions about the nature of the decaying field outside the fiber core.

P17: Design of Nanowire Based Selective Absorber and Emitter for Solar Thermophotovoltaic Applications by Exciting Magnetic Polariton
Jui-Yung Chang, Hao Wang, Liping Wang
Arizona State University (USA)

Selective solar absorber and thermal emitter are highly desired for improving the performance of solar thermophotovoltaic (STPV) systems. In this work, nanowire arrays made of different materials exhibiting either selective broadband absorption or narrowband thermal emission are numerically designed with finite-difference time-domain method. The spectral selectivity results from the excitation of magnetic polariton. Particle swarm optimization algorism is implemented for obtaining optimal geometric parameters of selective solar absorber and thermal emitter by maximizing conversion efficiency of the STPV system.

P18: Metamaterials for Wireless Generation of Microplasma Array
Pramod Singh[1], Saroj Rout[1], Jeffrey Hopwood[2], Sameer Sonkusale[1]
[1] *Tufts University (USA),* [2] *Department of Electrical and Computer Engineering-Tufts University (USA)*

Here, we present a novel-application of metamaterials for remote generation of plasma, the fourth state of matter. One of the most interesting property of the metamaterials, the sub-wavelength localization of incident electromagnetic wave energy, is employed for the generation of high electric field to ignite and sustain microwave plasmas. The two-dimensional array of microplasma is generated using metamaterials. Frequency selective generation of microplasma in a large array is made possible by employing metamaterial units each with different resonance frequencies.

P19: Probing electric field in an enclosed field mapper for characterizing metamaterials
Sucheng Li, Chendong Gu, Yadong Xu, Shahzad Anwar, Weixin Lu, Zhi Hong Hang, Bo Hou, Huanyang Chen
Soochow University (China)

Spatially mapping electromagnetic fields in the quasi-two-dimensional field mapper for charactering metamaterial devices, especially those integrating the metal boundary, may encounter troubles including electromagnetic leakage and energy guiding along finitely high metal walls. To eradicate them, a moving contact approach is proposed. The physical air gap between the mobile metal walls and the stationary upper plate of the mapper is closed. We demonstrate the method of closing the gap by mapping the E-field distribution in a rectangular waveguide.

P20: Design and Analysis of Reconfigurable Antenna Using Negative Index Metamaterial
Md Ikbal Hossain, M. R. I. Faruque, M. T. Islam
Universiti Kebangsaan Malaysia (Malaysia)

In this paper, a negative index metamaterial structure integrated with microstrip patch antenna is proposed. The antenna microstrip-fed line and ground plane are modified with the proposed metamaterial to obtain reconfigurable characteristics. The finite integration technique (FIT) of computer simulation technology (CST) microwave studio is used throughout the investigation. An anechoic chamber is used for the measurement purpose. The results indicate that the proposed metamaterial structure successfully can be used to make wideband to narrowband and vice versa.

P21: Thermal reshaping of metallic nanostructures far below melting point, and its implications for plasmonic based meta-materials
Adam B. Taylor, James Chon
Swinburne University (Australia)

Plasmonic meta-materials rely on exact nanostructure geometries for the production of many extraordinary optical effects. Here, we systematically study how the process of thermally driven surface diffusion can disturb and reshape the geometries of these structures, and that it can occur at temperatures 1000 K below the melting point of gold. Using a combination of in situ TEM heating observations and simulation techniques, we find that thermal stability decreases with increasing feature sharpness, impacting many proposed meta-material structures.

P22: Light Localization in the Presence of Non-Hermitian Defects
Ali Basiri[1], Milan Koirala[2], Alexey Yamilov[2], Yaron Bromberg[3], Hui Cao[3], Tsampikos Kottos[1]
[1] *Wesleyan University (USA),* [2] *Missouri University of Science and Technology (USA),* [3] *Yale University (USA)*

We have shown the appearance of Critical States Embedded in the Continuum(CSC) in an array of waveguides with one non-Hermitian defect. When the number of non-Hermitian impurities increases, the Floquet-Bloch (FB) modes of the system possess a localization feature which is distinct from the one found in the standard Anderson model.

P23: Extending resonant wavelengths of contour bowtie nano-antennas with fixed footprint size
Hui-Hsin Hsiao, Shian-Min Chiou, Yu-Ping Chang, Hung-chun Chang
National Taiwan University (Taiwan)

A series of bowtie antennas are designed for the purpose of extending the resonant wavelength in the near- and mid-infrared regime under the same antenna footprint size. The solid bowtie antenna is first modified to be a contour antenna and then changed into different contour shapes with extensive resonant paths to redshift the resonances while maintaining the gap enhancement factors at least comparable with that of the solid bowtie antenna.

P24: Fabrication of asymmetric planar terahertz metamaterials with Fano resonances based on double split ring resonators
Shengyan Yang, Xiaoxiang Xia, Zhe Liu, Junjie Li, Changzhi Gu
Chinese Academy of Sciences (China)

Ultrafine asymmetric planar terahertz metamaterial (MM) with Fano resonance consisted of double split ring resonators (DSRRs) were studied. They were fabricated by utilizing high-resolution electron-beam lithography method on intrinsic Si substrates. They show large potentials in biomaterial sensing, switching and surface enhanced Raman scattering. What's more, such research will be important in gaining a better understanding of interactions between nearest neighbor SRRs, and will in turn, facilitate the design of novel THz MM devices.

P25: 3D isotropic metamaterial design using smart transformation optics
Dongheok Shin[1], Ilsung Seo[1], Kyoungsik Kim[2]
[1] *Yonsei University (Korea),* [2] *Agency for Defense Development (Korea)*

We introduce new design method for 3D isotropic transformation optics device using smart transformation optics. In 2 dimension smart transformation optics, elastic deformation satisfied quasi-conformal transformation with negative Poisson's ratio -1. We extended smart transformation optics to 3 dimension and demonstrated 3D isotropic metamaterials waveguide. This 3D waveguide is arbitrary bendable and maintain phase in wave propagation.

P26: Optical properties of a 1D and 2D photonic crystals based on sulvanite compounds Cu3TMS4 (TM = V, Nb, Ta)
Luz Gonzalez Reyes, N. Porras-Montenegro

Universidad del Valle Cali-Colombia (Colombia)

In this work for the first time we present a theoretical study of the optical properties of 1D and 2D photonic crystals based on sulvanite compounds Cu 3 TMS 4 (TM = V, Nb, Ta). Using the transfer matrix technique, we investigate the photonic band structure, the transmission, reflection and absorption coefficients under the effects of various structural paremeters. Also, we study 2D photonic crystals using the FDTD method. In both cases, we use Drude model considering dissipation effects.

P27: Scattering of electromagnetic pulses on metallic nanospheres with account for plasmonic interference effects

Valery Astapenko, Sergey Svita
Moscow Institute of Physics and Technology (Russia)

In the work the radiation scattering by metal nanospheres in a dielectric matrix is studied theoretically for long and short pulses. Spectral-angular scattering efficiency and total probability are calculated and analyzed for different parameters of the problem. It is shown that plasmonic interference effects play important role in pulse scattering on metallic nanospheres in matrix with high value of dielectric permittivity

P28: Optimized scalable circular gratings for efficient photon collection from Nitrogen Vacancy centers in bulk diamond

Jiabao Zheng[1], Andreas Christou Liapis[2], Dirk Robert Englund[1]
[1]*Massachusetts Institute of Technology (USA),* [2]*Brookhaven National Laboratory (USA)*

Optical defects in diamond have attracted great attention for quantum information processing and sensing applications, but their performance is currently limited by low optical collection efficiency. We propose an optimized dielectric circular grating structure which simultaneously provides Purcell enhancement and improves extraction efficiency into low NA optics. The structures are fabricated using transferred hard mask lithography. These optimized gratings are a promising platform for defect integrated optical devices with highly efficient out-coupling.

P29: Aperture SNOM Studies of Light Emitting Semiconductor Nanostructures

Artyom Shelaev[1], Alexander Ankudinov[2], Alexander Mintairov[2], Sergey Slipchenko[2], Pavel Dorozhkin[1]
[1]*NT-MDT Co. (Russia),* [2]*Ioffe Institute (Russia)*

Aperture SNOM studies of semiconductor laser, quantum dots and quantum microdisks in near-IR spectral region are presented.

P30: Cooperative energy transfer in plasmonic systems

Vitaliy V. Pustovit[1], Augustine M. Urbas[2], Tigran V. Shahbazyan[2]
[1]*Jackson State University (USA),* [2]*Air Force Research Laboratory (USA)*

We address the role of cooperative effects in energy transfer (ET) from an ensemble of donors to an acceptor near a plasmonic nanostructure. We demonstrate that in cooperative regime ET takes place from plasmonic superradiant and subradiant states rather than from individual donors leading to a significant increase of ET efficiency. The cooperative amplification of ET relies on the large coupling of superradiant states to external fields and on the slow decay rate of subradiant states.

P31: Characterization of Ultra-Wideband Metamaterial Absorbers with Non-Foster Loads

Yifeng Fan, Hao Chi Zhang, Tie Jun Cui
Southeast University (China)

Comparing with conventional passive metamaterial (MTM) absorbers, it is shown that active MTM structure loaded with non-Foster circuits (NFCs) may overcome their inherent physical limitations, thus can achieve an ultra-wideband electromagnetic absorber. However, their performance may be restricted by the stability issue due to the active inclusions which needs to be explored. Here, based on the proposed circuit model, a detailed investigation on the design of a stable ultra-wideband active MTM absorber is presented and verified by simulations.

P32: Tailoring active far-infrared application with graphene metasurface

Lin Wang, Xiaoshuang Chen, Wei Lu
Chinese Academy of Sciences (China)

In this work, we demonstrate strong electric resonance response in perforated graphene sheet at far-infrared part of electromagnetic spectrum. Unlike the metallic meta-materials relying on the geometrical inductance

for magnetic response, the electric resonance in graphene is mainly caused by localized plasmons and thus enabling sub-wavelength confinement of electromagnetic field. The active tunable electric resonance by electrostatic doping on the graphene sheet provides efficient route for compact biosening, far-infrared imaging and detection.

P33: Shrinking the terahertz light into a point
Lin Wang, Xiaoshuang Chen, Wei Lu
Chinese Academy of Sciences (China)

This work demonstrates the ultra-subwavelength confinement of terahertz light in grating coupled graphene field effect transistors by employing a defect in one-dimensional plasmonic crystal. In comparison with metallic metamaterial, graphene plasmon offers the prospective for compact, electrical tunable applications at terahertz band. Due to the larger intrinsic inductance of graphene at terahertz frequency, we find strong concentration of electric field in the cavity composed of gates and graphene-channel.

P34: Tunable plasmonic properties of rounded object-arrays achievable via interferometric illumination of colloid sphere monolayers
A. Somogy, A. Sipos, G. Szabo, Maria Csete
University of Szeged (Hungary)

Interferometric illumination of colloid sphere monolayers by circularly polarized light makes possible complex plasmonic structure generation with six independently tunable geometrical parameters. According to plasmonic spectral engineering principles both the near-field and spectral properties can be controlled via predesigned geometrical parameters, including periodicity, mini-array composition and properties of composing nano-objects. The optimal azimuthal orientation and illumination direction are determined for various complex plasmonic patterns and the nanophotonical phenomena resulting in extrema on their transmission spectra are described.

P35: Nonlocality Induced Topological Transitions in Hyperbolic Metamaterials
Long Chen, Cheng Zhang, Jing Zhou, L. Jay Guo
University of Michigan (USA)

Hyperbolic metamaterials (HMMs) based on ultrathin metal-dielectric multilayers have been studied by considering the nonlocal response of electrons in metal. We show that nonlocality will induce topological transitions of the iso-frequency surfaces and intrinsically limit the wavenumber as well as photon local density of states for both type I and type II HMMs.

P36: Manufacturing thermal solar absorber with 2D tandem grating structures for high absorption efficiency
Ju-Hyeon Shin[1], Y. D. Kim[1], H. J. Choi[1], H. Lee[1], S. W. Han[2], B. J. Lee[2]
[1] *Korea University (Korea),* [2] *Korea Advanced Institute of Science and Technology (Korea)*

This study is about manufacturing technology of thermal solar absorber which consists of meta-structured 2D tandem grating. The 2D tandem grating structure contains metal grid, dielectric and metal film. Due to these complex grating structures, several resonances are occurred such as surface plasmonic resonance and magnetic resonance. As a result, absorption was increased on very wide region of wavelength.

Welcome Reception

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17:30 - 19:30

Friday 7th August, 2015

08:30 - 09:50 — Aronow Theater

Session 4A1

Plenary Session IV

Chaired by: Nikolay Zheludev

08:30 : Plenary talk
New Interface Between Quantum Optics and Nanoscience
Mikhail D. Lukin
Harvard University (USA)

We'll discuss recent developments at a new scientific interface between quantum optics and nanoscience. Specific examples include the use of quantum optical techniques for manipulation of individual atom-like impurities at a nanoscale and for realization of hybrid systems combining quantum emitters and nanophotonic devices. We'll discuss how these techniques are used for realization of quantum nonlinear optics and quantum networks, and for new applications like magnetic resonance imaging with single atom resolution, nanoscale sensing in biology and material science.

09:10 : Plenary talk
Spin-photon quantum interface
A. Delteil[1], **S. Zhe**[1], **E. Togan**[1], **W. Gao**[2], **A. Imamoglu**[1]
[1] *ETH Zurich (Switzerland),* [2] *NTU (Singapore)*

An important class of solid-state systems, such as quantum dots and nitrogen-vacancy centers, exhibit spin-state dependent optical transitions that allow for all-optical fast initialization, manipulation and measurement of spins. More importantly, the presence of quantum correlations between a scattered photon and the final spin-state in these emitters enables the realization of quantum information protocols such as heralded probabilistic teleportation and entanglement swapping. We will review recent progress in this field and discuss future prospects.

Coffee Break and Exhibit Inspection

09:50 - 10:20

10:20 - 12:35 — Aronow Theater

Session 4A2

Symposium 2: Industrial applications of metamaterials I

Organized by: David T. Crouse and Mike A. Fiddy

Chaired by: David T. Crouse and Mike A. Fiddy

10:20 : Invited talk
Industrial Applications of Metamaterials at Raytheon
J. W. A Wehner, J. Kasemodel, V. Shukunov, J. Puschell, R. K. Dodds
Raytheon (USA)

This paper discusses the metamaterials currently under investigation for applications at Raytheon. Electro-optical metamaterial devices for reducing dark current, improving device performance and functionality and

enhancing capability will be discussed. Some longer wavelength (RADAR) metamaterials will also be discussed briefly in the context of technologies of interest. Finally future directions for metamaterials of interest will also be touched upon.

10:40 : Invited talk
Phase Progressions in Layered Metamaterials and their Effects on Refractive Index
Amir Zaghloul, Gregory Talalai, Steven Weiss, Theo Anthony
Army Research Lab (USA)

A description of the mechanism of negative refraction is presented based solely on phase analysis and measurements for layered metamaterials.

11:00 : Invited talk
Low profile antennas realized with metamaterials
Steven Weiss, Gregory Mitchell
Army Research Lab (USA)

As a practical realization of a device created with metamaterials, we present measured data for a low profile, broadband antenna in the UHF/VHF range.

11:20 : Invited talk
Metamaterial-based microrectenna arrays for infrared rectification
Richard Osgood[1], Kenneth Diest[2], Jimmy Xu[3], Ryan O'Hayre[4], Prabhuram Joghee[4], Minyi Kang[5], Ki-Bum Kim[5], Gustavo Fernandes[3], Stephen Giardini[1], Lalitha Parameswaran[2], Mordechai Rothschild[2], Steven Kooi[6]
[1]US Army NSRDEC (USA), [2]MIT Lincoln Laboratory (USA), [3]Brown University (USA), [4]Colorado School of Mines (USA), [5]Seoul National University (Korea), [6]MIT Institute for Soldier Nanotechnologies (USA)

Stripe-teeth metamaterial microantenna arrays, coupled to vertical Metal-Insulator-Metal (MIM) diodes, were designed, fabricated, and characterized with FTIR microscopy and current-voltage (I-V) measurements, the former agreed well with FDTD models and the latter showed that the Al2O3-based diodes have very large barrier heights and breakdown voltages. These microrectenna arrays were illuminated by infrared and visible laser beams, and their direct current was characterized as a function of bias voltage and compared to quantum rectification models.

11:40 : Invited talk
Metamaterials and plasmonics for enhanced optical detectors
Augustine Urbas
Air Force Research Lab (USA)

New challenges arise in infrared detectors as pixel counts increase and the information is more widely used. Compressive sensing may allow for the acquisition of data with higher information content. Our research develops a combined method to integrate plasmonic and microptical elements onto detector structures for improvements and to introduce compressive sensing methods. We will present the results of several design studies and experimental verification of the modeled device performance.

12:00 : Invited talk
Opening Satellite Capacity to Consumers with Metamaterial Antennas
Mikala Johnson
Kymeta Corporation (USA)

A metamaterial antenna is being developed for satellite communication that is thin, light, and low cost. These antennas are built upon reconfigurable metamaterials and the principles of holography, and they produce a directed, steerable, powerful beam without mechanically moving parts and with lower power-consumption than the competing technologies. This paper briefly introduces this antenna, only made possible by the intentional engineering of metamaterials, that is poised to bring satellite data capacities to the mass market.

12:20 : Recycling radio waves with smart walls
Matthieu Dupre, N. Kaina, M. Fink, G. Lerosey
ESPCI ParisTech (France)

We propose to use electronically reconfigurable ultrathin metasurfaces as smart walls to reflect more intelligently the waves in indoor environments. We experimentally prove at 2.47 GHz that it is possible to use

these as spatial microwave modulators, using a simple energy feedback. In particular, we show that we can enhance the transmission between two antennas by orders of magnitude or locally conceal a volume from the penetration of waves in a typical office room.

10:20 - 12:30 — NAC 0/201

Session 4A3

Symposium 1: Functional Metastructures and Nanomaterials: Properties, Fabrication and Modeling IX

Organized by: Alexander Govorov and Hilmi Volkan Demir

Chaired by: Nicolae C. Panoiu and Ventsislav K. Valev

10:20 : Keynote talk
Quantum Photonic Computing
Jeremy O'Brien
University of Bristol (United Kingdom)

Of the various approaches to quantum computing, photons are appealing for their low-noise properties and ease of manipulation at the single qubit level, while the challenge of entangling interactions between photons can be met via measurement induced non-linearities. However, the real excitement with this architecture is the promise of ultimate manufacturability: All of the components-inc. sources, detectors, filters, switches, delay lines-have been implemented on chip, and increasingly sophisticated integration of these components is being achieved. We will present the opportunities and challenges of a fully integrated photonic quantum computer.

10:50 : Invited talk
Chaotic Light Trapping in Periodic Fiber Arrays
Marina Mariano[1], G. Kozyreff[2], G. Gerling[3], J. Puigdollers[3], P. Romero-Gomez[1], J. Bravo-Abad[4], Jordi Martorell[1]
[1] *ICFO-Institut de Ciencies Fotoniques (Spain),* [2] *ULB (Belgium),* [3] *Universitat Politecnica de Catalaunya (Spain),* [4] *Universidad Autonoma de Madrid (Spain)*

We implemented a novel light trapping mechanism based on an array of fibers capable of forcing a ninety-degree bending of the incident light. Light rays incident close to the intersection between to adjacent fibers can be trapped in the fiber structure thanks to a chaotic whispering gallery type propagation. When an organic cell is deposited on the backside of the array, sunlight harvesting is largely enhanced leading to a measured increase in photovoltaic cell performance higher than 30 percent.

11:10 : Invited talk
Hybrid Nanophotonic Materials for Enhanced Ultrafast Optical Response and Efficient Photoinduced Charge Separation
Gary Wiederrecht
Argonne National Laboratory (USA)

In this talk I describe the ultrafast response of hybrid nanomaterials of interest for nanoscale optical switching and optical energy conversion. I also describe novel means to visualize, temporally and spatially, photoinduced charge separation at nanoscale interfaces of hybrid materials. The materials and phenomena range from hybrid plasmonic materials with ultrafast hot electron responses, to highly reductive type II core/shell quantum dots that permit efficient separation of charge across the core/shell interface for enhanced opportunities in photoinduced charge separation.

11:30 : Invited talk
Near-fields of Nanoplasmonics Visualized with Ultrafast Transmission Electron Microscopy
Aycan Yurtsever
INRS (Canada)

We introduce a novel imaging methodology that can directly map the near-fields of nanoplasmonics with spatiotemporal resolutions that were not possible before. Ultrafast transmission electron microscopy enables the direct visualization of laser-induced electric fields as they rise and fall within the duration of the excitation laser pulse (hundreds of femtoseconds) with several nanometers of spatial resolution. We demonstrate this capability by investigating several nanoplasmonic systems, including particle dimers, particle ensembles and standing-wave plasmons at the edges of layered-graphene strips.

11:50 : Invited talk
Hit 'em where they ain't: super-resolution imaging of porous nanomaterials
C. F. Landes
Rice University Department of Chemistry (USA)

We introduce a super-resolution optical imaging technique that relies on probing the porous space within nanomaterials. The method provides sub-diffraction-limited structural information about the material as well as transport dynamics. Pore sizes and diffusion coefficients are better understood compared to diffraction-limited imaging and particle tracking.

12:10 : Invited talk
Multifunctional Materials for Electronics and Photonics
F. Rosei
INRS (Canada)

We demonstrate various strategies to control nanostructure assembly (both organic and inorganic) at the nanoscale. We study, in particular, multifunctional materials, namely materials that exhibit more than one functionality, and structure/property relationships in such systems.

10:20 - 12:35 — NAC Ballroom

Session 4A4

Radiative thermal emission control

Organized by: Ali Belarouci and Philippe Ben Abdallah

Chaired by: Ali Belarouci and Philippe Ben Abdallah

10:20 : Invited talk
Nanophotonics for Energy Applications
Marin Soljacic
MIT (USA)

Certain novel opportunities for exploring nanophotonics (including tailoring thermal radiation, and angular selectivity) for energy applications will be presented.

10:40 : Frequency-Tunable Coherent Thermal Emission from Graphene Coated Silicon Carbide Grating Metamaterials
Yue Yang, Hao Wang, Liping Wang
Arizona State University (USA)

We numerically demonstrate frequency-tunable coherent thermal emission from graphene coated silicon carbide (SiC) grating metamaterials. Rigorous coupled-wave analysis shows emission peaks associated with magnetic polariton, whose resonance frequency can be dynamically tuned by varying graphene chemical potential. The underlying physical mechanism is elucidated, while the geometric and directional effects on the selective emission peaks are explored. The metamaterial structures coated with multiple graphene sheets are further investigated to achieve a larger tunability up to 8.5 percent in peak frequency.

10:55 : Invited talk
Thermal emission control by manipulating electronic and photonic states: Energy Recycling and Dynamic Control

Susumu Noda, M. D. Doysa, T. Inoue, T. Asano
Kyoto University (Japan)

We describe thermal emission control by manipulating electronic and photonic states, more concretely, using an intersubband transition in quantum well and a photonic- crystal band-edge resonant effect. We show that the thermal emission peak intensity can be more than four times greater than that of a reference blackbody sample under the same input power and thermal management conditions.

11:15 : Invited talk
Thermal Beaming
David Norris
ETH Zurich (Switzerland)

We will discuss tailored thermal emission from periodic metallic structures. First, we will describe experiments on tungsten bull's eyes on which surface plasmon polaritons are excited at elevated temperatures. In the direction normal to the film, a spectrally narrow beam of thermal emission is observed at a wavelength equal to the spacing between the grooves. Second, we will describe a simple layered structure that is being explored as the selective emitter in a hybrid thermophotovoltaic device.

11:35 : Invited talk
Controlling Thermal Emission Using Photonic Structures for Radiative Cooling
Aaswath Raman, Linxiao Zhu, Shanhui Fan
Stanford University (USA)

The cold of outer space is a heat-sink for energy processes on Earth that can be accessed by thermal emission from a sky-facing surface. We first show that to maximally achieve radiative cooling through this mechanism, a selective emitter is necessary due to spectral features of atmospheric emissivity in the mid-infrared. We next report the first experimental demonstration of radiative cooling in the daytime using a photonic design that is both a selective thermal emitter and strong solar reflector.

11:55 : Invited talk
Engineering of optical absorption and radiative thermal emission using vanadium dioxide
Mikhail A. Kats
University of Wisconsin (USA)

I will discuss the use of vanadium dioxide (VO2) to achieve anomalous and thermal emission properties. The temperature-driven insulator-to-metal transition in VO2 results in widely-varying optical properties in the infrared, making it an excellent material for thermal emission engineering. We demonstrated structures with regions of negative differential thermal emission (emission inversely proportional to temperature) and super-positive differential thermal emission. Modifying the phase change properties of VO2 by doping provides a mechanism for custom design of thermal emission.

12:15 : Invited talk
Energy Manipulation in NanoScale Using Thermoplasmonics
M. Swillam
American University in Cairo (Egypt)

In this work, we propose a detailed study of various novel waveguides made using doped semiconductors at the mid-and far infrared ranges. These waveguides support a plasmonic-like mode with ability to confine the electromagnetic field at nanoscale in these wavelength ranges. The ability to control and harvest the thermal energy using Nanoantenna made using these structures are also demonstrated. The integration of thermal control devices on the same chip with photonic and electric devices is also demonstrated.

10:20 - 11:15 — NAC 1/202

Session 4A5

PT-symmetry in photonics, metamaterials and plasmonic systems III

Organized by: Anatole Lupu and Henri Benisty

Chaired by: Anatole Lupu and Henri Benisty

10:20 : Invited talk
Exceptional point dynamics of a bianisotropic transmission line
Shiyi Xiao[1], **Yong Sun**[2], **Hong Chen**[2], **Jensen Li**[1]
[1] *University of Birmingham (United Kingdom),* [2] *Tongji University (China)*

Bianisotropic metamaterials, with different impedances in the forward and backward propagation directions, can be used to achieve a unidirectional character in the reflection. Here, we show that such phenomenon can be associated to the exceptional point of an effective Hamiltonian, which can be regarded as the constitutive matrix of the system with non-ideal effective PT symmetry. It is further confirmed by using experiments on a transmission line platform.

10:40 : Parity-Time Chain of Whispering-Gallery Mode Resonators
Sendy Phang, Ana Vukovic, Stephen Creagh, Trevor Benson, G. Gradoni, Phillip Sewell
University of Nottingham (United Kingdom)

The paper analyses the dispersion characteristics of an infinitely long PT chain made of whispering gallery resonators with gain/loss modulation. The results show that the appearance of the threshold breaking point depends not only on both of coupling and gain/loss modulation but also on the Bloch phase. The Bloch phase is seen as an additional parameter that can reduce or even completely eliminate PT-breaking threshold.

10:55 : Invited talk
Spontaneous Parity-Time Symmetry Breaking and Light Amplification in Moving Media
Mario Silveirinha
University of Coimbra (Portugal)

It is shown that the emergence of optical instabilities in moving systems is strictly related to a spontaneous parity-time symmetry breaking of the relevant time evolution operator. It is proven that the frequency spectrum of lossless systems with moving components is generally complex valued, and has a mirror symmetry with respect to the real-frequency axis. The optical amplification of a light pulse in the broken parity-time symmetry regime is studied.

11:15 - 12:35 — NAC 1/202

Session 4A6

Metamaterials based on novel symmetries III

Organized by: Jensen Li and Minghui Lu

Chaired by: Jensen Li and Minghui Lu

11:15 : Invited talk
Wave Mechanics in Media with Local Symmetries: Systematic Pathway to the Breaking of Discrete Symmetries
Peter Schmelcher[1], **Christian Morfonios**[1], **Panagiotis Kalozoumis**[2], **Fotis Diakonos**[2]
[1] *University of Hamburg (Germany),* [2] *University of Athens (Greece)*

The concept of local symmetries which hold only in spatially limited domains is developed. This way the parity and Bloch theorems are generalized to the case of broken global symmetry. Local inversion or translation symmetries are shown to yield invariant currents that characterize wave propagation. These currents map the wave field from an arbitrary spatial domain to any symmetry-related domain. Our approach applies to acoustic,

optical and matter waves. As examples we provide a classification of perfectly transmitting resonances in completely locally symmetric scattering setups.

11:35 : Invited talk
Manipulation of Resonant Modes in a Typical Multi-Mode Laser Cavity by Parity-Time Symmetry
Liang Feng
The State University of New York at Buffalo (USA)

Effective manipulation of cavity resonant modes is crucial for emission control in laser physics and applications. Using the concept of parity-time symmetry to exploit the interplay between gain and loss, we demonstrate a parity-time symmetry-breaking laser with resonant modes that can be controlled at will. In contrast to conventional ring cavity lasers with multiple competing modes, our parity-time microring laser exhibits intrinsic single-mode with the selective whispering-gallery mode order.

11:55 : Invited talk
Bound States in the Continuum in Metamaterials
Boubacar Kante
University of California San Diego (USA)

We have recently demonstrated the possibility to construct electromagnetic bound states in the continuum in subwavelength and coupled dielectric particles. This new type of modes, previously conjectured in quantum mechanics have been design, simulated and fabricated. In this talk, I will introduce our approach in constructing BIC and the possibility to realize new photonic devices based on these modes. The current system addresses many challenges in nanophotonics.

12:15 : Invited talk
Spontaneous Symmetry Breaking of Scattering Eigenstates in Parity-Time Symmetric Multimode Waveguides
Li Ge[1], Konstantinos G. Makris Makris[2]
[1] *The Graduate Center City University of New York (USA),* [2] *Vienna University of Technology (Austria)*

Recently it was predicted that scattering eigenstates of an optical system with Parity-Time (PT) symmetry display a spontaneous symmetry breaking. This was verified in the microwave regime but remains an elusive goal in the optical regime. We propose to observe this phenomenon in a multimode PT-symmetric waveguide, without the need to tune any system parameter.

10:20 - 12:40 — ASRC Conference Room

Session 4A7

Nitrogen Vacancy Centers in Diamond I

Organized by: Carlos Meriles

Chaired by: Carlos Meriles

10:20 : Invited talk
Observation of Atomic Dipole Forces in Optically Trapped Nanodiamonds Containing NV Centers
C. Bradac, M. L. Juan, B. Besga, G. Molina-Terriza, T. Volz
Macquarie University (Australia)

We observe and measure atomic dipole forces for nanodiamonds (NDs) containing many NV centres, in a liquid environment. While holding the NDs (150 nm in size) at the focus of classical optical tweezers in liquid, we employ a second laser beam slightly detuned from the dipole transition of the target colour centres and measure dispersive variations in the trap stiffness, due to the resonant forces, of 10 percent.

10:40 : Invited talk
Coherent Control Over Diamond Nitrogen-Vacancy Center Spins with a Mechanical Resonator
Gregory Fuchs

Cornell University (USA)

We demonstrate coherent Rabi oscillations of single diamond nitrogen-vacancy (NV) center spins and spin ensembles driven directly by gigahertz frequency strain. These mechanically-driven spin transitions compliment magnetic field-based quantum control within the NV center spin triplet manifold to provide access to all spin transitions. This work demonstrates crucial steps toward a hybrid quantum interface between phonons and spins, and has potential applications that include quantum enhanced metrology of inertial motion and decoherence protection.

11:00 : Invited talk

Nitrogen Vacancy scanning magnetometry

Luis Javier Martinez Rodriguez, Thomas Hingant, Jean-Philippe Tetienne, Isabell Gross, Jean-François Roch, Vincent Jacques
Paris Sud University (France)

In this paper we present our recent work on scanning probe magnetometry with nitrogen vacancy centers in diamond. We focus on applications of this method to fundamental nanomagnetism.

11:20 : Invited talk

Nano-photonic quantum light-matter interfaces based on rare-earth-doped crystals

Tian Zhong, Jonathan Kindem, Evan Miyazono, Adrei Faraon
California Institute of Technology (USA)

We demonstrate coherent optical control of Nd rare-earth ions coupled to a nano-photonic resonator. Optical storage in the nano-resonator is demonstrated using multi-mode photon echo and atomic frequency comb protocols. The long optical and spin coherence of cavity-coupled rare-earth ions indicate that these are promising systems for on-chip quantum light-matter interfaces.

11:40 : Invited talk

Single spins in diamond as local probes for magnetic fields

Kevin Kai Chang[1], Antoine Dussaux[2], Jens Michael Boss[1], Chrisitan Lucas Degen[1]
[1] *ETH Zurich (Switzerland),* [2] *Nice Sophia-Antipolis University (France)*

The nitrogen-vacancy (NV) center has been demonstrated to be a robust magnetic field sensor with high sensitivity and spatial resolution. We illustrate the applications and challenges of using single NV centers to image magnetic features both at ambient conditions and at low temperatures. In addition, we show different types of scanning probes including tips fabricated on bulk diamond membranes.

12:00 : Invited talk

Diamond nanobeam waveguide optomechanics

Paul Barclay
University of Calgary (Canada)

Using a quasi-isotropic etching technique to undercut nanostructures in bulk single crystal diamond, we have fabricated diamond nanobeam mechanical resonators and optical waveguides. The nanobeams support mechanical resonances with quality factor greater than 700,000, and can be sensitively probed using phase-matched evanescent coupling with an optical fiber taper. Optomechanical and photothermal effects excite self-oscillations, resulting in emergence of nonlinear nanomechanical softening.

12:20 : Invited talk

Towards Efficient Spin-Photon Interfaces for Scalable Quantum Networks on Photonics Integrated Circuits

Tim Schroder[1], Luozhou Li[1], Edward H. Chen[1], Michael Walsh[1], Igal Bayn[1], Faraz Najafi[1], Sara Mouradian[1], Matthew E. Trusheim[1], Ming Lu[2], Mircea Cotlet[2], Matthew L. Markham[3], Karl Berggren[1], Daniel J. Twitchen[3], Dirk Englund[1]
[1] *MIT (USA),* [2] *Brookhaven National Laboratory (USA),* [3] *Element Six (USA)*

We discuss recent progress towards building on-chip quantum networks of multiple spin qubits in nitrogen vacancy (NV) centers in diamond. An essential component for quatum networks is an efficient light-matter interface to entangle photons and stationary qubits. We describe NV-nanocavity systems in the Purcell regime with electron spin coherence times approaching the millisecond regime. We also describe patterned NV-cavity implantation, and techniques for high-yield integration multiple functional NV-cavity systems and single photon detectors on-chip.

10:20 - 12:40 — NAC 1/203

Session 4A8

Plasmonics and nanophotonics VI

Chaired by: Xiaoping Liu

10:20 : Non-Bragg gap solitons and absorption effects in Kerr-metamaterial periodic and Fibonacci heterostructures
Ernesto Reyes-Gomez[1], Solange Bessa Cavalcanti[2], Luiz Eduardo Oliveira[3]
[1] *Universidad de Antioquia UdeA (Colombia),* [2] *Universidade Federal de Alagoas (Brazil),* [3] *Universidade Estadual de Campinas (Brazil)*

A detailed study of non-Bragg gap solitons in one-dimensional Kerr-metamaterial periodic and Fibonacci heterostructures is performed. The transmission coefficient is numerically obtained by considering the loss effects in the metamaterial slabs. A switching from states of no transparency in the linear regime to high-transparency states in the nonlinear regime is observed for both zero-order and plasmon-polariton gaps. The spatial localization of the non-Bragg gap solitons are also examined and the symmetry properties of the soliton waves are briefly discussed.

10:35 : Super-Collimation of Light Beyond Heisenberg's Uncertainty Principle
Kuan-Ren Chen, Jian-Shiung Hong
National Cheng Kung University (Taiwan)

Heisenberg's Uncertainty Principle is based on a smooth wave function without involving phase and sub-wavelength scale. The resultant wave function of light transmitted through a sub-wavelength slit may not be smooth, also, it involves length and phase in sub-wavelength scale. With plasmonic sub-wavelength structures in a metallic film, super-collimated light beam can be produced. As a fundamental scientific breakthrough, this novel phenomena and physics are studied by analytics, simulation and experiment.

10:50 : Strong coupling from few molecules in self-assembled plasmonic nanostructures
Rohit Chikkaraddy, Bart Nijs, Felix Benz, Oren Scherman, Jeremy Baumberg
University of Cambridge (United Kingdom)

We report the interaction of tightly localized plasmons and absorption resonances of few (10-20) isolated methylene blue molecules in the strong coupling regime. Ultra-small mode volumes in self-assembled nanoparticle-on-mirror geometry are coupled to molecular resonances with controlled orientation of dipoles to induce strong coupling. Dark-field and surface enhanced Raman scattering measurements (SERS) show plasmon-exciton coupling at the nanoparticle gaps. Dispersion curves obtained from analysis of 100 nanoparticles, show anticrossing behavior with Rabi splittings ranging from 120-260meV at room temperature.

11:05 : Mask-less recycling of highly efficient electron-beam defined three dimensional SERS substrates
M. Chirumamilla, A. Gopalakrishnan, A. Toma, R. Proietti Zaccaria, F. De Angelis, R. Krahne
Istituto Italiano di Tecnologia (Italy)

Top-down fabrication of electron-beam lithography defined metallic nanostructures is a successful route to obtain extremely high electromagnetic field enhancement via plasmonic effects in well-defined regions. We present three-dimensional nano-array devices that can be recycled via a mask-less metal etching and deposition processes, due to conservation of the nanostructure pattern in the 3D geometry of the underlying substrate. Surface Enhanced Raman Scattering at extremely low density up to the limit of few molecules is demonstrated.

11:20 : Partial decorrelation between TPL and SHG: a direct evidence for nonlocal bulk sources in noble metal nanostructures
L. Olgeirsson[1], S. Waterman[1], S. Huant[1], A. Bouhelier[2], J. Sharma[3], E. Dujardin[3], Guillaume Bachelier[1]
[1] *Joseph Fourier University (France),* [2] *Bourgogne University (France),* [3] *CEMES - CNRS Toulouse (France)*

Spatially resolved optical second harmonic generation (SHG) is reported for single gold nanoprisms and compared with two-photon photoluminescence (TPL). We demonstrate that the corresponding 2D maps obtained by scanning the sample are partially uncorrelated due to the specific nature of the second order nonlinear

sources. Hence, the TPL maps, which have been widely used to image the electric field distribution in plasmonic nanostructures, cannot be directly invoked in order to anticipate the efficiency and localization of the SHG response.

11:35 : Design of a high performance optical tweezer for nanoparticle trapping
D. Conteduca[1], F. Dell'Olio[1], T. F. Krauss[2], Caterina Ciminelli[1], M. N. Armenise[1]
[1] *Politecnico di Bari (Italy),* [2] *University of York (United Kingdom)*

The design of high performance optical nanotweezers based on a photonic/plasmonic microcavity has been carried out. High optical forces at pN-range with low input optical power (1mW) have been obtained, due to strong light-matter interaction in the cavity. The device is particularly suitable in biology and medicine because it enables the trapping of virus or single proteins.

11:50 : Magneto-Optical Response of Periodically Nano-Structured Metal-Dielectric Films
Yakov M. Strelniker[1], David J. Bergman[2]
[1] *Bar-Ilan University (Israel),* [2] *Tel Aviv University (Israel)*

The rotation and ellipticity of polarization of the light propagating through a metamaterial film with periodic nanostructure for arbitrary direction of the applied static magnetic field is studied. In the Voigt configuration the strong dependencies of the above mentioned effects on the direction of the applied field are found.

12:05 : Invited talk
Milling of antenna patterns with Au and Si ions
G. Seniutinas[1], A. Balcytis[1], Y. Nishijima[2], Saulius Juodkazis[1]
[1] *Swinburne University of Technology (Australia),* [2] *Yokohama National University (Japan)*

Focused ion beam milling with Au+, Au2+, Si+, Si2+ ion species has been carried out on Au sputtered films to define arrays of square and rectangular nanoparticles with strong extinction at around 800 nm wavelength. Si2+ ions were also used to define nanogaps for THz photoconductive switch avoiding an electrical short between nano-contacts. Performance of the fabricated patterns is compared with those milled with Ga+.

12:25 : Band gaps induced by vacuum photons in closed semiconductor cavities
Oleg Kibis[1], Kristin Bjorg Arnardottir[2], Ivan Shelykh[2]
[1] *Novosibirsk State Technical University (Russia),* [2] *University of Iceland (Iceland)*

We consider theoretically a closed (zero-dimensional) semiconductor microcavity where a confined vacuum photonic mode is coupled to electrons in the valence band of the semiconductor. It is shown that vacuum-induced virtual electron transitions between valence and conduction bands result in renormalization of electron energy spectrum. As a consequence, vacuum-induced band gaps appear within the valence band. Calculated values of the band gaps are of sub-meV scale, which makes this QED effect measurable in state-of-the-art experiments.

10:20 - 11:55 — NAC 1/211

Session 4A9

Large-scale metamaterial assemblies II

Organized by: Jake Fontana

Chaired by: Jake Fontana

10:20 : Metamaterial SERS Substrates Based on Au Nanoparticle and Block Copolymer Self-Assembly
Xin Zhang, Robert M. Briber, Oded Rabin
University of Maryland College Park (USA)

Metamaterials consisting of gold nanoparticle arrays on silicon and gold substrates were fabricated by self-assembly and were used as surface enhanced Raman scattering substrates. These large area and low cost substrates have uniform enhancement factors. All the metamaterial components contribute to the signal enhancement, as demonstrated by modifying the nanoparticle size, substrate materials, and degree of ordering

of the array. Metamaterial optimization resulted in enhancement factors using 4-aminothiophenol as a probe and 785 nm laser excitation.

10:35 : Invited talk
Chiral Plasmonic Nanolens Arrays via Directed Assembly of Gold Nanoparticles
Sushmita Biswas[1], Xiaoying Liu[2], Jeremy Jarrett[3], Vitaliy Pustovit[1], Augustine Urbas[1], Kenneth L. Knappenberger Jr.[3], Paul Nealey[2], Richard Vaia[1]
[1] *Air Force Research Laboratory (USA),* [2] *The Institute for Molecular Engineering-University of Chicago (USA),* [3] *Florida State University (USA)*

Efficient focusing of linear and higher order optical fields holds immense potential in nanophotonics, such as enabling novel on-chip optical functionality. Metal nanoparticle assemblies are promising due to their intense inter-particle electromagnetic interactions, however large-area fabrication of ordered arrays with request local architectural precision and surface quality is extremely challenging. In this work, we demonstrate the feasibility of surface-directed assembly of gold nanoparticles to produce deterministic arrays with high-yield and controlled orientation of complex homo and hetero-architectures.

10:55 : Invited talk
Nanocrystal superlattices as tunable metamaterial assemblies
Matteo Cargnello
Stanford University (USA)

Nanocrystal superlattices as tunable metamaterial assemblies are the focus of this contribution. Self-assembly strategies can be utilized to obtain films with long range ordering and properties that are dictated by the appropriate choice of building blocks and their spatial organization. As key examples, quasi-quaternary and doped nanocrystal superlattices are reported, where optical and electrical properties of ordered layers are tuned by varying the 3D arrangement of the constituent building blocks.

11:15 : Invited talk
High-throughput Optical Metamaterials
Jake Fontana, S. A. Trammell, C. M. Soto, J. Naciri, B. R. Ratna
Naval Research Lab (USA)

By controlling the spatial and orientational order of plasmonic nanoparticles unique electromagnetic, electronic and chemical properties have been demonstrated. Developing assembly strategies to bridge these properties into materials for disruptive technologies is critical. Here I highlight our recent approaches to develop high-throughput macroscopic metamaterials.

11:35 : Invited talk
Large-area metamaterials and gram-scale metafluids: design, fabrication, and nano-optical tomographic characterization
Jennifer A. Dionne
Stanford University (USA)

We introduce the design, fabrication, and three-dimensional nano-optical characterization of large-area metamaterials and gram-scale metafluids. First, we use transformation optics to design a broadband metamaterial constituent. Then, we describe a novel tomographic technique to visualize radiative optical transitions in this metamaterial constituent with nanometer-scale resolution. Finally, we demonstrate the fabrication of large-area metamaterials and gram-scale metafluids, and show how these materials can be used to enhance the efficiency of solar upconversion.

10:20 - 11:35 — NAC 1/201

Session 4A10

Metamaterials and negative index materials V

Chaired by: Min Qiu

10:20 : Design of metamaterial microwave devices
E. Laamari[1], Saleh Chaker[1], D. Bensafieddine[1], M. Bouzouad[2]
[1] *Telecommunications, Signal and Systems Laboratory (Algeria),* [2] *University Amar Telidji of Laghouat (Algeria)*

The main goal of this work is to design metamaterial based microwave devices. The body metamaterial layer behaves as an a refractive index close to zero (n1). On this body metamaterial layer we can specify different zones, with arbitrary shape size, and position, behaving as an effective medium with a refractive index greater than unity (n2). we obtain waveguides (circular, rectangular, etc) horn antennas (conical or pyramidal, etc) with different size.

10:35 : Reconfigurable microwave metamaterial based on arrays of magnetic nanowires
Ivan Lisenkov[1], Anatoly Belanovsky[2], Sergey Nikitov[2], Vasyl Tyberkevych[1], Andrei Slavin[1]
[1] *Oakland University (USA),* [2] *Moscow Institute of Physics and Technology (Russia)*

We propose to use arrays of magnetic nanowires in the ferromagnetic and antiferromagnetic ground states as a reconfigurable metamaterial for microwave applications. We show that the reflection of a plane electromagnetic wave from the array strongly depends on the magnetic ground state of the array. In particular, in the case of a ferromagnetic ground state the reflected signal is nearly circularly polarized in a wide range of the angles of incidence.

10:50 : Polarization-independent negative index metamaterial
Morteza Karami, Steven Kitchin, Michael Fiddy
University of North Carolina at Charlotte (USA)

We have designed a polarization-independent left-handed metamaterial, and describe its electromagnetic properties. A 3D crossed design based on a meandering wire structure is demonstrated as a polarization insensitive metamaterial with negative effective index.

11:05 : Temperature tunable semiconductor metameterial for THz applications
Kirill Koshelev[1], Andrey Bogdanov[2]
[1] *State Polytechnic University (Russia),* [2] *ITMO University (Russia)*

We introduce a new model of homogeneous temperature tunable THz metamaterial with controllable frequency range of hyperbolic dispersion based on semiconductor superlattice with doped quantum wells. We propose a method of thermal manipulating the shape of equal fre- quency surface in k-space. We discuss the phenomenon of permittivity tensor signature changing which results in transition from dielectric to hyperbolic regime of the material.

11:20 : Measurements of Green function and local density of states in hyperbolic metamaterials.
Kaizad Rustomji[1], Charaf Abdeddaim[1], Md. Mahbub Alam[1], Md. Shofiqul Islam Khan[1], Redha Abdeddaim[1], Sebastien Guenneau[1], Boris Kuhlmey[2], Stefan Enoch[1]
[1] *Institut Fresnel (France),* [2] *University of Sydney (Australia)*

We will present microwave measurements and modelling of hyperbolic metamaterial. We focus on measurements of emission properties of embedded sources in addition to effective permeability and permittivity.

11:35 - 12:20 — NAC 1/201

Session 4A11

Acoustic metamaterials II

Chaired by: Fabrice Lemoult

11:35 : A Lightweight yet Sound-proofing Honeycomb Acoustic Metamaterial
N. Sui[1], X. Yan[1], T. Y. Huang[1], J. Xu[2], F. G. Yuan[1], Yun Jing[1]
[1] *North Carolina State University (USA),* [2] *Massachusetts Institute of Technology (USA)*

A class of honeycomb acoustic metamaterial possessing lightweight and yet sound-proofing properties is designed and experimentally verified. This metamaterial having a remarkably small area density can achieve

low frequency (<500 Hz) sound transmission loss (STL) >45 dB. The high STL is attributed to the large acoustic impedance and the broad-band negative effective density introduced by no-mass-attached membranes. The proposed metamaterial can also be used as the core in sandwich structures that could exhibit strong, lightweight, and sound-proofing properties.

11:50 : Coriolis Force Induced Topological Order for Classical Vibration
Yao-Ting Wang[1], Pi-Gang Luan[2], Shuang Zhang[1]
[1] *University of Birmingham (United Kingdom),* [2] *National Central University (Taiwan)*

A two-dimensional mass-spring system with Honeycomb lattice for topologically protected vibrational edge modes is proposed. Interestingly, as the system is placed on a constantly rotational coordinate system, the Coriolis force resulted from the non-inertial reference frame provides a possibility to break the time-reversal symmetry. Thus, caused from topologically non-trivial band gaps, phononic edge modes are present between bands, which are verified by the calculation of Chern numbers for corresponding bands.

12:05 : Multiplexed Acoustic Sensing with Metamaterial-based Physical Layer Encoding
Yangbo Xie, Tsung-Han Tsai, David J. Brady, Steven Cummer
Duke University (USA)

We present an acoustic sensing system that combines acoustic metamaterials and multiplexed computational sensing. Acoustic signals are directly encoded on the physical layer by the tailored resonant modulations of metamaterials in the measurement stage, and the object information is computed with L1-norm regularization algorithms in the reconstruction stage. The experimental results of two sensing tasks are demonstrated. The presented design method may be useful for sound source localization, robust speech recognition and other acoustic imaging modalities.

Lunch and Exhibit Inspection

12:30 - 14:00

14:00 - 14:35 — Aronow Theater

Session 4A12

Symposium 2: Industrial applications of metamaterials II

Organized by: David T. Crouse and Mike A. Fiddy

Chaired by: David T. Crouse and Mike A. Fiddy

14:00 : Invited talk
A 384 x 288 microbolometer-based pixel camera with metamaterial absorbers for real-time terahertz imaging applications
H. Oulachgar, Linda Marchese, M. Terroux, S. Ilias, J.-E. Paultre, D. D'Amato, B. Tremblay, Patrick Beaupre Francis Provençal, C. Alain, P. Topart, F. Genereux, H. Jerominek, A. Bergeron
INO (Canada)

INO has leveraged its expertise in the development of uncooled microbolometer detectors for infrared imaging to produce terahertz (THz) imaging systems. Optimization of the sensitivity in the THz band has been accomplished by the addition of metamaterial-based absorbers to its microbolometer focal plane arrays. With the addition of custom THz lens objectives, INO now produces the IRXCAM-THz-384 camera, capable of imaging hidden objects for applications such as non-destructive testing, non-intrusive threat detection and see-through-the-wall imaging.

14:20 : Tunable Photonic Band Gap Materials for High Sensitivity Displacement Transduction in MEMS Inertial Sensors
Salvatore Baglio, Bruno Ando, Carlo Trigona
University of Catania (Italy)

This paper deals with the synergic use of Photonic Band Gap (PBG) materials and Micro-Electro-Mechanical Systems. Stacked metal-dielectric PBG structures which include also one air gap are considered, changes induced in the air gap will affect the overall optical properties thus making the PBG mechanically tunable. Applications to MEMS inertial sensors are presented with particular emphasis on integrated Gyroscopes where the proposed approach allows for conjugating two diverging features as mechanical robustness and high sensitivity to very small displacements.

14:35 - 15:35 — Aronow Theater

Session 4A13

Emerging applications

Chaired by: Zubin Jacob

14:35 : Passive Terahertz Compressive Imaging with Fano Resonances
Xuefeng Li, Xinya Bian, Bill Milne, Daping Chu
University of Cambridge (United Kingdom)

We introduce a novel approach for terahertz compressive imaging with a single-pixel camera. Instead of actively switching sensing matrix, we utilize the source frequency (0.8-1.6 THz) as an index for various measurement masks. Using a systematic approach to engineer ultra-sharp Fano resonances, we are able to design an efficient passive metamaterial aperture for near perfect reconstruction. Such a device architecture could provide a new path for cost-effective THz imaging.

14:50 : Frequency selection in mid-IR quantum cascade lasers using built-in meta-surfaces of periodic nano-antennas
Tommaso Ongarello, Adel Bousseksou, Aloyse Degiron, Raffaele Colombelli
Paris Sud University (France)

A meta-surface, consisting of a periodic array of linear nano-antennas, is implemented onto the top-surface of a mid-infrared quantum-cascade laser (QCL). The surface exhibits relatively narrow resonances, due to a collective diffractive response. Once implemented onto the QCL, mimicking a 2nd-order distributed feedback laser resonator, frequency selectivity is achieved with 1.5 percent of the laser surface covered by metal. The laser-antenna coupled-mode presents anomalous effective-index dispersion, demonstrating that the array acts as a meta-surface in a surface-emitting laser source.

15:05 : Metamaterial Antireflection Coating for Biological Tissues at Millimeter Waves
Helena Cano Garcia[1], Panagiotis Kosmas[1], Efthymios Kallos[2]
[1]*King's College London (United Kingdom),* [2]*Medical Wireless Sensing Ltd. - Metamaterial Technologies Inc. (United Kingdom)*

This paper presents simulation results of two different metamaterial-based antireflection coatings operating at millimeter waves. The first design minimizes the reflection from an acrylic slab and the second design minimizes the reflection from human skin. These designs achieve a reduction in the reflected power by 16 percent and 39 percent, respectively, at 60 GHz. The results open up the possibility of enhanced medical diagnostics using radio waves by reducing the EM impedance mismatch between the human skin and the surrounding environment.

15:20 : Quantum efficiency enhancement of a midwave infrared photodetector by coupling to surface plasmon polariton modes
Jill Nolde[1], M. Kim[2], Chul Kim[1], Eric Jackson[1], Chase Ellis[1], Joshua Abell[1], Orest Glembocki[1], Chadwick Canedy[1], Joseph Tischler[1], Igor Vurgaftman[1], Jerry Meyer[1], Edward Aifer[1]
[1]*Naval Research Laboratory (USA),* [2]*Sotera Defense Solutions, Inc. (USA)*

We demonstrated enhancement of the quantum efficiency (QE) of a thin InAsSb photodetector using a 1D plasmonic surface grating. The relation between grating period and enhancement wavelength is clearly shown as resonant dips in the measured grating reflectance and as peaks in the QE spectra. The QE and reflectance data are well matched to numerical simulations. From these results, we estimate a grating coupling efficiency

of 34 percent.

15:35 - 16:20 — Aronow Theater

Session 4A14

Transformational electromagnetics

Chaired by: Amir Zaghloul

15:35 : Optical Carpet Cloaking Using Metamaterials
Mohamed M. Badr, Nourhan H. Fouad, Khaled G. Abdel-Wahab, Eslam M. Hefny, Kareem S. Elassy, Hussein H. Ghouz
Arab Academy for Science-Technology and Maritime Transport (Egypt)

Invisibility has always been a science fiction, but due to the emergence of the metamaterials it is now turned to reality. In this paper, by using the mathematical approaches which are mixing rules of materials and transformation optics technique, we were able to design and simulate an optical carpet cloak operating at 700nm wavelength on COMSOL Multiphysics. We designed a triangular invisibility cloak with layered structure of alternative silicon air layers according to Transformation optics technique.

15:50 : Fano-induced cloaking of dielectric objects via Mie resonances
K. Samusev, M. Rybin, D. Filonov, P. Belov, Yury Kivshar, Mikhail Limonov
ITMO University (Russia)

We reveal that the Fano resonances can be employed for achieving an efficient cloaking of dielectric structures with high refractive index at any angle of observation. Our finding is based on novel physics of the cascades of Fano resonances observed in the classical Mie scattering, and it is also verified by direct experimental results for switching of a water cylinder filled with water from visible to invisible regimes by changing dielectric permittivity of water with heating.

16:05 : Parallel transport design for gradient index lenses
David Schurig[1], S. Venkatesh[1], N. Korevarr[2]
[1] *University of Utah ECE Department (USA),* [2] *University of Utah Math Department (USA)*

The design of polarization dynamics through the connection to torsion and parallel transport is inexact for finite wavelength, since the approach relies on the ray curves of geometric optics. We compare the polarization fields of parallel-transport-designed, chirality-enhanced gradient index lenses from full-wave simulations with those of their geometric optic specification.

14:00 - 14:55 — NAC 0/201

Session 4A15

Symposium 1: Functional Metastructures and Nanomaterials: Properties, Fabrication and Modeling X

Organized by: Alexander Govorov and Hilmi Volkan Demir

Chaired by: Gary Wiederrecht and Aycan Yurtsever

14:00 : Invited talk
Functional Assemblies with Plasmonic Semiconductor and Metal Nanoparticles
Jessica Rodriguez-Fernandez
Ludwig Maximilians University (Germany)

In this talk several examples of functional assemblies of plasmonic nanoparticles based on metal and vacancy-

doped semiconductors will be presented. It will be shown how various self-assembly approaches can be used to control the spatial positioning and self-organization of different plasmonic building-blocks and how this grants access to the investigation of interesting optical effects.

14:20 : Invited talk
Chiral plasmonic nanostructures induced by PCR assembly
Liguang Xu, Hua Kuang, Chuanlai Xu
Jiangnan University (China)

Plasmon induced circular dichroism (CD) response in the region of visible light is an emerging scientific subject. Although great progress has made in novel chiral nanostructure design and preparation, there are still significant difficulties in scaling-up preparation and real applications. Herein, we report a powerful tool of polymerase chain reaction (PCR) to assembly nanoparticles. CD responses of nanostructures can be manipulated on both intensity and wavelength in the range of 400 nm to 700 nm.

14:40 : Coupling single fluorescent molecules to plasmonic antennas with DNA
Mickael Busson[1], Vincent Maillard[1], Alexis Devilez[2], Brian Stout[2], Nicolas Bonod[2], Jerome Wenger[2], Sebastien Bidault[1]
[1] *ESPCI ParisTech (France),* [2] *Aix-Marseille University (France)*

We use DNA self-assembly to introduce reproducibly single emitters in the center of plasmonic antennas. A nanometer control of the emitter position allows us to enhance its spontaneous decay rate by two orders of magnitude. The effective quantum yield and emission rate of these nanostructures can be optimized by increasing the gold particle diameters. Furthermore, a control over the excitation polarization allows us to select emitters whose transition dipole is preferentially parallel to the axis of the dimer antenna.

14:55 - 16:10 — NAC 0/201

Session 4A16

FSS, HIS and Extraordinary transmission

Chaired by: Mahbub Hoque

14:55 : A New Approach for Extraordinary Transmission through Subwavelength Apertures Using ENNZ Metamaterials
Elham Baladi, Justin G. Pollock, Ashwin K. Iyer
University of Alberta (Canada)

Extraordinary transmission (ET) through a square array of subwavelength apertures on a metallic screen has been studied extensively, and has been attributed mainly to the interaction of surface plasmons, or the formation of leaky waves. This work describes a novel approach for achieving ET, in which the subwavelength apertures are treated as below-cutoff circular waveguides. Lining these apertures with epsilon-negative and near-zero (ENNZ) permittivity metamaterials enables the propagation of frequency-reduced guided modes through the apertures, resulting in strong transmission.

15:10 : Hybridized Concentric-Twisted DSRRs Leading to Plasmon Induced Transparency
Mohammad Hokmabadi, Patrick Kung, Seongsin Kim
The University of Alabama (USA)

We introduce a novel scheme to generate Plasmon Induced Transparency (PIT) by hybridizing two concentric-twisted double split ring resonators. We demonstrate that counter-directional twisting of small SRRs can perturb both SRRs response eventuating new states through red shift of the first and blue shift of the second resonance. Contrarily, by co-directional twisting of small SRRs and focusing on first resonance, we manifest PIT which is formed as a result of splitting the first resonance into two dependent bright modes.

15:25 : Design of a novel dual-band 2.4/5.5 GHz Frequency Selective Surface using loop elements
Reza Chaharmir, J. Ethier, J. Shaker
Communication research Centre Canada (Canada)

A novel dual-band Frequency Selective Surface (FSS) using a combination of open and closed loops is designed to block Wi-Fi signals at 2.45 GHz and 5.5 GHz and transmit the signals outside of the Wi-Fi bands. The structure was fabricated using Printed Electronics (PE) technology and good agreement between measured and simulated results was achieved.

15:40 : Role of waveguide mode in the extraordinary optical transmission without plasmons
Yunya Xie, Haitao Liu, Hongwei Jia, Ying Zhong
Nankai University (China)

We propose a microscopic surface-mode model for the extraordinary optical transmission through subwavelength metallic slit array covered with a thin dielectric layer under illumination of transverse-electric polarization. The model captures the main feature of EOT and provides a phase-matching condition to predict the transmission resonance. Quantitative comparison between numerical calculations and model predictions shows that besides the fundamental waveguide mode, other residual field in the thin dielectric layer also contributes to the EOT without surface plasmon polariton.

15:55 : Ultra-wide Band Metasurface for Low-profile RF Antenna Applications Based on High-Mu Low-Epsilon Composites
Taulant Rexhepi, David Crouse
CUNY City College of New York (USA)

Metamaterial based antennas have been extensively studied in the past decade as means to reduce size of planar antennas. However they suffer from imposed bandwidth limitations which confines their use to only narrowband applications. In this work we present an ultra-wide band high impedance surface based on high permeability low permittivity substrate containing composite materials.

14:00 - 15:15 — NAC Ballroom

Session 4A17

Structured light

Chaired by: Jennifer Dionne

14:00 : Invited talk
High-Q All-dielectric Metasurfaces
Yuanmu Yang[1], Ivan I. Kravchenko[2], Dayrl P. Briggs[2], Jason Valentine[1]
[1] *Vanderbilt University (USA),* [2] *Oak Ridge National Laboratory (USA)*

Here,we present an experimentally demonstration of a classical analogue of EIT using all-dielectric silicon-based metasurfaces. Due to extremely low absorption loss and coherent interaction of neighboring meta-atoms, a Q-factor of 483 is observed, leading to a refractive index sensor with a figure-of-merit of 103. Furthermore, we show that the silicon-based metasurfaces can be utilized for significantly enhancing nonlinear conversion.

14:20 : Aperiodic Nanophotonics: A New Paradigm for Engineering Light's Orbital Angular Momentum
Hong Liu, Muhammad Q. Mehmood, Kun Huang, Lin Ke, Huapeng Ye, Patrice Genevet, Mingsheng Zhang, Cheng-Wei Qiu, Jinghua Teng
*A*STAR (Singapore)*

I would like to introduce our recent works using aperiodic nanostructures to engineer light's orbital angular momentum (OAM), which has a wide spectrum of promising applications. We propose nanostructured flat logarithmic-spiral zone plates (LSZP) to produce as well as focus optical vortices in the broadband visible range. Another work is about an analog optical vortex transmitter producing theoretically boundless quanta of OAM. This novel approach bridges the technology gap between digitalization, discretization and analog generations of optical OAM.

14:35 : Invited talk
Absorption of the Twisted Photons by Atoms

Andrei Afanasev[1], **C. E. Carlson**[2], **A. Mukherjee**[3]
[1] *The George Washington University (USA),* [2] *College of William and Mary (USA),* [3] *Indian Institute of Technology Bombay (India)*

We discuss novel features of twisted-light absorption both by hydrogen-like atoms. In particular, we extend the treatment of atomic photoexcitation by twisted photons to include atomic recoil, derive generalized quantum selection rules and consider phenomena of forbidden atomic transitions. We also suggest the measurements that demonstrate unique features of the optical vortices at the quantum level.

14:55 : Invited talk
Spin-orbit interactions of resonating metasurfaces
Xiaobo Yin
University of Colorado (USA)

The spin-orbit interaction destroys the rotational symmetry of particles' spin degree of freedom and introduces a universal transverse spin current regardless the particle nature of an electron or photon. Here we show that an optically thin metasurface refracts light anomalously and supports negative photonic spin Hall effect when a light beam is negatively refracted. Moreover, we will show how the inversion symmetry in the 2D metasurfaces plays a role and generates a new type of photonic Hall effect.

15:15 - 16:15 — NAC Ballroom

Session 4A18

Photonics based on 2D materials

Chaired by: Liang Feng

15:15 : Graphene Nano-roads for Nanoscale Particle Transport
Mohammad Danesh[1], **Zhengtong Liu**[2], **Cheng-Wei Qiu**[1]
[1] *National University of Singapore (Singapore),* [2] *Institute of High Performance Computing (Singapore)*

The capability to accurately control the position of nanoparticles is of great interest in the nano-sciences. However, controlling the exact position of sub 10nm particles can be particularly challenging. Here we propose a low power method to overcome this challenge by utilizing the tunable dirac plasmons in a nanostructured graphene nanoroad. In our nanoroad we produce an electrically tunable optical potential and carefully study the nanoparticle transport using langevin dynamics and also consider the plasmonic heating effects.

15:30 : Perfect extinction of millimeter waves through a single atomic layer
Hyeong-Ryeol Park[1], **Seon Namgung**[1], **Xiaoshu Chen**[1], **Nathan Lindquist**[2], **Vincenzo Giannini**[3], **Yan Francescato**[3], **Stefan Maier**[3], **Sang-Hyun Oh**[1]
[1] *University of Minnesota (USA),* [2] *Bethel University (USA),* [3] *Imperial College London (United Kingdom)*

We experimentally demonstrate 99 percent extinction of millimeter wave transmission when single layer graphene covers the openings of 2-nm-wide apertures through a metal film. By resonantly coupling millimeter waves with annular nanogaps, the extremely localized fields lead to the nearly-perfect extinction and strong absorption in SLG. Furthermore, by integrating these ionic gel, enhanced intraband absorption in the graphene leads to 80 percent modulation of millimeter waves with an operational voltage as low as 1.5V.

15:45 : Distortion of Surface Plasmon Polariton Propagation on Graphene due to Chemical Potential Variation
Stamatios Amanatiadis, Nikolaos Kantartzis
Aristotle University of Thessaloniki (Greece)

The variation of graphene's chemical potential owing to surface plasmon polariton excitation and the influence of the former on their propagation properties is examined in this paper. Although the chemical potential is controlled though a constant electric field bias, the excitation of the highly confined surface wave is capable of affecting the chemical potential, thus disrupting the wave's natural propagation. Numerical results, extracted by means of an accurate finite-difference time-domain scheme, validate this interesting convention.

16:00 : Fiber-to-chip meta-grating couplers
Kristjan Leosson[1], J. P. B. Mueller[2], Federico Capasso[2]
[1] *University of Iceland (Iceland),* [2] *Harvard University (USA)*

We analyze coupling of light to planar dielectric waveguides using polarization-selective meta-grating couplers. The meta-grating couplers are based on metal nanoantenna arrays, arranged in a fishbone pattern. High index contrast waveguide platforms like TiO2/SiO2 and silicon-on-insulator are considered.

14:00 - 15:35 — NAC 1/202

Session 4A19

Metamaterials based on novel symmetries IV

Organized by: Jensen Li and Minghui Lu

Chaired by: Jensen Li and Minghui Lu

14:00 : Invited talk
Dielectric metasurfaces for phase, amplitude and polarization control
Uriel Levy, Boris Desiatov, Jonathan Bar David
The Hebrew University of Jerusalem (Israel)

In this talk we present our recent work on dielectric metasurfaces for phase, amplitude and polarization control. We show new results in the near IR and the mid IR regime, in which the control over the properties of light can be achieve by controlling the retardation of a subwavelength periodic structure or by controlling the resonances of nano beams in semiconductors. We discuss approaches for achieving broadband retardation of light by tailoring the dispersion properties of the metasurface.

14:20 : Photonic Analogue of Quantum Spin Hall Effect
Xiao-Chen Sun, Cheng He, Xiaoping Liu, Ming-Hui Lu, Yan-Feng Chen
Nanjing University (China)

Recently, some works doubt that the robustness of the previous reported photonic topological insulators (PTIs) is not protected by time-reversal (TR) symmetry, which destroys the foundation of the principle of topological insulator (TI). To clarify the symmetry protected mechanism of PTIs, we introduce a new symmetry operator, which has the similar form with TR symmetry operator of electrons. By constructing photonic crystal, we demonstrate that the there will always be TI phenomenon protected by such new symmetry.

14:35 : PT - symmetry, complex coordinates, and the suppression of reflection
Simon Horsley
University of Exeter (United Kingdom)

In this talk I will explain when it can be useful to treat space - time coordinates as complex numbers. Our results demonstrate that there is a simple way to control reflection from an inhomogeneous medium in terms of the properties of the permittivity in the complex position plane, and that this is intimately related to PT - symmetry.

14:50 : Manipulating gauge-field with metamaterials
Fu Liu[1], Simon Horsley[2], Jensen Li[1]
[1] *University of Birmingham (United Kingdom),* [2] *University of Exeter (United Kingdom)*

By considering the local symmetries of a special duality operation in exchanging electric and magnetic fields for two dimensional wave propagation, we identify a real-space gauge field realized using reciprocal anisotropic metamaterials. It manipulates waves by shifting the centers of local dispersion surfaces instead of varying their sizes and shapes. It allows us to design spin-enabled optical devices, such as beam splitters, waveguides with asymmetric transmission and invisibility cloaks.

15:05 : Transition between propagation, perfect absorption and lasing states in energy-balanced materials with both gain and loss

Ping Bai[1], **Ying Wu**[2], **Yun Lai**[1]
[1] *Soochow University (China),* [2] *King Abdullah University of Science and Technology (Saudi Arabia)*

We investigate the propagation of electromagnetic waves in materials with both gain and loss in either permittivity or permeability. When the gain and loss are balanced with refractive index being a real number, such materials can support propagating waves like media without gain or loss. Based on photonic crystals with both gain and loss, we have achieved effective media of such energy-balanced materials.

15:20 : Roles of PT and RT symmetries in non-reciprocal periodic photonic systems: simple examples
Kin Hung Fung
The Hong Kong Polytechnic University (Hong Kong)

We discuss the roles of PT symmetry and RT symmetry in phenomena associated with non-reciprocal dispersion. We present a one-way surface mode in a PT symmetric magnetized photonic system at effective mu close to zero. The new mode is non-propagating when the system is infinite while it becomes propagating in the finite case. In another example, we show that a magnetized diatomic chain of plasmonic nanoparticles can support non-reciprocal dispersion and its relation to RT symmetry.

15:35 - 16:20 — NAC 1/202

Session 4A20

Plasmonics and nanophotonics VII

Chaired by: Chuanlai Xu

15:35 : Lasing in plasmonic periodic, aperiod and disordered systems
Aaltje Schokker, Femius Koenderink
FOM institute AMOLF (Netherlands)

We show lasing in lattices of silver particles in a dye-doped waveguide. Due to the strong scattering strength of silver particles, the band diagram shows an unconventionally large stop gap. We use these large stop-gap systems to investigate a basic question: how much order do we need to obtain lasing?

15:50 : Thermo-Optically Tunable Flat-Lenses at Near Infrared Wavelengths
Jonathan Pugh[1], **Jamie Stokes**[1], **Martin Lopez-Garcia**[1], **Choon-How Gan**[2], **Geoff Nash**[2], **John Rarity**[1], **Martin Cryan**[1]
[1] *University of Bristol (United Kingdom),* [2] *University of Exeter (United Kingdom)*

We present a slot-grating flat lens fabricated in thin layers of amorphous silicon-on-aluminum. The structures are designed to collimate the light propagating through the slot at lambda=833nm and 1550nm. The high dependency of refractive index on temperature for amorphous silicon has the potential to enable thermo-optic focusing and steering.

16:05 : 3D manipulation with plasmonic nanotweezers
Johann Berthelot[1], **Srdjan Acimovic**[2], **Mathieu Juan**[3], **Mark Kreuzer**[1], **Jan Renger**[1], **Romain Quidant**[1]
[1] *ICFO (Spain),* [2] *Chalmers University (Spain),* [3] *Macquarie University (Australia)*

We demonstrate in this paper stable optical trapping and accurate 3D manipulation of a single dielectric nanoparticle with a scanning optical near field probe.

14:00 - 16:40 — ASRC Conference Room

Session 4A21

Nitrogen Vacancy Centers in Diamond II

Organized by: Carlos Meriles

Chaired by: Carlos Meriles

14:00 : Invited talk
Quantum information with nuclear spins in diamond
Tim Hugo Taminiau
Delft University of Technology (Netherlands)

In this talk I will present our latest results towards optically connected quantum networks and quantum error correction based on nuclear spins in diamond.

14:20 : Invited talk
Nanoscale Imaging of Thermal Conductivity Using Nitrogen Vacancy Center in Nanodiamond
Abdelghani Laraoui[1], Halley Aycock-Rizzo[1], Xi Lu[2], Elisa Riedo[2], Carlos Meriles[1]
[1] *CUNY-City College of New York (USA),* [2] *Georgia Institute of Technology (USA)*

We use nanodiamond-hosted nitrogen-vacancy (NV) center attached to the apex of a silicon tip as a local temperature sensor. We apply an electrical current to heat up the tip to a predefined temperature and rely on the NV to monitor the small thermal changes the tip experiences as it is brought into contact with surfaces of varying thermal conductivity. With the aid of a combined AFM/confocal setup, we image the thermal conductivity of engineered microstructures with 10 nm resolution

14:40 : Invited talk
Fast Control of Electron-Nuclear Spin Systems in Diamond
Paola Cappellaro
Massachusetts Institute of Technology (USA)

Fast and high fidelity control of quantum systems and protection from decoherence are critical for quantum computation and sensing devices, but they often pose contradicting requirements. To overcome these issues, a strategy is to use a quantum actuator that interfaces the system of interest with the classical controller, thus allowing fast operations while preserving the system coherence. As a paradigmatic example, we focus on implementation based on the NV center electronic spin in diamond and nearby nuclear spins.

15:00 : Invited talk
Towards the silicon-vacancy centre in diamond as a spin-photon interface
Lachlan Rogers
Ulm University (Germany)

The silicon vacancy (SiV) centre in diamond is a remarkable single photon emitter. Half of its total fluorescence is contained within a stable spectral peak with lifetime-limited linewidth. These properties have enabled the demonstration of indistinguishable photons from distinct SiV centres, which might be used to distribute entanglement between qubits for quantum information processing. Coherent electronic spin states have been prepared optically in SiV centres, and it may be possible to produce technologically useful spin-photon interfaces.

15:20 : Invited talk
High fidelity storage of arbitrary photon states in a single nuclear spin in NV center in diamond
Sen Yang[1], Ya Wang[1], Thai Hien Tran[1], S. Ali Momenzadeh[1], Matthew Markham[2], Daniel Twitchen[3], Ping Wang[4], Wen Yang[4], Rainer Stohr[1], Philipp Neumann[1], Hideo Kosaka[5], Jorg Wrachtrup[1]
[1] *University of Stuttgart (Germany),* [2] *Global Innovation Centre (United Kingdom),* [3] *Element Six Technologies US Corporation (USA),* [4] *Beijing Computational Science Research Center (China),* [5] *Yokohama National University (Japan)*

Interfacing photons with solid state quantum systems is important for quantum information processing and communication. Here we demonstrate storage of a photon qubit in a single solid-state nuclear spin qubit with fidelity exceeding 95 percent. The nuclear spin memory is made robust against repetitive excitation of the electron spin, a key requirement for a versatile quantum node. The photon-nuclear spin interface and the

nuclear spin memory demonstrated here constitutes a further step towards a practical solid-state quantum network.

15:40 : Invited talk
Magnetic Resonance with Single Nuclear-Spin Sensitivity
Alexander O. Sushkov[1], Igor Lovchinsky[1], Nick Chisholm[1], Elana Urbach[1], Nathalie de Leon[1], Kristiaan De Greve[1], Ruffin Evans[1], Eric Bersin[1], Fedor Jelezko[1], Ronald Walsworth[2], Hongkun Park[1], Mikhail Lukin[1]
[1] *Harvard University (USA),* [2] *Harvard-Smithsonian Center for Astrophysics (USA)*

Our method of nanoscale magnetic sensing and imaging makes use of nitrogen-vacancy (NV) color centers a few nanometers below the surface of a diamond crystal. Using individual NV centers, we perform NMR experiments on single protein molecules. We use isolated electronic-spin quantum bits (qubits), that are present on the diamond surface, as magnetic resonance reporters, for sensing, coherent coupling, and imaging of individual proton spins on the diamond surface with angstrom resolution, under ambient conditions, at room temperature.

16:00 : Invited talk
Nuclear spin cooling and statistics with diamond NV centers
Susanne F. Yelin, Swati Singh
Harvard University (USA)

A method for controlling the nuclear spin environment of artificial atoms like NV centers makes use of laser manipulation of an electronic spin transition. We describe the nuclear spin dynamics and its interplay with the optical excitation of the electronic spin and introduce a simple model of this process that allows us to study both optimal cooling parameters for nuclear spins and optimal information transfer between the optical measurement of the electron and the nuclear bath dynamics.

16:20 : Invited talk
Quantum and Nonlinear Nanophotonics with Diamond
Michael Burek, Pawel Latawiec, I-Chun Huang, Xiao Xiong, Haig Atikian, Vivek Venkataraman, Shota Kita, Marko Loncar
Harvard University (USA)

Approaches to engineer light-matter interaction in crystal diamond are discussed, along with applications in quantum information science and nonlinear optics. Examples include enhancement of emission of diamond color centers and realization of frequency combs operating in visible wavelength range.

14:00 - 15:15 — NAC 1/203

Session 4A22

Optomechanics II

Chaired by: Eric Plum

14:00 : Nonlinear mechanics of photonic crystal deformable mirrors actuated via electrostatic force
Avishek Chowdhury, I. Yeo, G. Beaudoin, I. Robert-Philip, R. Braive
CNRS (France)

Non-linearity in the nanomechanical systems have essential applications in sensing, signal processing and in many different fields of modern science and its applications. In this paper we demonstrate use of a unique photonic crystal membrane-electrode system for optomechanics where we were able to demonstrate bistability in the system along with parametric sub-harmonic excitations. These platforms are fabricated using 3D-heterogenous integration techniques and uses electrostatic force for excitation and optical interferometric schemes for detection of the mechanical modes.

14:15 : Integrated optomechanical cavity-waveguide system for coherent photonic-microwave signal processing

Kejie Fang, Matt Matheny, Xingsheng Luan, Oskar Painter
California Institute of Technology (USA)

In an integrated silicon optomechanical cavity-waveguide system, we demonstrated on-chip coherent photonic-microwave signal processing which shows clear advantages over purely photonic methods. Specifically, we obtain an optical delay of 13.3 us for a phonon waveguide length of 43 um. In addition, we demonstrated microwave filter with reconfigurable pass/rejection bands in the gigahertz band due to the radiation-pressure force induced boundary condition change.

14:30 : Remote Phonon Entanglement on a Photonic Crystal Architecture
H. Flayac, M. Minkov, V. Savona
Ecole Polytechnique Federale de Lausanne (Switzerland)

We propose a realistic heralding protocol for the preparation of remote entangled mechanical states in photonic crystal cavities. Our approach relies on the optomechanical properties of a silicon-based nanobeam structure. Pulsed sideband excitation of a Stokes process combined with a single photon detection allows writing a mechanical Bell state which can be transferred to the optical field through the anti-Stokes process. The entanglement of the nonclassical state is tested through the visibility of a characteristic quantum interference pattern.

14:45 : Reversible Quantum Opto-Acoustic Convertor
Vitaly Shumeiko
Chalmers University of Technology (Sweden)

We propose reversible interface between quantized microwave field and optical field using surface acoustic waves (SAW) as a mediator medium. SAW in piezoelectric crystals are strongly coupled to microwave photons at GHz frequencies commonly used in operation of solid state quantum devices. Coupling of SAW to optical photons is provided by elastooptic interaction, and quantum phonon-photon conversion employs the effect of stimulated Brillouin scattering. With the proposed method conversion can be realized on integrated solid state chip.

15:00 : Dispersive and dissipative optomechanical coupling in heterogeneously integrated 2D photonic crystal system
Viktor Tsvirkun, A. Surrente, G. Beaudoin, F. Raineri, R. Raj, I. Robert-Philip, R. Braive
Laboratoire de Photonique et de Nanostructures, LPN-CNRS (France)

We report on optomechanical effects in 2D photonic crystal defect cavities coupled to integrated silicon waveguides of different widths. Mechanical modes are observed systematically on a chip scale. By tuning the excitation laser wavelength, we observe optical spring effects. We extract optomechanical coupling coefficients and demonstrate the dispersive and dissipative nature of optomechanical coupling. Their relative contribution can be controlled by modifying the waveguide width, thereby paving the way for a control of optomechanical coupling on the wafer level.

15:15 - 16:00 — NAC 1/203

Session 4A23

Nanobiophotonics

Chaired by: Kuan-Ren Chen

15:15 : Molecular Optomechanics with Plasmons: backaction at the nanoscale
Philippe Roelli, Christophe Galland, Nicolas Piro, Tobias Kippenberg
Ecole Polytechnique de Lausanne (Switzerland)

We describe the coupled molecular-plasmonic systems studied in surface- and tip-enhanced Raman scattering as optomechanical cavities. Our theory unravels a hitherto overlooked mechanism: the backaction force of the plasmon on the molecular vibration. Under precise conditions it could lead to coherent amplification of the vibrational motion. This enhancement mechanism could be leveraged to design novel and more efficient sensing systems.

15:30 : Investigation of amyloidogenic proteins interaction with lipid bilayers using local plasmonic probes
V. Snika[1], L. Ramanauskaite[1], N. Grinceviciute[1], H. Xu[2]
[1] *Kaunas University of Technology (Lithuania),* [2] *St. John's University (USA)*

In this work we investigated the application of novel AFM plasmonic probes for TERS measurements of amyloidogenic proteins deposited on bilayer lipid membranes (BLM). BLMs were formed on the silver nanowedges decorated substrates for Surface Enhanced Raman Spectroscopy(SERS). The fabricated SERS substrates were found to be an appropriate tool allowing the detection of vibrational fingerprints of BLMs. The idea of the work was the investigation of structural changes of proteins and BLM's determined by their interaction with each other.

15:45 : Uptake of Liposomal Hybrids in Tumor Cells Using Surface-Enhanced Raman Spectroscopy
Dan Zhu, Zhuyuan Wang, Shenfei Zong, Hui Chen, Peng Chen, Lei Wu, Mingyue Li, Yiping Cui
Southeast University (China)

Understanding the pathways responsible for liposomes internalization into tumor cells is still crucial both from a fundamental point of liposomes and further optimization of liposomes-based intracellular delivery systems. Our study focused on the endocytosis mechanism of nanoparticles functionalized liposomes in the presence of different well-known cellular uptake inhibitors by employing surface-enhanced Raman spectroscopy (SERS). Our results reveal that the liposomal hybrids are taken up by HeLa cells mainly through clathrin-mediated endocytosis (CME), which is an energy-dependent process.

14:00 - 16:00 — NAC 1/211

Session 4A24

Metamaterials and negative index materials VI

Chaired by: Mouloud Bouzouad and Boubacar Kante

14:00 : Near-zero refractive index metamaterials boost graphene-polymer heterostructures absorbers in GHz regime
Michael Lobet, Luc Henrard, Philippe Lambin
University of Namur (Belgium)

Graphene-polymer heterostructures have recently been shown to efficiently absorb GHz electromagnetic radiation up to 50 percent. We demonstrate that those structures are robust to fabrication process defects (microscopic holes, microscopic embryos of second layer or grain boundaries). Moreover, using near-zero refractive index metamaterial as a substrate, the device tends towards perfect absorption. Absorption is consequently enhanced from 41.8 percent to 87.5 percent using a near-zero epsilon as a substrate.

14:15 : Spontaneous emission in metal-dielectric metamaterials including losses
Azat Gubaydullin, Mikhail Kaliteevski
St Petersburg Academic University (Russia)

We study the emission rate enhancement of the dipole emitter centered in the stratified metal-dielectric metamaterial, characterized by the hyperbolic isofrequency surfaces. We find out a limited enhancement of the Purcell factor in the layered metamaterial. We demonstrate that the radiative decay rate is strongly depends on a ratio of the thickness of layers and is affected by the level of losses.

14:30 : Aperiodic metallic gratings transparent for broadband electromagnetic waves
Ru-Wen Peng, Xiao-Ping Ren, Ren-Hao Fan, Mu Wang
Nanjing University (China)

In this work, we demonstrate both theoretically and experimentally that aperiodic metallic gratings can become transparent for broadband electromagnetic waves. It is shown that broadband high transmission appears in aperiodic metallic gratings (including quasi-periodic and disordered ones), which originates from the non-resonant excitations in the grating system. An optimal condition is also achieved for broadband high transparency in the grating system. The findings can be applied for transparent conducting panels, perfect

white-beam polarizers, antireflective conducting solar cells, and beyond.

14:45 : Metamaterial Inspired Multiband Antenna at UHF Band
N. A. Borhan, N. A. Murad, M. K. A. Rahim
Universiti Teknologi Malaysia (Malaysia)

In this paper, metamaterial based multiband antenna is proposed. The antenna consists of four units of double split ring resonator (DSRR) and a planar fed straight line monopole. The combination of the DSRRs and the monopole enable the resonance frequency at Ultra High Frequency (UHF) band which are 0.52 GHz, 0.54 GHz, 0.63 GHz, 0.65 GHz and 0.75 GHz for the multiple band operation. Simulation results are presented and discussed.

15:00 : A Wavelength-Sized Filter and THz Spectrometer Based on Bound Resonances of a Slotted Waveguide
Meredith A. Henstridge, Jing Zhou, L. Jay Guo, Roberto Merlin
University of Michigan (USA)

We discuss a structure consisting of two parallel copper plates bisected by subwavelength slits, which exhibits long lived Fabry Perot like resonances bound to the slits at THz frequencies. Using THz time-domain spectroscopy (THz-TDS), we measured the transmission of a focused pulse through the slotted plates. Results show good agreement with simulations. The scalability, tunability, and high quality factors of the resonances make the slotted plates a promising candidate for narrowband filtering and spectroscopic applications.

15:15 : Near infrared photon trapping in amorphous HgCdTe metamaterials
Young U. Jung[1], Igor Bendoym[2], David Crouse[1]
[1] *City College of New York (USA),* [2] *Phoebus Optoelectronics LLC (USA)*

Recently, amorphous HgCdTe films have been extensively studied for various spectral detection applications due to their interesting properties. Such properties include film deposition on any substrate, direct growth on device and higher operating temperatures with the low dark current. In this work, we investigate the photon trapping in amorphous HgCdTe metamaterial detectors that confines the light near the surface of the detecting materials and consequently reduces the thickness of the semiconducting layer with the low dark current.

15:30 : Metamaterial Perfect Absorber Based Hot Electron Photodetection
Wei Li, Zachary Coppens, Jason Valentine
Vanderbilt University (USA)

We demonstrate how metamaterial perfect absorbers can be used to achieve near-unity optical absorption using ultrathin plasmonic nanostructures with thicknesses of 15 nm, smaller than the hot electron diffusion length. By integrating the metamaterial with a silicon substrate, we experimentally demonstrate a broadband and omnidirectional hot electron photodetector with a photoresponsivity that is among the highest yet reported. We also show how this approach can be used to realize highly selective detection of circularly polarized light.

15:45 : Wideband Polarization Insensitive Metamaterial Absorber with Perfect Dual Resonances.
Osman Ayop, M. K. A. Rahim, N. A. Murad, N. A. Samsuri
Universiti Teknologi Malaysia (Malaysia)

This paper presents the analysis of wideband polarization insensitive metamaterial absorber with perfect dual resonances. The structure is designed using lossy FR4 substrate with copper layers. The resonating elements are designed using the combination of circular ring with modified circular structure. From the simulation, the proposed design achieves nearly perfect absorption at 9.81 GHz and 10.41 GHz with absorbance bandwidth of 10.29 percent. From observation, the structure can maintain the absorbance characteristic for all polarization angle.

14:00 - 16:00 — NAC 1/201

Session 4A25

Modeling and Computational Techniques II

Chaired by: Cuong Nguyen

14:00 : Quantum vacuum photon modes tuning: a new route towards multifunctional surfaces
L. Dellieu, O. Deparis, J. Muller, M. Sarrazin
University of Namur (Belgium)

While wettability phenomena have been extensively studied over the last decade, the alteration of van der Waals forces via vacuum photon modes tuning has been unnoticed in theoretical models. Using first-principles calculations, we show that superhydrophibicity of nanostructured surfaces is dramatically enhanced by properly designed vacuum photon-mode modifications. As a case study, wetting contact angles of a water droplet above a polyethylene nanostructured surface are obtained from the potential energy calculated as a function of the droplet-surface separation distance.

14:15 : Simulation and Observation of Enhanced Emission from Patterned Hyperbolic Metamaterials
Daniel Fullager[1], Ravi Hegde[2], Michael Fiddy[1]
[1] *University of North Carolina (USA),* [2] *A*STAR (Singapore)*

Hyperbolic metamaterials (HMMs) are known to possess an unbounded range of wave vectors to which radiation can couple due to the hyperbolic shape of the HMM isofrequency surface. Thus, there exists a large range of modes that can be excited by thermal fluctuations which can then reradiate by coupling to high spatial frequency features. Herein we show predicted transmission in an alternating GZO/ZnO HMM using CST microwave studio and actual observation of enhanced emission in the infrared

14:30 : Vertical Mode Expansion Method for Analyzing Metallic Nanoparticles
Xun Lu, Hualiang Shi, Ya Yan Lu
City University of Hong Kong (Hong Kong)

For analyzing cylindrical metallic nanoparticles, we present an efficient method based on expanding the electromagnetic field in one-dimensional (1D) vertical modes and solving related two-dimensional (2D) Helmholtz equations by boundary integral equations or cylindrical wave expansions. The method effectively reduces the original three-dimensional (3D) problems to 2D problems.

14:45 : Unidirectional Light Propagation Through Two-Layer Nanostructures by Momentum Transfer via Optical Near-Fields
Makoto Naruse[1], Hirokazu Hori[2], Satoshi Ishii[3], Aurelien Drezet[4], Serge Huant[4], Morihisa Hoga[5], Yasuyuki Ohyagi[5], Tsutomu Matsumoto[6], Naoya Tate[7], Motoichi Ohtsu[8]
[1] *National Institute of Information and Communications Technology (Japan),* [2] *University of Yamanashi (Japan),* [3] *National Institute for Materials Science (Japan),* [4] *Institut Neel (France),* [5] *Dai Nippon Printing Co. Ltd. (Japan),* [6] *Yokohama National University (Japan),* [7] *Kyushu University (Japan),* [8] *The University of Tokyo (Japan)*

We theoretically demonstrate direction-dependent polarization conversion efficiency, yielding unidirectional light transmission, through a two-layer nanostructure by using the angular spectrum representation of optical near-fields. The direction-dependent efficiency is characterized based on the momentum of near-field light, which is much larger than that of propagating light. The theory provides results that are consistent with electromagnetic numerical simulations. This study offers a design principle for metamaterials in realizing optical properties, such as the unidirectionality observed here.

15:00 : An improvement over the effective index method for photonic crystal simulations
Sebastian Andreas Schulz, Anthony Park, Israel De Leon, Jeremy Upham, Robert W. Boyd
University of Ottawa (Canada)

We show that the effective index method in its current form is not appropriate for the calculation of slow light behavior in photonic crystal waveguides. It consistently underestimates the group index of devices under investigation and consequently also predicts a wrong propagation loss behavior. Instead we demonstrate that 2D simulations performed using the bulk refractive index, with appropriate renormalization of the results, yield a more accurate description of device performance for the same simulation complexity.

15:15 : Efficient treatment and optimization of stacked, complex shaped homogeneous metasurfaces by an 4x4 S-Matrix formalism

Jan Sperrhake, Christoph Menzel, Thomas Pertsch
Friedrich-Schiller Universitat Jena (Germany)

We propose a 4x4 S-Matrix formalism for efficient design and optimization of stacked homogeneous metasurfaces (MS). Based on the S-Matrices of the individual MS layers arbitrary stacks with rotated or flipped layers even of incommensurable periods can be treated analytically. By choosing arbitrary layers as well as intermediate spacer layers the method provides additional degrees of freedom for optimizing optical systems with full polarization and dispersion control.

15:30 : Efficient Computation of the Spontaneous Decay Rate of Arbitrarily Shaped 3D Nanosized Resonators - A Krylov Model-Order Reduction Approach

Jorn T. Zimmerling, Lei Wei, Paul Urbach, Rob Remis
Delft University of Technology (Netherlands)

We present a Krylov model-order reduction approach to efficiently compute the spontaneous decay(SD) rate of arbitrarily shaped 3D nanosized resonators. We exploit the symmetry of Maxwell's equations to efficiently construct so-called reduced-order models that approximate the SD rate of a quantum emitter embedded in a resonating nanostructure. The models allow for frequency sweeps meaning that a single model provides SD rate approximations over an entire spectral interval. Field approximations and dominant quasinormal modes can be determined at low cost.

15:45 : Efficiency Improvement in Organic Solar Cells with Nano-structured ITO Electrodes

C. D. Wang[1], U. Hajime[2], P. Ruankham[3], T. Sagawa[2], M. J. Cryan[1]
[1] *University of Bristol (United Kingdom),* [2] *Kyoto University (Japan),* [3] *Chiang Mai University (Thailand)*

This paper uses the Finite Difference Time Domain (FDTD) method to show that the efficiency of an Organic PhotoVoltaic (OPV) cell can be significantly improved by nano-structuring the Indium Tin Oxide (ITO) electrode with a periodic arrays of holes. With air filling of the ITO structure, the number of absorbed photons is increased by 24.8 percent. Preliminary experimental results show that the power conversion efficiency (PCE) of this OPV cell can been improved by up to 14.0 percent.

Index