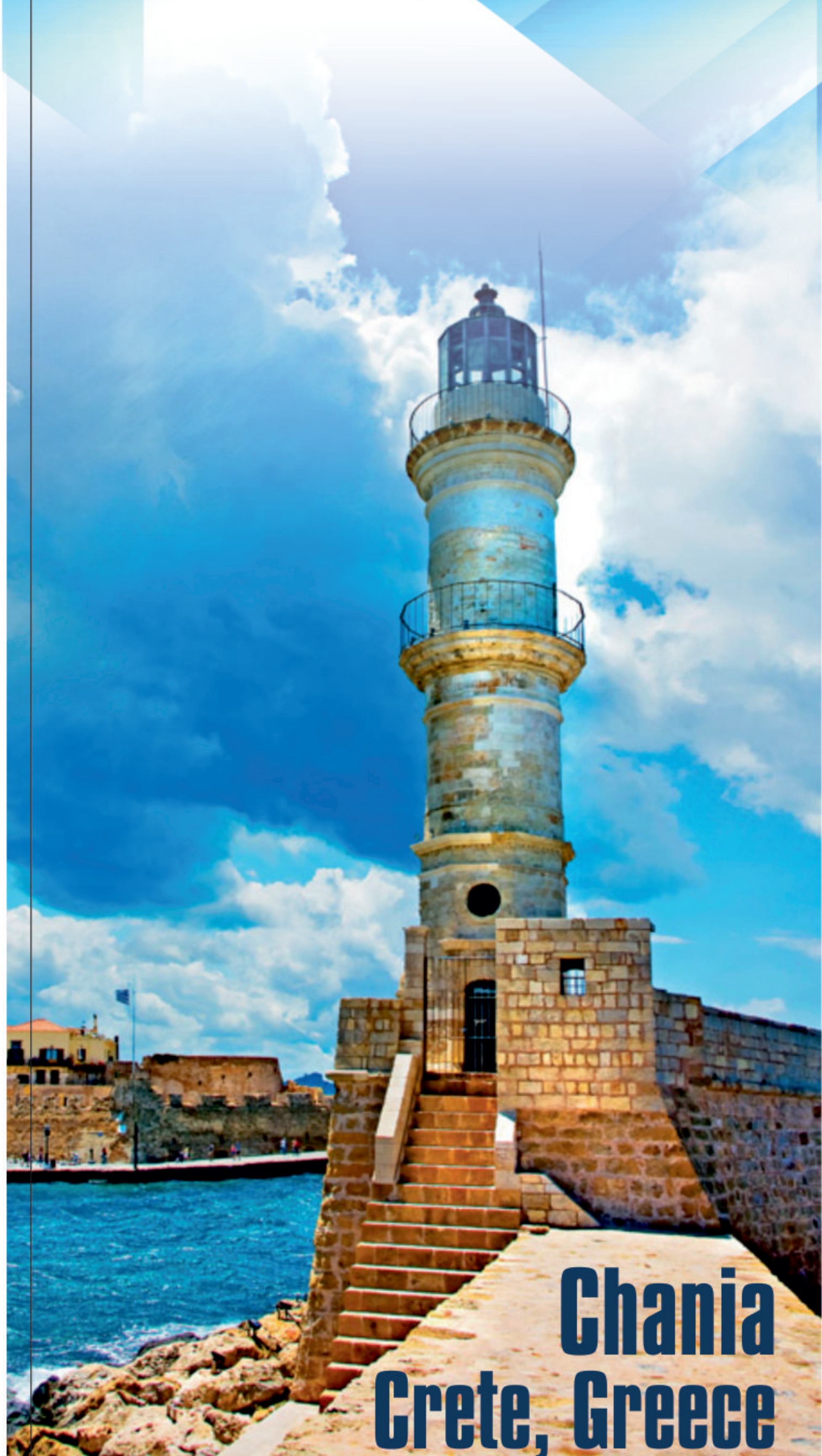
Metamaterials 2016

September 17-22

10th International Congress on Advanced Electromagnetic Materials in Microwaves and Optics

Programme



Chania
Crete, Greece

FORTH
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meta morphose VIRTUAL INSTITUTE

METAMATERIALS CONGRESS

http://congress2016.metamorphose-vi.org

Metamaterials 2016

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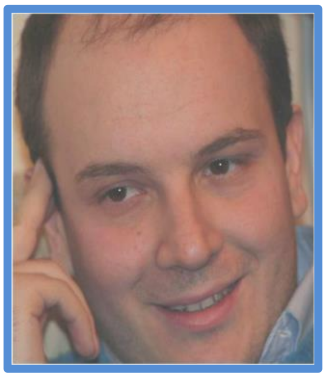
Foreword



It It is our great pleasure to welcome you at the 10th International Congress on Advanced Electromagnetic Materials in Microwaves and Optics (Metamaterials 2016) in Chania, Greece. This event is co-organised by the Virtual Institute for Artificial Electromagnetic Materials and Metamaterials (METAMORPHOSE VI) and FORTH.

The Congress series, initiated by the European Network of Excellence METAMORPHOSE and convened annually by the METAMORPHOSE VI, is recognised as a prime event in the metamaterial community. Owing to the multidisciplinary nature of artificial electromagnetic materials, the Congress brings together researchers and engineers working in material science and electromagnetic theory, optics and microwaves, physics of solids and acoustics, nanofabrication, chemistry, and device design. This provides a unique forum for presenting the latest results in the rapidly growing fields of metamaterials and their applications. The Congress traditions, established and nurtured by its preceding editions and predecessors, International Conferences on Complex Media and Metamaterials (Bianisotropics) and Rome International Workshops on Metamaterials and Special Materials for Electromagnetic Applications and TLC, will be further advanced in Chania.

The Congress programme covers a broad range of research in artificial electromagnetic materials and surfaces for radio, microwave, terahertz, and optical frequencies, as well as in acoustic, thermal, mechanical, superconductor and quantum metamaterials and their applications. A balanced mix of plenary, invited, contributed and poster presentations, all subjected to rigorous peer review, encompasses diverse aspects of the fundamental theory, modelling, design, applications, fabrication, and measurements.

The Congress is traditionally accompanied by the European Doctoral School on Metamaterials. This year school is devoted to “Metamaterials from THz to optics”.

We would like to thank all our sponsors and colleagues who have helped with the Congress organisation and offered their scientific and technical contributions.

The success of the conference series allows METAMORPHOSE VI, as a non-for-profit international association, to provide financial support to a number of participants and particularly students, operate European Doctoral Programme on Metamaterials (EUPROMETA) and deliver other services to the Community.

Filiberto Bilotti, Geneal Chair

Andrea Alù, General Co-Chair

Metamaterials 2016

Preface

Research on metamaterials and metasurfaces is developing and expanding fast. Artificial materials with engineered properties are created and studied not only for the whole electromagnetic spectrum, but also for acoustics and mechanics.

Although the term “metamaterial” appeared only about 15 years ago, research on artificial electromagnetic materials started very soon after J.C. Maxwell wrote his equations. The history of this congress goes back to 1993, when the first workshops on complex media electromagnetics were initiated. This edition of the congress is a special one, celebrating the tenth anniversary of the congress series in its present format.

The selection of papers for the focused program with only three parallel sessions from over 350 submitted abstracts was a difficult task. The program includes 174 oral presentations (15 min), 39 invited talks (30 min) and 3 extended oral presentations, upgraded based on the submitted abstracts (30 min). More than 100 posters will be discussed in two interactive sessions. I would like to thank all the members of the Technical Program Committee and our great team of 63 reviewers who have helped to form the program. The names of the reviewers can be found on the conference web site. We hope that constructive review comments will be helpful for you also in future work.

Traditionally, the plenary talks are highlights of the congress. This year, the three speakers will talk about nonreciprocal and nonlinear metasurfaces, topological principles, and science and applications of microwave metasurfaces. Three special sessions will focus on seismic metamaterials, bio-inspired advanced materials, and on commercialization of metamaterials. To celebrate the Congress anniversary, we have organized a special evening event.

I hope that you will enjoy the presentations, interactions, and return with many new ideas for your future work. I wish you a wonderful stay on Crete!

Sergei Tretyakov, Chair of the Technical Programme Committee

Metamaterials 2016

Welcome message

Dear Friends and Colleagues,

We are happy to welcome you in Crete for the 10th Edition of the International Congress on Advanced Electromagnetic Materials in Microwaves and Optics – Metamaterials 2016. The conference takes place in West Crete, close to the picturesque town of Chania, in a place that combines rich history, high quality education and research, and a unique natural environment composed of beautiful beaches, wild gorges, and green and wild mountains.

The conference is co-organized by the Foundation for Research and Technology – Hellas (FORTH), one of the biggest and most successful research centres in Greece, and in particular by its Institute of Electronic Structure and Laser (IESL), which is an internationally recognized center of excellence in Lasers and Applications, Microelectronics and Devices, Materials Science and Theoretical and Computational Physics. Besides FORTH, Crete has other Institutions, with more recognized the University of Crete, centered at Heraklion, which was classified among the top 100 young (less than 50 years old) Universities worldwide, as well as the Technical University of Crete, located in Chania, with emphasis in Engineering Sciences. All these institutions are characterized by high quality research and education, making Crete a place that combines a glorious past with an inspiring present.

We are happy for another reason too: this year's conference is the 10th anniversary of the Metamaterials Conference, a conference series that we followed from its first steps and which we believe is started and it continues to be among the highest quality conferences in the fascinating area of Metamaterials.

We wish and hope that you will enjoy the conference, you will have the chance to have fruitful discussions with colleagues and friends and to stay updated with the latest important developments in the Metamaterials field.

Moreover, we wish you to enjoy not only the lectures and the conference time, but also the nice surrounding countryside and the unique environment and opportunities offered by West Crete.

Finally, we would like to thank the Foundation for Research and Technology - Hellas, the Metamorphose Virtual Institute, the University of Crete and all the conference sponsors and supporters. Their contribution to the organization of the conference is invaluable.

Costas Soukoulis, Maria Kafesaki, Chairs of the Local Committee

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Location

The conference will take place in West Crete, very close to the picturesque town of Chania, in Platanias area.

Chania is the second largest town in Crete, with a very rich history, being at the crossroads of many different cultures and civilizations.

Today, Chania has almost 100000 habitants.

Chania: A modern …old town

A characteristic part of Chania is the picturesque old town with the Venetian harbor, featuring many historical buildings, and the narrow streets with the many traditional shops and restaurants, where one can enjoy delicious local and Greek recipes.

Unique natural beauty

West Crete is full of exotic beaches, like the beach of Balos, which is ranked 35th among the 100 World's best beaches. Falasarna beach and the Elafonisi peninsula also attract thousants of sea-lovers each year.

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Location

Elafonisi: A corner in paradise

Elafonisi peninsula is a place of exceptional natural beauty, and it has been included in Natura 2000. It is located in the southwest end of the prefecture of Chania, about 70 km from the town of Chania.

Samaria Gorge

Less than 1 hour driving from Chania is the famous Samaria Gorge, which is the second touristic attraction of Crete (after Knossos Minoan Palace). Being 16 km long it is the longest gorge in Europe, and an area of stunning natural beauty, combining rare flora and fauna, and wild, high and steep surrounding mountains.

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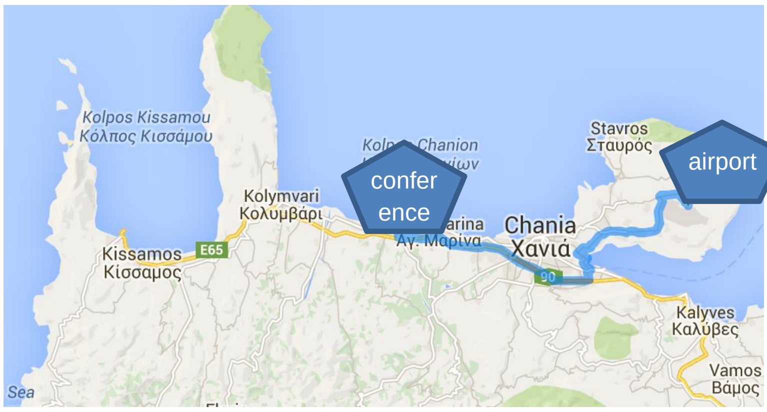
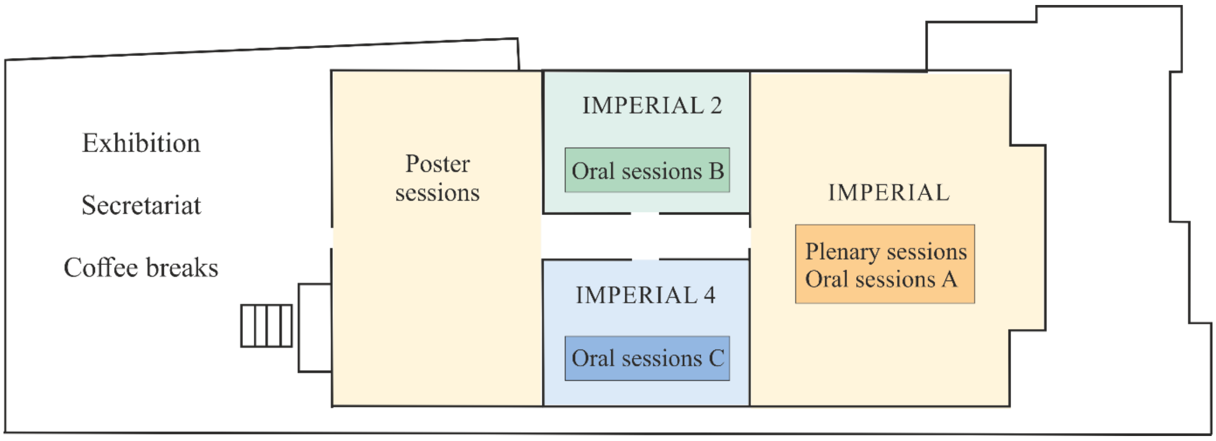
Conference Venue

The conference will take place in the conference center of Minoa Palace Hotel, located in the area of Platanias, 12km west of the picturesque town of Chania and only 30min drive from Chania International Airport.



Minoa Palace Conference center is a big conference center with many lecture rooms and modern facilities. The conference will take place at the Imperial Congress Hall, depicted in the drawing below.



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Social Events

Welcome Reception

The Welcome reception will take place on Monday 19 September, starting at 18:30, right after the end of the sessions, in the Minoa Palace hotel (conference venue).

We hope to see you all there. Take a chance to enjoy a friendly atmosphere of meeting old friends and creating new contacts. Beverages with some finger-food will be served.

Conference Dinner

The Conference dinner will take place at Minoa Palace Hotel (conference venue) on Wednesday, September 21, starting at 8:00. You will have the chance to enjoy and experience local dishes, combined with traditional music and dancing.

Excursions

There is the possibility for excursions and guided tours for the accompanying persons. Please ask the conference secretary for the available options and declare your participation.

Moreover, for the people who will stay on Friday, September 23, there will be an organized boat trip to the famous and exotic Gramvousa Island and Balos Lagoon. More information on the above will be posted at the conference web-page.

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Session Matrix

Monday, 19th September

	Imperial room Sessions A	Imperial 2 room Sessions B	Imperial 4 room Sessions C
08:45 – 09:00	Opening Ceremony		
09:00 – 10:00	Plenary session I		
10:00 – 10:30	Coffee break		
10:30 – 12:30	Hyperbolic metamaterials	All-dielectric metastructures and metasurfaces	Acoustics and mechanics I
12:30 – 14:00	Lunch		
14:00 – 16:00	Microwave and mm-wave metamaterials	Propagating surface plasmons	Acoustics and mechanics II
16:00 – 17:30	Coffee break & Poster session I		
17:30 – 18:30	Bio-inspired advanced materials	Commercialization of metamaterials	Chiral structures
19:00 – 20:30	Welcome reception		

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Session Matrix

Tuesday, 20th September

	Imperial room Sessions A	Imperial 2 room Sessions B	Imperial 4 room Sessions C
09:00 – 10:00	Plenary session II		
10:00 – 10:30	Coffee break		
10:30 – 12:30	RF and microwave metasurfaces	Plasmonics of metallic nanoparticles	Acoustics and mechanics III
12:30 – 14:00	Lunch		
14:00 – 16:00	Graphene and superconducting structures	Metasurfaces I	Cloaking and transformation approaches I
16:00 – 16:30	Coffee break		
16:30 – 18:30	Tunable and nonreciprocal metamaterials	Optical effects	Cloaking and transformation approaches II

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Session Matrix

Wednesday, 21st September

	Imperial room Sessions A	Imperial 2 room Sessions B	Imperial 4 room Sessions C
09:00 – 10:00	Plenary session III		
10:00 – 10:30	Coffee break		
10:30 – 12:30	Nonlinear structures	Plasmonic metasurfaces	Geometry and topology
12:30 – 14:00	Lunch		
14:00 – 16:00	Exotic structures and effects	Plasmonic sensing	Metasurfaces II
16:00 – 17:30	Coffee break & Poster session II		
17:30 – 19:00	10th Anniversary Special Session		
20:00 – 23:00	Gala dinner		

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Session Matrix

Thursday, 22nd September

	Imperial room Sessions A	Imperial 2 room Sessions B	Imperial 4 room Sessions C
09:00 – 10:30	Metasurface applications	Plasmonics	Seismic metamaterials
10:30 – 11:00	Coffee break		
11:00 – 12:30	Microwave metamaterial devices	Plasmonics: Particle phenomena	Theory and modelling
12:30 – 14:00	Lunch		
14:00 – 16:00	Toroidal and multi-polar metamaterials	Novel plasmonic materials	Advanced optical structures
16:00 – 16:30	Coffee break		
16:30 – 18:00	Antennas, from microwaves to optics	New effects	Homogenization
18:00 – 18:30	Closing ceremony		

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Programme

Sunday, 18th September

15:00-18:00	**Sunday Registration**

Monday, 19th September

07:00-08:45	**Monday Registration**
08:45-09:00	**Opening Ceremony** — **Imperial**
09:00-10:00	**Plenary Session 1** — **Imperial** Chair: Sergei Tretyakov **Enhancing Metasurfaces and Metamaterials with Time-Modulation and Nonlinear Responses** **Andrea Alu**, *The University of Texas at Austin, USA* Metasurfaces and metamaterials have been enabling a new and exciting platform to manipulate the propagation, transmission and reflection of electromagnetic waves, sound, heat, and other wave phenomena. In this talk, I will provide an overview of our recent efforts to enhance metasurfaces and metamaterials by enabling time modulation and giant nonlinearities in their basic inclusions, opening new horizons for metamaterial technology in various fields of science and technology. I will discuss how suitably tailored temporal modulation and nonlinearities may be able to overcome some of the conventional constraints associated with passive, linear and time-invariant metamaterial devices, including bandwidth constraints, reciprocal responses, and the large influence of losses.
10:00-10:30	**Coffee Break**
Oral Sessions (Monday 19 – Morning)	

10:30-12:30	Oral Session M1-A **Hyperbolic metamaterials** Chair: Alexander Kildishev	Oral Session M1-B **All-dielectric metastructures and metasurfaces** Chair: Arseniy Kuznetsov	Oral Session M1-C **Acoustics and mechanics I** Chair: Sebastien Guenneau
	Imperial	**Imperial 2**	**Imperial 4**
10:30	**Hyper-Structured Illumination: Super-Resolution Imaging with Planar Hyperbolic Media** **Evgenii Narimanov**, *Purdue University, USA* We present a new approach to super-resolution optical imaging, based on structured illumination in hyperbolic media. Supporting propagating waves with the wavenumbers unlimited by the frequency, hyperbolic materials allow the generation of subwavelength illumination patterns, thus dramatically improving the imaging resolution. The proposed system has planar geometry, offers unlimited field of view, and is robust with respect to optical noise and material losses.	**Metasurfaces and Nanoantenna Devices Based on Resonant Dielectric Nanostructures** Invited **Arseniy Kuznetsov**, *Data Storage Institute, A*STAR, Singapore* Resonant dielectric nanostructures has recently emerged as a new direction in nanophotonics, which may solve the major problems of plasmonics related to high losses, low magnetic response and CMOS incompatibility. In this talk I will review the recent progress in this rapidly developing field and demonstrate recent results from our team showing application of resonant dielectric nanostructures to design of highly efficient nanoantennas and metasurfaces.	**Tailored Buckling 3D Metamaterials as Reusable Light-Weight Shock Absorbers** Extended **Tobias Frenzel**, *Institute of Applied Physics, Karlsruhe Institute of Technology, Germany* **Claudio Findeisen**, *Institute for Applied Materials, Karlsruhe Institute of Technology; Fraunhofer Institute for Mechanics of Materials, Germany* **Muamer Kadic**, *Institute of Applied Physics, Karlsruhe Institute of Technology, Germany* **Vittoria Schuster**, *Institute of Applied Physics, Karlsruhe Institute of Technology, Germany* **Peter Gumbsch**, *Institute for Applied Materials, Karlsruhe Institute of Technology; Fraunhofer Institute for Mechanics of Materials, Germany* **Martin Wegener**, *Institute of Applied Physics, Karlsruhe Institute of Technology; Institute of Nanotechnology, Karlsruhe Institute of Technology, Germany* Mechanical shock absorbers plays an important role in every-day life and are commonly based on viscoelasticity or on destructive modification. Here, we design, fabricate, and characterize three-dimensional micro-structured light-weight mechanical metamaterials operating differently. Using mechanical buckling instabilities, we achieve a sequence of snap-ins followed by irreversible hysteretic, yet repeatable self-recovery.
10:45	**Radiation Enhancement by Irregular Wire Media** **Sergei Kosulnikov**, *Aalto University and ITMO University, Finland and Russia* **Dmytro Vovchuk**, *Aalto University and Yuriy Fedkovych Chernivtsi National University, Finland and the Ukrain* **Mohammad Mirmoosa**, *Department of Radio Science and Engineering, Aalto University, Finland* **Sergei Tretyakov**, *Department of Radio Science and Engineering, Aalto University, Finland* **Stanislav Glybovski**, *ITMO University, Russia* **Constantin Simovski**, *Department of Radio Science and Engineering, Aalto University, Finland* We show that an irregular metamaterial formed by long metal wires enables a broadband enhancement of radiation from small sources. This metamaterial results from randomization of a usual wire-medium slab formed by wires orthogonal to the interfaces. Such a regular slab enhances radiation of embedded dipole sources at its Fabry-Perot resonances only. Introducing a random tilt of the wires with a reasonable maximal deviation from the normal direction we achieve a considerable enhancement also in between the resonant maxima. Unlike the wire-medium hyperlens, the enhancement refers to sources which can be spread over a large area.		

11:00	**Broadband Non-Unity Magnetic Permeability in Planar Hyperbolic Metamaterials** **Georgia Theano Papadakis**, *California Institute of Technology, USA* **Harry A. Atwater**, *California Institute of Technology, USA* We report metal/ dielectric/ semiconductor multilayer metamaterials with non-unity effective magnetic permeabilities. By relaxing the usually imposed constraint of assuming nonmagnetic effective response and taking into account the finite size of the superlattice, we show that hyperbolic metamaterials with high index contrast layers can even exhibit negative values of the magnetic permeability, expanding the properties of hyperbolic metamaterials to both polarizations. We theoretically identify the origin of this effective magnetic response and experimentally validate the values of magnetic permeability with spectroscopic ellipsometry. We investigate on the usefulness of such metamaterials as TE hyperbolic media and for TE surface wave propagation.	**All-dielectric Bianisotropic Metasurfaces** **Mikhail Odit**, *ITMO University, Russia* **Polina Kapitanova**, *ITMO University, Russia* **Yuri Kivshar**, *Australian National University, Australia* **Pavel Belov**, *ITMO University, Russia* Bianisotropic all-dielectric metasurfaces are demonstrated experimentally and their properties are studied in the microwave frequency range. Such metasurfaces are composed of dielectric particles with broken symmetry that exhibit different backscattering for the opposite excitation directions. An array of dielectric bianisotropic ceramic particles is fabricated and experimentally investigated for microwaves. Experimental data demonstrate that such a metasurface provides a 2π phase change in the reflection spectrum when excited from the opposite directions.	**Ultra Thin Acoustic Metamaterial Panels Based on Resonant Bricks for Perfect Absorption** **Vicent Romero García**, *Laboratoire d'Acoustique de l'Univeversité du Maine, CNRS, France* **Noé Jiménez**, *Laboratoire d'Acoustique de l'Univeversité du Maine, CNRS, France* **Weichun Huang**, *Laboratoire d'Acoustique de l'Univeversité du Maine, CNRS, France* **Jean Philippe Groby**, *Laboratoire d'Acoustique de l'Univeversité du Maine, CNRS, France* **Vincent Pagneux**, *Laboratoire d'Acoustique de l'Univeversité du Maine, CNRS, France* Perfect absorption by an ultra thin acoustic metamaterial panel working in reflection is theoretically and experimentally reported. The system is made by a rigid panel with a periodic distribution of thin closed slits with Helmholtz Resonators. Theoretical predictions and data show the design simple structures with deep sub-wavelengths dimensions λ/88.
11:15	**Optical Properties of Self-Assembled Plasmonic Hyperbolic Metasurfaces and Metamaterials Extracted by (Mueller Matrix) Spectroscopic Ellipsometry** **Morten Kildemo**, *NTNU, Norway* **Xuan Wang**, *University of Bordeaux, France* **Virginie Ponsinet**, *University of Bordeaux, France* **Daniel Chiappa**, *Universita di Genova, Italy* **Francesco Buatier de Mongeot**, *Universita di Genova, Italy* Hyperbolic metamaterials use the concept of controlling the propagative modes through the engineering of the dispersion relation, and are considered highly promising to reach different meta-properties. Spectroscopic Mueller Matrix Ellipsometry with variable angle of incidence and full azimuthal rotation of the sample is a powerful optical technique to characterize both anisotropic and bi-anisotropic materials. We here discuss the experimentally extracted uniaxial and biaxial optical properties of two self-assembled plasmonic systems that appear to have the appropriate meta-dispersion relations. The metasurface was produced by oblique incidence angle ion beam sputtering of glass followed by	**Near-Field Characterisation of Anisotropic All-Dielectric Terahertz Resonators** **Irina Khromova**, *King's College London, United Kingdom* **Petr Kuzel**, *Academy of Sciences of the Czech Republic, Czech Republic* **Igal Brener**, *Sandia National Laboratories, USA* **John Reno**, *Sandia National Laboratories, USA* **U-Chan Chung Seu**, *University of Bordeaux, France* **Catherine Elissalde**, *University of Bordeaux, France* **Mario Maglione**, *University of Bordeaux, France* **Patrick Mounaix**, *University of Bordeaux, France* **Oleg Mitrofanov**, *University College London, United Kingdom* We extract the intrinsic properties of micrometre-sized anisotropic dielectric resonators through near-field time-domain terahertz spectorscopy. Narrow terahertz resonances corresponding to magnetic dipole modes in ≈30μm-sized mono-crystalline TiO_2 spheres split due to material anisotropy. Ensembles of TiO_2 resonators can form complex meta-atoms for unusual electromagnetic	**Design of Sub-Wavelength Acoustic Absorbing Panels Using Accumulation of Resonances Due to Slow Sound** **Noé Jiménez**, *Laboratoire d'Acustique d l'Université du Maine, CNRS, UMR 6613, France* **Jean-Philippe Groby**, *Laboratoire d'Acustique d l'Université du Maine, CNRS, UMR 6613, France* **Vicent Romero-García**, *Laboratoire d'Acustique d l'Université du Maine, CNRS, UMR 6613, France* **Vincent Pagneux**, *Laboratoire d'Acustique d l'Université du Maine, CNRS, UMR 6613, France* We report sub-wavelength resonant panels for low-frequency sound absorption by using the accumulation of cavity resonances due to the slow sound phenomenon. The panels are built by bricks of sub-wavelength thickness with periodically distributed horizontal slits, in the walls of which identical Helmholtz resonators are attached (HRs). Due to the presence of the HRs, the propagation in the slit is highly dispersive with low group velocity that goes to zero due to the gap produced by the resonance of the HRs. In the slow-sound regime, the resonant frequency of cavity modes in the slit are shifted

	shadow deposition of Au [Aas et al. Optics Express 21, 30918-30931, 2013]. The second bulk metamaterial was a block-copolymer based self-assembled hyperbolic metamaterial of nanocomposites based on metal nanoparticles embedded in a self-assembled anisotropic polymer host, presenting a strong spectrally selective optical anisotropy [Wang et al. (Manuscript in preparation)]. The extracted effective dielectric functions and the resulting dispersion relations are presented.	response in terahertz all-dielectric metamaterials.	down and they are accumulated before the HRs frequency. Near the accumulation point, simultaneously symmetric and antisymmetric modes can be nearly critically coupled and produce nearly perfect absorption. However, due to the distribution of the resonant modes perfect absorption is not possible in this kind of structures. Therefore, we further analyze the case of different HRs in the slit, in which the structure of resonances is modified and symmetric and antisymmetric resonances can be simultaneously critical coupled. In this conditions we report perfect absorption for a transparent panel of 1/26 wavelength thickness.
11:30	**Extreme Sensitivity Biosensing Platform Based on Hyperbolic Metamaterials** **Giuseppe Strangi**, *Case Western Reserve University* Optical sensor technology offers significant opportunities in the field of medical research and clinical diagnostics, particularly for the detection of small numbers of molecules in highly-diluted solutions. Several methods have been developed for this purpose, including label-free plasmonic biosensors based on metamaterials. However, the detection of lower-molecular-weight (<500 Da) biomolecules in highly-diluted solutions is still a challenging issue due to their lower polarizability. In this context, we have developed a miniaturized plasmonic biosensor platform based on a hyperbolic metamaterial that can support highly confined bulk plasmon guided modes over a broad wavelength range from visible to near infrared. By exciting these modes using a grating-coupling technique, we achieved different extreme sensitivity modes with a maximum of 30,000 nm per refractive index unit (RIU) and a record figure of merit (FOM) of 590. We report the ability of the metamaterial platform to detect ultralow-molecular-weight (244 Da) biomolecules at picomolar concentrations by largely exceeding current biosensing technologies.	**Electrical Tuning of All Dielectric Metasurfaces** **Andrei Komar**, *The Australian National University, Australia* We demonstrate experimentally electrical tuning of dielectric metasurface, consisting of silicon disks infiltrated with nematic liquid crystals. In particular, we show that by switching a control voltage on and off we can achieve 100% amplitude modulation and approximately π phase shift. This is for the first time to our knowledge demonstration of electrical tuning of dielectric metasurfaces thus opening the way for new types of electrically tunable metadevices, including dynamic displays and holograms.	**Evaluation and Verification of Three Dimensional Acoustic Black Hole Based on Acoustic Metamaterial** **Kazuki Fukaya**, *Department of Aerospace Engineering, Nagoya University, Japan* **Koichi Mori**, *Department of Aerospace Engineering, Nagoya University, Japan* Sound absorber “Acoustic Black Hole”, a kind of acoustic metamaterial, has been made in the new configuration to control three dimensional propagation of acoustic wave and it has been examined by experiment and numerical simulation.
11:45	**Super-Coulombic Dipole-Dipole Interactions in Hyperbolic Metamaterials** **Zubin Jacob**, *Purdue university/university of Alberta, USA* **Cristian Cortes**, *Purdue university/university of Alberta, USA*	**Substrate Influence on Resonant Optical Response of High-Refractive Index Dielectric Nanoparticles** **Andrey Evlyukhin**, *Laser Zentrum Hannover e. V., Germany* Scattering of light by individual high-refractive-index dielectric nanoparticles (NPs) located on a dielectric or	**High Broadband Absorption of Acoustic Waves by Elastic-Framed Metaporous Layer** **Thomas Weisser**, *ENSISA, Université de Haute-Alsace, France* **Jean-Philippe Groby**, *LAUM, UMR CNRS 6613, Université du Maine, France*

	Ward Newman, *Purdue university/university of Alberta, USA* We demonstrate experimentally that hyperbolic metamaterials fundamentally alter non-radiative dipole-dipole interactions conventionally limited to the near-field and enhance it by four orders of magnitude compared to a metal or dielectric.	metal substrate and supporting electric and magnetic dipole resonances in the visible spectral range is considered. Numerical calculations are carried out by making use of the multipole decomposition procedure. Extinction and scattering cross section spectra of spheroid silicon NPs in visible and near-infrared are presented and discussed.	**Olivier Dazel**, *LAUM, UMR CNRS 6613, Université du Maine, France* **Logan Schwan**, *LAUM, UMR CNRS 6613, Université du Maine, France* The acoustic behaviour of a metaporous materials constituted of resonant elastic shells embedded in a poro-elastic matrix is reported. Using the multiple scattering theory in a dissipative Biot continuum, it is shown that high broadband absorption of sound is achieved along with deep subwavelength absorption peaks induced by flexural resonances.
12:00	**High-Contrast Nanoparticle Sensing using a Hyperbolic Metamaterial** **Wenqi Zhu**, *National Institute of Standards and Technology, USA* Using planar hyperbolic metamaterials composed of alternating layers of metal (Ag) and dielectric (SiO2), we demonstrate a transmission device for dark-field imaging of nanoparticles that exhibits extremely high optical contrast.	**Light Scattering and Localization by Silicon Nanoparticle on Metal** **Ivan Sinev**, *ITMO University, Russia* **Ivan Iorsh**, *ITMO University, Russia* **Andrey Bogdanov**, *ITMO University, Russia* **Dmitry Permyakov**, *ITMO University, Russia* **Filipp Komissarenko**, *ITMO University, Russia* **Ivan Mukhin**, *ITMO University; St. Petersburg Academic University, Russia* **Anton Samusev**, *ITMO University, Russia* **Andrey Miroshnichenko**, *Australian National University, Australia* **Yuri Kivshar**, *Australian National University; ITMO University, Australia; Russia* We reveal remarkable substrate-driven transformations of electric and magnetic dipole resonances of a silicon nanoparticle on metal, manifesting as the modification of Q-factor of the resonances followed by strong enhancement of the respective fields.	**Depolarization of Mechanical Waves by Elastodynamic Metasurface** **Logan Schwan**, *LAUM, UMR CNRS 6613, Université du Maine, France* **Claude Boutin**, *ENTPE, UMR CNRS 5513, Université de Lyon, France* **Matthew S. Dietz**, *University of Bristol, Department of Civil Engineering, United Kingdom* The concept of microstructured surfaces with inner resonance is reported in elastodynamics. Such a metasurface can tune the boundary conditions at specific frequencies and achieve the depolarization of mechanical waves without introducing heterogeneities in the medium. The concept is put into practice experimentally and results bear testament to its efficacy.
12:15	**Anomalous Dispersive Interface States of Hyperbolic Metamaterials** **Ieng Wai Un**, *National Tsing Hua University, Taiwan* **Ta Jen Yen**, *National Tsing Hua University, Taiwan* We first calculate the plasmonic band structure of binary hyperbolic metamaterials and analytically deduce the band crossing conditions. Then we analyze the existence of interface states in the plasmonic band gap on three types of interfaces: dielectric/1DHMM, metal/1DHMM and 1DHMM/1DHMM. By breaking the inversion symmetry, we find that 1DHMM can support interface state with anomalous dispersion.	**Active Organic Dipolar Antenna** **Mady Elbahri**, *Aalto University, Finland* **Mehdi Keshavarz Hedayati**, *University of Kiel, Germany* **Moheb Abdelaziz**, *Aalto University, Finland* Here, we demonstrate experimentally for the first time the coherent oscillation and coupling of photoactive molecules integrated randomly in a polymeric medium which act cooperatively upon irradiation with UV light. Accordingly, we showed the specular reflection and Brewster phenomenon change of photochromic molecular dipole antennas. We successfully demonstrate the concept of Brewster wavelength, which is based on	**Micro-Structured 3D Metamaterials with Negative Thermal-Expansion Coefficient from Positive Constituents** **Jingyuan Qu**, *Karlsruhe Institute of Technology, Germany* **Muamer Kadic**, *Karlsruhe Institute of Technology, Germany* **Andreas Naber**, *Karlsruhe Institute of Technology, Germany* **Martin Wegener**, *Karlsruhe Institute of Technology, Germany* To obtain the opposite sign, near-zero expansion, or a much larger effective thermal-expansion coefficient, at

		the dipolar interaction between radiating dipoles and the surrounding matrix possessing a net dipole moment, as a key tool for highly localized sensing of matrix polarity. Our results enrich our understanding of coherent dipole radiation and pave the way of research based on glassy disordered dipolar composites for new application in switchable optical devices.	least two different constituent materials (and air voids) are required. Corresponding 3D blueprints have been proposed theoretically by Lakes. Here, we design, fabricate, and characterize corresponding 3D micro-structured polymer metamaterials made by laser printing.
12:30-14:00	**Lunch Break**		
Oral Sessions (Monday 19 – Afternoon 1)			
14:00-16:00	**Oral Session M2-A** **Microwave and millimetre-wave metamaterials** Chair: Ferran Martin	**Oral Session M2-B** **Propagating surface plasmons** Chair: Albert Polman	**Oral Session M2-C** **Acoustics and mechanics II** Chair: Martin Wegener
	Imperial	**Imperial 2**	**Imperial 4**
14:00	**Simple In-front-of-class Experiments for Metamaterial Education** **Silvio Hrabar**, *University of Zagreb, Croatia* This paper briefly reports several simple and cheap devices and accompanying experiments designed for metamaterial education, both in engineering and physics university courses.	**Short-Range Surface Plasmonics and its Subfemtosecond Dynamics** Extended **Harald Giessen**, *University of Stuttgart, 4th Physics Institute, Germany* Using atomically flat gold surfaces, we observe long- and short- range surfaces plasmons on unstructured as well as patterned surfaces. Time-resolved two-photon photoemission microscopy reveals the rich dynamics of plasmon propagation, including spin-orbit coupling in surface plasmons with orbital angular momentum up to l=20.	**Impedance Approach to Modeling and Designing Acoustic Metamaterials** Invited **Yuri Bobrovnitskii** *Blagonravov Mechanical Engineering Research Institute of Russian Academy of Sciences, Russia* Theoretical solutions to the problems of acoustic invisibility (cloaking), of the best absorber of sound and some other are obtained by the impedance method in terms of certain surface impedance characteristics that can be realized with the help of coatings made of 2D acoustic or mechanical metamaterials. Results of computer simulation and laboratory experiments of applying the approach are presented.
14:15	**Generating Structured Fields at Microwave Frequencies** **Mirko Barbuto**, *"Niccolò Cusano" University, Italy* **Filiberto Bilotti**, *"Roma Tre" University, Italy* **Alessandro Toscano**, *"Roma Tre" University, Italy* “Structured light” is an emerging research field aiming at obtaining unusual amplitude and phase distributions of an optical beam, with potential applications ranging from manipulation of microscopic particles to communications or imaging systems. Typically confined to optical frequencies, it has recently been extended to microwaves but limited to the generation of an electromagnetic field with orbital angular momentum. In		

	this contribution, we extend the possibility of generating structured fields at microwave frequencies to the case of an electromagnetic field with a Möbius strip polarization state. In particular, by using the cavity model, we analytically show that the required phase and amplitude patterns can be obtained by superimposing the radiated fields generated by different modes of a patch antenna.		
14:30	**Hypersensitive Transport in Nonlinear Asymmetric Photonic Layered Media** **Andrey Chabanov**, *University of Texas at San Antonio, USA* **Kyle Smith**, *University of Texas at San Antonio, USA* **Eleana Makri**, *Wesleyan University, USA* **Tsampikos Kottos**, *Wesleyan University, USA* **Ilya Vitebskiy**, *AFRL, USA* A localized mode in a photonic layered medium can develop nodal points (nodal planes) where the oscillating electric field is negligible. Placing a thin metallic layer at such a nodal point leads to the phenomena of induced transmission, whereas shifting the nodal point away from the metallic layer results in the suppression of the localized mode along with the resonant transmission. Here we show that if the nodal point is not a point of symmetry of the layered medium, an abrupt transition from the resonant transmission to broadband opacity can be brought about by a tiny alteration of the permittivity in the vicinity of the metallic layer. Applications of this hypersensitive transport to microwave and optical limiting and switching are discussed.	**Surface Waves on Metamaterials Interfaces** Invited **Andrei Lavrinenko**, *Technical University of Denmark, Denmark* **Osamu Takayama**, *Technical University of Denmark, Denmark* **Evgeniy Shkondin**, *Technical University of Denmark, Denmark* **Mohammad Aryaee Panah**, *Technical University of Denmark, Denmark* **Taavi Repän**, *Technical University of Denmark, Denmark* **Radu Malureanu**, *Technical University of Denmark, Denmark* **Flemming Jensen**, *Technical University of Denmark, Denmark* We analyze surface waves supported at the interface between isotropic medium and effective anisotropic material that can be realized by alternating conductive and dielectrics layers. This configuration can host various types of surface waves most of which are directional waves and as such their propagation can be effectively controlled by wavelength or material parameters tuning.	**Negative Refraction of Lamb Waves** **Benoît Gérardin**, *Institut Langevin - CNRS, France* **Jérome Laurent**, *Institut Langevin - CNRS, France* **Arnaud Derode**, *Institut Langevin - CNRS, France* **Claire Prada**, *Institut Langevin - CNRS, France* **Arnaud Derode**, *Institut Langevin - CNRS, 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.
14:45	**3D-Printed Metamaterials with Periodic Metallic Elements** **Shiyu Zhang**, *Loughborough University, United Kingdom* **William Whittow**, *Loughborough University, United Kingdom* **Yiannis Vardaxoglou**, *Loughborough University, United Kingdom* This paper presents a study on artificial heterogeneous metamaterials that were synthesized by adding metallic rectangular cuboid inclusions (meta-atoms) into a dielectric host material. Multi-layered metamaterial substrates were fabricated using the addictive manufacturing technique. Varying the space between the		**Dynamic Homogenization of Viscoelastic Metamaterials** **Hélène Pichard**, *Institut de Mecanique et d'Ingenierie, Talence, France* **Daniel Torrent**, *Centre de recherche Paul Pascal, Pessac, France* The effect of viscosity on the complex band structure and on the effective properties of metasolids is analyzed. The studied structure is a phononic crystal with local resonances, which consists of coated cylinders arranged in a triangular lattice in a viscoelastic background. When viscosity is neglected, this structure shows interesting effective properties like strongly resonant and anisotropic mass density tensor. In view of practical applications of

	metallic inclusions in the material affects its effective electromagnetic properties including the relative permittivity, permeability and loss tangent.		metamaterials, the evolution of the effective parameters when increasing viscosity is studied.
15:00	**Retrieval of Coupling Coefficients for Dense Metamaterials** **Pavel Petrov**, *M.V. Lomonosov Moscow State University, Russia* **Anna Radkovskaya**, *M.V. Lomonosov Moscow State University, Russia* **Ekaterina Shamonina** *University of Oxford, UK* Electromagnetic properties of metamaterials are strongly affected by inter-element coupling between meta-atoms. Our recently proposed method enabling a retrieval of coupling coefficients in metamaterials is based on a transformation of the frequency dependence of complex current amplitudes in interacting meta-atoms, enabling separate deduction of the magnetic and electric coupling coefficients. This method relies on our ability to measure separately currents on two interacting elements. However, in case of dense metamaterials fields from the surroundings mask the required signals severely. In this paper we present a novel technique of coupling retrieval for dense metamaterials, in which spurious fields from environment are accounted for by correction factors. The method is verified on a number of examples using both experimental and simulation data in a wide frequency range from MHz to THz. Our method will serve as a basis for design of densely packed metamaterials with strong inter-element coupling.	**Metal-Insulator-Metal Waveguides for Non Linear Second Order Effects Enhancement** **Sébastien Héron**, *MINAO - ONERA - The French Aerospace Lab, France* **Benjamin Vest**, *Laboratoire Charles Fabry de l'Institut d'Optique, France* **Baptiste Fix**, *MINAO - ONERA - The French Aerospace Lab, France* **Julien Jaeck**, *MINAO - ONERA - The French Aerospace Lab, France* **Patrick Bouchon**, *MINAO - ONERA - The French Aerospace Lab, France* **Riad Haïdar**, *MINAO - ONERA - The French Aerospace Lab, France* Metal-insulator-metal resonators act as metamaterials able to resonantly enhance second order frequency generation processes. They behave as nano-antennas providing multiple resonant wavelengths that respect the energy conservation conditions of second order frequency conversion schemes. Such antennas also confines incoming electric field at resonance therefore favoring non linear processes.	**Dynamic Homogenization of Anisotropic and Non-Local Acoustic Metamaterials** **Marie-Fraise Ponge**, *I2M Institute Bordeaux, France* **Olivier Poncelet**, *I2M Institute Bordeaux, France* **Daniel Torrent**, *Centre de Recherche Paul Pascal, France* We present a dynamical homogenization model for the propagation of acoustic waves in periodic arrangements of scatterers. The model is based on the plane wave expansion method and leads to the effective parameters associated with the propagation. It is shown that the effective mass density and bulk modulus depend on both the frequency and wave vector, which means that the medium presents a non-local response in both time and space. As a numerical example, a rectangular lattice of cylinders is investigated. It is shown that it presents a frequency-dependent anisotropic mass density in the local approximation, while additional solutions in the dispersion curves show that a non-local model is required for a better description of the metamaterial.
15:15	**Extremely Thin Fabry-Perot Resonators Based on High Permitivity Artificial Dielectric** **Juan P. del Risco**, *Universidad Nacional de Colombia, Colombia* **Juan D. Baena**, *Universidad Nacional de Colombia, Colombia* A extremely thin Fabry-Perot resonator has been designed. It is based on a high permittivity artificial dielectric layer. An analytical model has been developed to predict the transmission coefficient from its geometrical parameters. The Fabry-Perot resonator has a thickness 74 smaller than the free space wavelength at the lowest resonance.	**Embedding a Plasmonic Nanoantenna into a Silicon Waveguide Gap: Simulations and Experimental Demonstration** **Alba Espinosa-Soria**, *Universitat Politècnica de València, Spain* **Amadeu Griol**, *Universitat Politècnica de València, Spain* **Alejandro Martínez**, *Universitat Politècnica de València, Spain* A gold nanostrip acting as a plasmonic nanoantenna is embedded into a gap created in a silicon waveguide to ensure maximum interaction between the guided field and the nanoantenna. We study numerically this system and demonstrate experimentally at telecom wavelengths	**Surface Acoustic Waves Propagation at Lossy Metasurfaces: Experimental and Theoretical Characterization of Complex Dispersion Relations** **Logan Schwan**, *LAUM, UMR CNRS 6613, Université du Maine, France* **Alan Geslain**, *ISAT, DRIVE EA1859 , Université de Bourgogne Franche Comté, France* **Jean-Philippe Groby**, *LAUM, UMR CNRS 6613, Université du Maine, France* **Vicent Romero-Garcia**, *LAUM, UMR CNRS 6613, Université du Maine, France* The experimental and theoretical characterization of Surface Acoustic Wave (SAW) propagation and attenuation in the presence of a lossy metasurface is

		that contrast beyond 10 dB can be achieved in transmission, opening a route for the efficient use of nanoantennas in silicon photonics chips.	reported. Complex SAW wavenumbers are retrieved experimentally using a spatial Laplace Transform. The experimental complex dispersion relation is in good agreement with that from a Plane Wave Expansion model.
15:30	**Demonstration of Enhancing the Transmission of 60 GHz waves Through Biological Tissue Using Thin Metamaterial Antireflection Coatings** **Helena Cano-Garcia**, *King's College London, Medical Wireless Sensing Ltd, Metamaterial Technologies Inc, United Kingdom* **Panagiotis Kosmas**, *King's College London, United Kingdom* **Efthymios Kallos**, *Metamaterial Technologies Inc, Medical Wireless Sensing Ltd, Canada, United Kingdom* We present analytical and experimental results of an antireflection coating for biological tissues at 60 GHz. The analytical study estimates the improvement in the transmitted power when perfect impedance matching is achieved by placing a metamaterial film in front of skin tissue. The estimated improvement is up to 4 dB. We subsequently present results from an animal trial where we demonstrate 1.9 dB improvement in the transmission through a 2.7 mm thick pig's ear that was sandwiched between patch antennas. To the best of our knowledge this is the first demonstration of a metamaterial antireflection coating for lossy biological tissues at this frequency range.	**Nonreciprocal Near-Field Effects Due to the Excitation of Magnetoplasmons in THz Range** **Vladimir Kuzmiak**, *Institute of Photonics and Electronics AS CR, v.v.i. , Czech Republic* We have studied theoretically spectral changes in near-field emission of InSb surface in the presence of a static external magnetic field in Voigt configuration. We used an approximate expression for the density states $N(omega,x)$ in the limit of large wave vector $k_{\|}$ to calculate density of surface modes propagating along InSb/interface under magnetic field and we found that the InSb surface reveals almost monochromatic emission at the frequencies belonging to effective plasma frequencies of the Voigt dielectric function. The sharp peaks correspond to the branches belonging to real-excitation-plasmon type surface polaritons which, unlike the virtual-excitation modes, extent to infinite wave vectors. The resonant frequencies at which the peaks corresponding to the forward (backward) propagating waves, appear below(above) the plasma frequency and decrease(increase) with increasing intensity of the magnetic field.	**A Scattered Field Formulation In Elastodynamics** **Andre Diatta**, *Aix-Marseille Université, CNRS, Ecole Centrale, Institut Fresnel, France* **Muamer Kadic**, *Institute of Applied Physics, Karlsruhe Institute of Technology, Germany* **Martin Wegener**, *Institute of Applied Physics, Karlsruhe Institute of Technology, Germany* **Sébastien Guenneau**, *Aix-Marseille Université, CNRS, Ecole Centrale, Institut Fresnel, France* We present a general framework for calculating the scattered field in elastodynamics from quasi-static (long-wavelengths) to dynamic (short wavelengths) ranges. Our work is based on the use of virtual sources and adaptative perfectly matched layers (PMLs). The formalism encompasses non-symmetric elasticity tensors and thus can be used in transformational elastodynamics and in particular for PMLs deduced from a geometric transform. We notably discuss the implementation of adaptative PMLs in elastodynamics and their efficiency in the numerically challenging quasi-static and high-frequency cases. Finally, we show the scattering field for three types of scatterers (solid, stress-free and clamped).
15:45	**Low Plasma Frequency Zigzag Metamaterials** **Juan D. Baena**, *Universidad Nacional de Colombia, Colombia* **Juan P. del Risco**, *Universidad Nacional de Colombia, Colombia* **Stanislav Glybovski**, *ITMO University, Russia* We have demonstrated that a periodic array of zigzag-shaped metal strips emulates an artificial plasma much better than the array of straight metal strips. We have found an excellent agreement between the plasma model and numerical results for the zigzag-shaped strips, while the agreement was poor for the straight strips.	**Focusing Optical Waves via Graded-Epsilon-Near-Zero Metalens** **V. Pacheco-Peña**, *Universidad Pública de Navarra, Spain* **M. Navarro-Cía**, *School of Physics and Astronomy, University of Birmingham, United Kingdom* **M. Beruete**, *Universidad Pública de Navarra, Spain* A parallel plate plasmonic waveguide is proposed in order to emulate the performance of a permittivity-near-zero metamaterial (ENZ) at optical wavelengths by working near the cut-off of the TE1 mode. The ENZ region can be tuned by simply modifying the electrical width of the dielectric spacer of the plasmonic waveguide. Also, a graded index (GRIN) epsilon-near-zero lens working at 474.9nm is designed by stacking 51 non-uniform plasmonic parallel plates, demonstrating	**Cloaking for Mechanical Waves by Direct Lattice Transformation** **Muamer Kadic**, *Karlsuhe Institute of Technology, Germany* **André Diatta**, *Aix-Marseille Université, CNRS, Centrale Marseille, Institut Fresnel UMR 7249, France* **Sebastien Guenneau**, *Aix-Marseille Université, CNRS, Centrale Marseille, Institut Fresnel UMR 7249, France* **Martin Wegener**, *Karlsuhe Institute of Technology, Germany* We ask whether the direct-lattice-transformation design approach, which we have recently introduced for static mechanics, is also applicable to mechanical waves at finite frequencies. A major hurdle for answering this question numerically has been the absence of perfectly matched layers for microstructures in mechanics.

		numerically that this structure may be used to focus optical waves.	
16:00-17:30	**Coffee Break**		
16:00	**Poster Session I**		

1 - Scattering Camouflage And Manipulation Using Metasurfaces

Stefano Vellucci, *"RomaTre" University, Italy*
Alessio Monti, *Niccolò Cusano University, Italy*
Giacomo Oliveri, *University of Trento, Italy*
Andrea Massa, *University of Trento, Italy*
Alessandro Toscano, *"RomaTre" University, Italy*
Filiberto Bilotti, *"RomaTre" University, Italy*

In this contribution, we propose the use of metasurfaces not only to cloak an object but also to change its scattering response in view of camouflage and scattering manipulation applications. We present the analytical formulation for the case of a cylindrical object with the goal of deriving the surface impedance of the surrounding metasurface to make the object appearing as it were either larger or thinner. We find that not all the camouflage cases can be achieved by using only passive metasurfaces and active components may be required. The analytical and numerical results are discussed, in view of possible actual applications.

2 -Reactively-Loaded EBG-Based Transmission Lines and Application to Power Splitters

Jordi Selga, *Universitat Autonoma de Barcelona, Spain*
Paris Velez, *Universitat Autonoma de Barcelona, Spain*
Jordi Bonache, *Universitat Autonoma de Barcelona, Spain*
Ferran Martin, *Universitat Autonoma de Barcelona, Spain*

In this paper, artificial transmission lines based on electromagnetic bandgaps (EBGs) consisting of periodic reactive loads are analyzed. Two types of artificial lines are considered: lines based on capacitive loading, and lines based on inductive loading. In both cases, two important implications related to the periodic reactive loading arise: (i) size reduction, due to the slow-wave effect derived from the presence of the shunt connected capacitances or series connected inductances, and (ii) stop-band behavior, due to the Bragg effect, derived from periodicity. The equations useful for design purposes are presented in both cases, and an example of application, i.e., a compact power splitter, is reported. These artificial lines are of special interest in applications where size reduction and filtering (e.g., for spurious suppression) are a due.

3 - Compact UWB LPF Based on Uni-Planar Metamaterial Complementary Split

27 - Microwave Permeability of Hollow Iron Spheres

Conor McKeever, *University of Exeter, United Kingdom*
Feodor Ogrin, *University of Exeter, United Kingdom*
Mustafa Aziz, *University of Exeter, United Kingdom*
Roy Sambles, *University of Exeter, United Kingdom*
Alastair Hibbins, *University of Exeter, United Kingdom*
Cameron Gallagher, *University of Exeter, United Kingdom*

Here we report on micromagnetic computations showing several intensive peaks as high as 40 GHz in the permeability spectrum of hollow iron spheres when excited from their minimum energy state.

28 - Analytical Studies of the Electromagnetic Properties of Asymmetric Metamaterial Resonators by the Riemann-Hilbert Approach

Piotr M. Kaminski, *Technical University of Denmark, Denmark*
Richard W. Ziolkowski, *University of Arizona, United States*
Samel Arslanagic, *Technical University of Denmark, Denmark*

We present analytical studies of the electromagnetic properties of asymmetric metamaterial-based resonators excited by an electric line source. The resonators consist of two concentric infinite cylindrical material layers covered with an infinitely thin conducting shell with an infinite axial aperture. An exact analytical solution of this canonical problem is derived; the solution is based on the dual series approach which is cast into the equivalent Riemann-Hilbert problem. It is found that specific asymmetric configurations can lead to large enhancements of the radiated field and to highly steerable Huygens-like directivity patterns. As such, the presented results may offer an alternative route towards beam shaping and steering capabilities in electrically small configurations.

29 - Investigation of Spin Waves in Metallized Magnonic Crystal

Vitaliy Vitko, *Saint Petersburg Electrotechnical University , Russia*
Andrey Nikitin, *Saint Petersburg Electrotechnical University , Russia*
Alexey Ustinov, *Saint Petersburg Electrotechnical University , Russia*
Andrey Drozdovskii, *Saint Petersburg Electrotechnical University , Russia*
Mikhail Cherkasskii, *Saint Petersburg Electrotechnical University , Russia*

Ring Resonator

Mahmoud Abdalla, *MTC College, Egypt*
Ghadeer Arafa, *University of Modern sciences and Arts University, Department of electronics and communication, Giza, Egypt*
Mahmoud Saad, *University of Modern sciences and Arts University, Department of electronics and communication, Giza, Egypt*

This paper presents a compact ultra-wide low pass filter based on a uni planar configuration of metamaterial complementary split ring resonator. The filter has insertion loss close to 0 dB over the frequency band DC up to 10.8 GHz. Also, the filter has the advantage of small size (18 mm × 7 mm) whose length is only about 32% of the guided wave length at mid frequency. Different order types of this filter are discussed in the paper. The filter design is explained and its performance is validated using full wave simulation and experimental measurements. Very good agreement between the two results is achieved which confirm the theoretical design.

4 - A Compact SIW Metamaterial Coupled Gap Zeroth Order Bandpass Filter with Two Transmission Zeros

Mahmoud Abdalla, *MTC College, Egypt*
Kareem Mahmoud, *MSA University, Electronics and Communications Department, Giza., Egypt*

This paper presents a new compact metamaterial bandpass filter based on coupled gap composite right left handed transmission line resonator using substrate integrated waveguide to become low loss. The filter size is only 20 × 15 mm2 which is (0.61 λg) at center frequency (6.8 GHz). Moreover, the filter was designed to demonstrate a zeroth order at 6.8 GHz with two transmission zeros; the first one is at -44 dB and the second one is close to -50 dB in a high selective characteristics (less than only 300 MHz from centre frequency). The paper exhibits the equivalent circuit model, 3D full wave simulation and fabrication measurement results. Good agreement between the presented data is achieved.

5 - Dynamic Permeability in a Dissipative Ferromagnetic Medium

Roberto Zivieri, *Department of Physics and Earh Sciences, University of Ferrara, Italy*

It is calculated the dynamic relative permeability in a ferromagnetic film with in-plane magnetization in the presence of intrinsic dissipation. The behaviour of the dynamic permeability is studied for microwave frequencies belonging to those of backward volume waves where both the real part and the imaginary part exhibit negative values.

6 - Demagnetizing Field Effect on the Complex Permeability Spectra of Ferromagnetic Metal Flake Composite Materials in the Microwave Frequency Range

Teruhiro Kasagi, *National Institute of Technology, Tokuyama College, Japan*
Massango Herieta, *Hiroshima University, Japan*
Takanori Tsutaoka, *Hiroshima University, Japan*

Alexander Semenov, *Saint Petersburg Electrotechnical University , Russia*

A theoretical model of spin waves (SWs) in ferrite magnonic crystals with periodical metallization taking into account finite metal conductivity was developed. Influence of different parameters on dispersion characteristics of SW and transmission characteristics of the magnonic crystals were analyzed. Features of transmission characteristics of the magnonic crystals with periodical metallization were described with a high accuracy by the developed theory.

30 - Frequency Tunable Directive Radiation by Ferromagnetic Photonic Crystals

Rui-Xin Wu, *Nanjing University, China*

We theoretically study the radiation of current line source embedded in two dimensional magnetic photonic crystal (MPC). Our results show that by lowering the symmetry of MPC the radiation could be highly directive when operating at the band edge of the PC. Further, the directive radiation can be tuned in a broadband frequency by changing the magnitude of bias magnetic fields.

31 - Hexagonal-Shaped Metamaterial Energy Harvester Design

Cenk Mulazimoglu, *Ankara University, Turkey*
Emrullah Karakaya, *Ankara University, Turkey*
Sultan Can, *Ankara University, Turkey*
A. Egemen Yilmaz, *Ankara University, Turkey*
Barıs Akaoglu, *Ankara University, Turkey*

In this study, an energy harvester metamaterial is proposed for frequency ranges where the electromagnetic pollution occurs. A structure is scaled for different frequencies and efficiency values of over % 90 are achieved. The harvesters are evaluated for different resistance values, thickness values, scaling factors, and for different material properties and the results proposed.

32 - Metamaterial Grid Resonators Structures for Enhancing the Radiofrequency Magnetic Field

Petr Drexler, *Department of Theoretical and Experimental Electrical Engineering, Brno University of Technology, Czech Republic*
Dusan Nespor, *Department of Theoretical and Experimental Electrical Engineering, Brno University of Technology, Czech Republic*
Radim Kadlec, *Department of Theoretical and Experimental Electrical Engineering, Brno University of Technology, Czech Republic*

In the contribution, a novel resonant structure – Grid Quasi-Periodic Resonant structure, is introduced. It allows to modify the RF magnetic field in MRI in order to obtain better field homogeneity. The structure is free of lumped elements. Simulated results are verified by the measurement.

33 - Influence of Metamaterial Surface Impedance on Patch Antenna Coupling

Alexander Kukharenko, *Institute of space device engineering, Russia*

Shinichiro Yamamoto, *University of Hyogo, Japan*
Kenichi Hatakeyama, *University of Hyogo, Japan*

Complex permeability spectra of Permendur and Cobalt flake composite materials in the microwave frequency range has been studied to reveal the demagnetizing field effect. In Permendur composites, a negative permeability caused by the magnetic resonance is obtained and its frequency dispersion can be controlled by the demagnetizing field.

7 - Time Domain Model for Reaction of Radiation on Thin Cut Wires

Takuya Kimura, *Kyoto University, Japan*
Takashi Hisakado, *Kyoto University, Japan*
Tohlu Matsushima, *Kyoto University, Japan*
Osami Wada, *Kyoto University, Japan*

This paper describes a time domain model for current and charge density on thin cut wire structures. The model represents the reaction of radiation from the cut wires with retarded couples which express the loss, and the validity of the model is confirmed by comparing it with electromagnetic simulations.

8 - Modeling of a Metamaterial Antenna on a Radial Transmission Line using the Discrete Dipole Approximation

Erik Shipton, *Kymeta Corporation, USA*
Mikala Johnson, *Kymeta Corporation, USA*
Patrick Bowen, *Kymeta Corporation, Duke University, USA*
Nathan Kundtz, *Kymeta Corporation, USA*

In this work, we demonstrate a discrete dipole approximation (DDA) model of a radially, waveguide-fed metamaterial antenna. We focus on the practical consideration of extracting an accurate polarizability of the individual unit cells from full wave simulation. We present a comparison of resulting prediction of the beam pattern from the DDA model against the simpler array factor calculation and a full wave simulation. We show that the DDA modelin this radial configuration yields significantly more accurate results than the array factor at a fraction of the computational cost of the full wave simulation.

9 - Bandpass Filter with Enhanced Selectivity and Harmonic Suppression Based on Novel Composite Right/Left-Handed Zeroth-Order Resonator

Xinyu Zhou, *City University of Hong Kong, Hong Kong*

A bandpass filter (BPF) with enhanced selectivity and harmonic suppression based on a novel modified composite right/left-handed (CRLH) zeroth-order resonator (ZOR) is presented. The equivalent circuit model of the modified CRLH ZOR is developed based on Bloch & Floquet theory. A second-order classical BPF employing the modified CRLH ZOR was designed and fabricated. Simulated and measured results achieved a bandwidth of 4.5 % centered at 2.2 GHz and a harmonic suppression of less than -20 dB up to 9 GHz (over 4f0).

Andrey Yelizarov, *Higher School of Economics, Russia*

A method of antenna element coupling control using the readjust of the surface impedance of the mounting plane is described. A construction of a tunable metamaterial-based antenna ground plane is presented. Results of antenna VSWR measurements, which show the coupling change, are shown.

34 - Cloaking of Ocean Waves with Anisotropic Fluid

Takahito Iida, *Osaka University, Japan*
Masashi Kashiwagi, *Osaka University, Japan*

We present an extension of 3D water wave cloaking for ocean waves. By noting the equivalence between the shallow water problem and the deep water problem, a 2D cloaking method is extended to free surface waves on the ocean. Consequently, anisotropic fluid density is necessary to cloak an offshore structure.

35 - Energy Harvesting Antennas based on Meta-structured Transmission Line

Jeong-Hae Lee, *Department of Electronic Information and Communication Engineering, Hongik University, Korea (South)*
Chang-Hyun Lee, *Department of Electronic Information and Communication Engineering, Hongik University, Korea (South)*
Kwi Seob Um, *Department of Electronic Information and Communication Engineering, Hongik University, Korea (South)*
Jong Chang Yi, *Department of Electronic Information and Communication Engineering, Hongik University, Korea (South)*
Young Kwan Kim, *Department of Information Display, Hongik University, Korea (South)*

In this paper, two RF energy harvesting antennas are presented. One is designed by mounting a 2 by 2 array of mu zero resonance antennas on a wideband tapered monopole antenna with an etched hole and a patch on the other side. The patch and hole provide the better impedance matching in the harvesting band. The harvesting antenna has wide 6 dB bandwidth of 0.62~1.3 GHz and 1.58~3.62 GHz. The radiation efficiency of 77%~99% was measured in the whole harvesting band. In addition, it has the peak gain of 10.18 dBi at 5.8 GHz and operates as WPT receiving antenna. The other is designed by combining a monopole and two unit cells mu zero resonance antenna. The monopole antenna operates as a radiator in the low band but it operates as a ground in the higher band. The radiation efficiencies are measured as 92.6 % at 0.86 GHz, 93.1 % at 1.84 GHz, and 88.9 % at 2.37 GHz, respectively.

36 - Double Negative Permeability and Permittivity Spectra of Fe50Co50/Cu Granular Composite Materials in the Microwave Range

Massango Herieta, *Hiroshima University, Japan*
Takanori Tsutaoka, *Hiroshima University, Japan*
Teruhiro Kasagi, *National Institute of Technology, Tokuyama College, Japan*
Shinichiro Yamamoto, *University of Hyogo, Japan*
Kenichi Hatakeyama, *University of Hyogo, Japan*

10 - Streamlined Flow of Displacement Current in Metatronic-Inspired Anisotropic Structure

Boris Okorn, *Ruđer Bošković Institute, Croatia*
Silvio Hrabar, *University of Zagreb, Croatia*
Jordi Sancho-Parramon, *Ruđer Bošković Institute, Croatia*
Antonija Perić, *University of Zagreb, Croatia*

Original concept of 'D-dot' wire relies on a dielectric cylinder embedded in an isotropic ENZ host that acts as an 'optical insulator', causing directional flow of the displacement current. Here, it is shown that a directional flow of displacement current can also be achieved by using anisotropic ENZ 'insulating' tube of finite thickness. This guiding phenomenon was investigated by scaled RF experiments.

11 - Self Consistent Modeling of High Power Microwave Breakdown in Split Ring Resonator Based Metamaterials

Konstantinos Kourtzanidis, *The University of Texas at Austin, USA*
Dylan Pederson, *The University of Texas at Austin, USA*
Laxminarayan Raja, *The University of Texas at Austin, USA*

We perform self-consistent three dimensional simulations of a SRR array under high power microwave radiation demonstrating the plasma formation at the gaps. The response of the array is strongly affected by the plasma presence, which shifts the resonance and modifies the transmittance of the whole metamaterial.

12 - Multiferroic Bilayer Metamaterials Prepared Using Metal-organic Decomposition

Kazuma Kunihara, *Nara Institute of Science and Technology, Japan*
Toshiyuki Kodama, *Nara Institute of Science and Technology, Japan*
Satoshi Tomita, *Nara Institute of Science and Technology, Japan*
Nobuyoshi Hosoito, *Nara Institute of Science and Technology, Japan*
Hisao Yanagi, *Nara Institute of Science and Technology, Japan*
Tetsuya Ueda, *Kyoto Institute of Technology, Japan*
Kei Sawada, *RIKEN SPring-8 Center, Japan*
Mirza Bichurin, *Novgorod State University, Russia*
Roman Petrov, *Novgorod State University, Russia*

We prepare ferromagnetic yttrium iron garnet (YIG) films and ferroelectric lead zirconate titanate (PZT) films using a metal-organic decomposition technique for multiferroic bilayer metamaterials. An X-ray diffraction together with magnetization curve and ferromagnetic resonance indicates that ferromagnetic YIG is crystallized on quartz substrates after 1000 degree C annealing.

13 - Hybrid Microwire Metacomposites for Microwave Applications

Yang Luo, *University of Bristol, United Kingdom*
Fabrizio Scarrpa, *University of Bristol, United Kingdom*

Complex permittivity and permeability spectra of Fe50Co50/Cu hybrid granular composite materials have been investigated in the RF to microwave range. Simultaneous negative permittivity and permeability have been observed in the percolated state with the Cu particle content above about 16 vol.% where the metallic electrical conduction is stabilized. Negative permittivity is attributed to the low frequency plasmonic state in the percolated Cu particle clusters; negative permeability is caused by the gyromagnetic natural resonance in the ferromagnetic Fe50Co50 particles.

37 - A Negative Refractive Index Terahertz Waveguide Measured Using Time-Domain Techniques

Shashank Pandey, *University of Utah, USA*
Barun Gupta, *University of Utah, USA*
Brandon Cui, *University of Utah, USA*
David Schurig, *University of Utah, USA*
Ajay Nahata, *University of Utah, USA*

We present the first experimental realization of a terahertz (THz) waveguide that exhibits a negative index of refraction. We accomplish this by designing three-dimensional structures that consist of split ring resonators and posts. THz radiation is guided in the form of surface plasmon polaritons (SPPs) along the 3D metallic structures, which, in turn, is fabricated on a metallized substrate. We use THz time-domain spectroscopy to measure the temporal properties of a narrowband THz pulse as it propagates along the waveguide. The changes in these time-domain waveforms yield direct evidence of a negative refractive index.

38 - Low Profile Antenna Based On Lossy High Impedance Surface

Zui Tao, *Southeast University, China*
Xiang Wan, *Southeast University, China*
Tie Jun Cui, *Southeast University, China*

This paper proposes a kind of horizontal polarized planar antenna with unidirectional radiation patterns with properties of broadband and low-profile. The proposed design is composed of a planar antenna and a high impedance surface (HIS) with lumped resistance components.

39 - Magnon Transistor and Majority Gate for Wave-Based Computing

Andrii Chumak, *University of Kaiserslautern, Germany*
Alexander Serga, *University of Kaiserslautern, Germany*
Philipp Pirro, *University of Kaiserslautern, Germany*
Burkard Hillebrands, *University of Kaiserslautern, Germany*

With the fast growth in the volume of information being processed, researchers are charged with the primary task of finding new ways for fast and efficient processing and transfer of data. Spin excitations – spin waves and their quanta magnons – open up a promising branch of high-speed and low-power information processing. In contrast to conventional spintronics, which relies on the transport of spin-polarized electron

Faxiang Qin, *Zhejiang University, China*
Jorge Carbonell, *Universitat Politècnica de Valencia, Spain*
Mihail Ipatov, *Universidad del Pais Vasco, Spain*
Arkady Zhukov, *Universidad del Pais Vasco, Spain*
Hua-Xin Peng, *Zhejiang University, China*

We propose an engineering metacomposite containing ferromagnetic microwires with double negative properties at microwave frequencies. A tunable metamaterial behaviour, expanded operating frequency band and a band-stop feature are realised in the wire-metacomposites by controlling mesostructural factors and wire selection.

14 - Glass-Based Tunable Single Negative Metamaterial for X-Band Applications

Sultan CAN, *Ankara University, Turkey*
A. Egemen Yilmaz, *Ankara University, Turkey*

In this paper glass based μ-negative tunable metamaterial is presented which filters the X-band frequencies but not the visible spectrum. Since the substrate is glass (Pyrex, εr=4.92), it gives opportunity to pass visible spectrum while filtering X-band frequencies. Multiple frequencies are achieved by inserting multiple equilateral triangular loops and the structure excited magnetically for achieving μ-negative region for each frequency values. Parameter retrieval analysis is performed by using the magnitude and phase values, which are obtained via CST Microwave Studio, and the surface current characteristics presented as well as the results.

15 - A Compact Multi-band Dielectric Resonator Antenna Loaded with CSRRs for Communication Systems

Shouzheng Zhu, *East China Normal University, China*
Rensheng Xie, *East China Normal University, China*
Jie Cao, *East China Normal University, China*

In this paper, a compact multi-band cylindrical dielectric resonator antenna (DRA) loaded with CSRR is presented. The DRA is composed of a semi-cylindrical dielectric resonator with metal ground sheet on the cut plane loaded with metamaterial structure. It is fed by aperture coupled microstrip line. The antenna size is about 50% decreased compared with the full cylindrical DRA. The SCRR is used to broaden bandwidth of the antenna. Simulation result shows that the antenna bandwidth can cover the 3G, 4G and WLAN usage. The antenna gain is above 5dB in its working band.

16 - Wire Medium as a Metamaterial with Tuned Spectral Characteristics

Liubov Ivzhenko, *O.Ya. Usikov Institute for Radiophysics and Electronics of the National Academy of Sciences of Ukraine (IRE NASU), Ukraine*
Evgen Odarenko, *Kharkiv National University of Radioelectronics, Ukraine*
Sergey Tarapov, *O.Ya. Usikov Institute for Radiophysics and Electronics of the National Academy of Sciences of Ukraine (IRE NASU), Ukraine*

The paper is devoted to experimental and theoretical study of the spectral

currents, magnon currents are spin fluxes, which propagate entirely without charge transfer through magnetically ordered conducting and insulating materials. Down-to-nm wavelengths, GHz-to-THz frequency range, Joule-heat-less transfer of spin information, and access to the novel wave-based computing concepts allow for the developing of a novel technology without drawbacks inherent to modern semiconductor electronics. In my talk I will discuss spin-wave majority gate and magnon transistor - two the most promising candidates for magnon-based data processing.

40 - Valley-dependent Pseudo-magnetic Field in Distorted Photonic Graphene

Fusheng Deng, *Shanxi Datong University, China*

The photonic analogy for generation and control of valley pseudospin currents using the pseudomagnetic fields induced in a strained graphene is investigated in microwave regime. In a photonic graphene with a uniaxial distortion, photons in two different valleys experience pseudomagnetic fields with opposite signs and valley-dependent propagations in bended paths are observed.

41 - Sensing In Inhomogeneous Media Using Metamaterial Inspired Sensors

Aysegul Musul, *Antalya International University, Turkey*
Hasan Yilmaz, *Antalya International University, Turkey*
Muhammed Boybay, *Antalya International University, Turkey*

Behavior of sensors based on complementary split ring resonators (CSRR) in inhomogeneous medium is presented. Spatial harmonics of the field generated by CSRR structure is analyzed and the relationship with homogenization is studied. By selecting proper gap and trace widths in the CSRR structure, it is possible to design a sensor that can detect cracks in carbon fiber reinforced polymers (CFRP) without being affected by the inhomogeneous nature of CFRP.

42 - A Dual-Frequency MRI Coil for Small Animal Imaging at 7 Tesla Based on Metamaterial-Inspired Wire Structures

Anton Nikulin, *ITMO University, Russia*
Stanislav Glybovski, *ITMO University, Russia*
Irina Melchakova, *ITMO University, Russia*
Pavel Belov, *ITMO University, Russia*
Redha Abdeddaim, *Institut Fresnel, France*
Stefan Enoch, *Institut Fresnel, France*

In this contribution we propose and numerically verify a new approach to de-sign of radio frequency (RF) coils for imaging of small animals in 7T MRI. The proposed coils inspired by wire media take advantage of multimode resonant structures composed of multi-ple printed metal strips.

43 - Leaky Wave Antennas Based on Metallic Wire with Gradient Radial Grooves

Jia Yuan Yin, *Chinese, China*
Tie Jun Cui, *Chinese, China*

characteristics of anisotropic wire metamaterials within tunable2Dunit-cell dimensions.We experimentally demonstrate possibility of effective operating of the spectral characteristics of the wire medium by varying the 2D unit-cell dimensions.In addition, we show that depending on geometric parameters of the unit-cell wire medium can operate both as high-pass filter, and as a band gap structure.We underline that investigated structure with rectangular unit-cell is a plasmonic-type medium when performing$\lambda p/b \geq 3$ conditions at lower values the wire medium is an electromagnetic bandgap crystal.

17 - Strong Magnetic Field Localization in Toroidal Metamaterials

Nikita Volsky, *National University of Science and Techology , Russia*

In this work we present and investigate a planar metamaterial with toroidal topology. We show that that this structure is a high Q resonator with highly concentrated magnetic field due to the toroidal response.

18 - Plasma Based Metamaterials : Numerical Studies On Reconfigurability And Tunability Of A Plasma - Split Ring Resonator Array

Konstantinos Kourtzanidis, *The University of Texas at Austin, USA*
Dylan Pederson, *The University of Texas at Austin, USA*
Laxminarayan Raja, *The University of Texas at Austin, USA*

A novel plasma based SRR metamaterial is studied numerically and we demonstrate that by external control of basic plasma parameters, the electromagnetic resonances can be shifted and their resonant response magnitude controlled. Parametric studies on the transmittance versus constitutive plasma parameters as well as on the plasma position in respect to the SRR array are performed.

19 - Isolation Improvement For Dual-frequency MIMO Patch With Spoof Surface Plasmon Polaritons And Substrate Integrated Waveguide

Bai Cao Pan, *State Key Laboratory of Millimetre Waves, School of Information Science and Engineering, Southeast University, China*
Tie Jun Cui, *State Key Laboratory of Millimetre Waves, School of Information Science and Engineering, Southeast University, China*

A decoupling design composed of both SSPP and SIW waveguides is proposed. A prototype is introduced to validate its function to improve the isolation between transmitting and receiving ports of a dual-frequency dual-polarization patch antenna. And a 20dB improvement for both excitations with broadband frequency band is realized.

20 - Numerical Modeling of Electromagnetic Scattering from Periodic Structures by Transformation Electromagnetics

Ozlem Ozgun, *Hacettepe University, Turkey*
Mustafa Kuzuoglu, *Middle East Technical University, Turkey*

The transformation electromagnetics is applied to the modeling of electromagnetic

We propose a kind of leaky-wave antennas based on the metallic wire with gradient radial grooves. The operating frequency range of the proposed antenna is 3-7GHz with an average gain of 9.29dBi, and the total scanning angle reaches 118.3, indicating the great potential in real applications. To the best knowledge of the authors, this is the first time to realize such a wide scanning angle by the leaky-wave antenna based on the surface plasmon polaritons.

44 - Bulk Terahertz Metamaterials Based On TiO2 Microresonators

Christelle Kadlec, *Institute of Physics, ASCR v.v.i., Czech Republic*
Michal Šindler, *Institute of Physics, ASCR v.v.i., Czech Republic*
Filip Dominec, *Institute of Physics, ASCR v.v.i., Czech Republic*
Petr Kužel, *Institute of Physics, ASCR v.v.i., Czech Republic*
Catherine Elissalde, *ICMCB, Univ. Bordeaux, CNRS-UPR 9048, France*
Patrick Mounaix, *IMS, Univ. Bordeaux, UMR CNRS 5218, France*
Hynek Němec, *Institute of Physics, ASCR, v.v.i., Czech Republic*

Rigid metamaterials were prepared by embedding TiO_2 microspheres into polyethylene. These structures exhibit a series of Mie resonances where the lowest one is associated with a strong dispersion in the effective magnetic permeability. Using time-domain terahertz spectroscopy, we experimentally demonstrated the magnetic nature of the observed resonance.

45 - Transformation Electromagnetics Modal Analysis

Theodoros Kaifas, *AUTH-DUTH, Greece*
Elias Vafiadis, *AUTH-DUTH, Greece*
John Sahalos, *University of Nicosia, Cyprus*
Gerard Granet, *Clermont Université, Université Blaise Pascal, Institut Pascal, France*
George Kyriacou, *DUTH, Greece*

Transformation Electromagnetics is frequently used to study analyze and design cloacking electromagnetic cavities. Here we employ transformation electromagetics in order to perform modal analysis in general convex finite domains - electromagnetic cavities. A properly chosen coordinate transformation is utilized to map the initial general cavity to an inhomogeneous and anisotropic spherical one. This process, called electromagnetic transformation, is based on the fact that Maxwell's equations are form-invariant. In the new coordinate system we focus on the weak form of the Maxwell's equations for extracting the solution. Instead of using finite element basis functions, we utilize entire domain ones and specifically the vector basis functions of the empty spherical cavity. In this way the electromagnetic problem takes the form of a generalized eigenvalue one which provides the modal analysis, (resonance frequencies and respective vector mode patterns), of the anisotropic inhomogeneous spherical cavity. The modal analysis of the initial general cavity is provided by the inverse electromagnetic transformation.

46 - Effective Parameter Retrieval of 3D Bianisotropic Scatterer Arrays for Oblique Propagation

scattering from periodic structures in conjunction with the finite element method with periodic boundary conditions. In a unit cell of periodic structure, a uniform mesh is used over a flat surface and the arbitrary periodic surface is modeled by a coordinate transformation. The major advantage of this approach is that arbitrary geometries can be handled by using a single and simple mesh. Therefore, repeated computations (such as in Monte Carlo simulations or optimization methods) corresponding to different geometries can be performed easily. Some numerical examples are demonstrated involving singly periodic structures.

21 - Designing of Extremely Subwavelength Epsilon-negative Metamaterials

Kai Fang, *Tongji University, China*
Hongzhong Chen, *Tongji University, China*
Yunhui Li, *Tongji University, China*
Junfei Zhao, *Tongji University, China*
Quan Wang, *Tongji University, China*
Yewen Zhang, *Tongji University, China*

The fabricated metamaterials include epsilon-negative, mu-negative and double-negative. The designing of the extremely subwavelength epsilon-negative metamaterials is presented at radio frequencies. The real parts of permittivity and permeability should be assuming negative values in the artificial materials. To validate the formulation results, the measurement of epsilon is also accomplished.

22 - Ultra-Broadband and Polarization-Insensitive Metamaterial Absorber Based on Coupling Frequency Selective Surface

Haibing Xu, *Huazhong university of science and technology, China*
Shaowei Bie, *Huazhong university of science and technology, China*
Jianjun Jiang, *Huazhong university of science and technology, China*

In this letter, we report the fabrication, and measurement of an ultra-broadband polarization-insensitive metamaterial absorber (MA), consisting of three layers. The EW and flaky carbonyl iron powders were used to produce two kinds of silicone rubber matrix magnetic composites for the top and the bottom layer, respectively. The middle layer is frequency selective surface (FSS) in the form of single square loop. The results show that the proposed 2.0 mm thick RAM can provide a **10 -**dB reflectivity over the frequency range of 5.35-18 GHz and exhibit polarization-insensitive properties over the whole range of 2-18 GHz. Experimental results were in good agreement with simulated ones

23 - Studying of two-layer Metamaterial Absorber at K band Frequency

Tran Manh Cuong, *Hanoi National University of education, Vietnam*
Thanh Huong Nguyen, *Hanoi National University of education, Vietnam*

This paper presents the study of a two-dielectric-layer metamaterial absorber structure, two perfect absorption frequency band at K band (f1 = 26.5 GHz and f2 = 28.6 GHz) were observed. The study of the dependence of absorption and frequency on relative distance between the layers of material and the material structure

Theodosios Karamanos, *Aristotle University of Thessaloniki, Greece*
Nikolaos Kantartzis, *Aristotle University of Thessaloniki, Greece*

In this paper, the effective parameters of infinite 3D arrays composed of bianisotropic particles for oblique wave illumination are extracted. First, the polarizability matrix of the simple bianisotropic scatterers that constitute the array is obtained along with the complex wavenumber for oblique propagation through the same array. Findings are, then, implemented into a first-principles homogenization technique and the desired effective parameters are finally retrieved. The proposed methodology is applied to two well-known bianistropic particles for various incidence angles of propagation.

47 - Decoupling from Spoof Surface Plasmon Polaritons waveguide by Periodic Reversal of Cross-linking architecture

Junjun Xu, *Southeast University, China*

We propose a method for decoupling of spoof plasmon-polaritons (SPPs) which are highly confined on two antiparallel ultrathin corrugated strips. Periodic reversal of cross linking element between the two parallel pair, which can ensuring the continuity of the transmission waveguide, providing a periodic perturbation to generate space harmonics. By altering the distance between two parallel corrugated strips to change the dispersion relations, we demonstrate theoretically and experimentally that spoof SPP waves are converted into spatial propagating waves with high efficiency, which are further radiated with flexible beam steering. The proposed method sets up a link between SPP waves and radiation waves in a highly controllable way, which would possibly open an avenue in designing new kinds of microwave and optical elements in scanning application.

48 - THz Sensing with Classical FSS

Irato Jáuregui, *Public University of Navarra, Spain*
Pablo Rodriguez Ulibarri, *Public University of Navarra, Spain*
Sergei Kuznetsov, *Novosibirsk State University, Russian Federation*
Miguel Beruete, *Public University of Navarra, Spain*

In this work a classical frequency selective surface is proposed for sensing applications at the terahertz regime. We design and experimentally test a FSS operating near 0.8 THz based on a cross-dipole periodic structure laying on a thin polypropylene substrate. A good sensing capability is tested by depositing a dielectric layer on the FSS, reaching a sensitivity up to 20%. Finally, an application towards the detection of microorganisms is proposed by means of a numerical study, demonstrating the potential of the technique in biomedical applications.

49 - An Enhancement of Extrinsic 2D Chirality Using Non-Chiral Metasurface

Chenwei Wei, *Dalian University of Technology, China*
Yang Zou, *Dalian University of Technology, China*
Tun Cao, *Dalian University of Technology, China*

Chirality routinely occurs in 3D metamaterials (MMs) lacking mirror symmetry or quasi

parameters are also discussed.

24 - Reduction of RCS in Ku-band Based on a Thin Metasurface

Jie Zhao, *Southeast University, China*
Qiang Cheng, *Southeast University, China*
Tie Jun Cui, *Southeast University, China*

A metasurface for the radar cross section (RCS) reduction is designed in this manuscript. The proposed metasurface is constructed by three kinds of basic units with different reflected phases, which brings in the destructive interferences on the incident waves, suppressing the main lobe of the scattering significantly. The array pattern of the meta-units are optimized to achieve the low-scattering feature at all direction, which mimics the diffusion reflection effect. Simulation results show that the designed metasurface suppresses the RCS by at least 10 dB from 11.7 GHz to 18.8 GHz with the thickness of 1.5 mm. The proposed metasurface may find wide applications in a series areas, such as stealth, imaging, and so on.

25 - Nearly Flat Bands in Two-Dimensional Magnetic Photonic Crystals and Associated Topological Properties

Bing Yang, *Beijing Institute of Technology, China*
Tong Wu, *Beijing Institute of Technology, China*
Xiangdong Zhang, *Beijing Institute of Technology, China*

Based on exact numerical calculations and physical analyses, we demonstrate that there are two types of flat band in two-dimensional (2D) magnetic photonic crystals (PhCs). One has trivial topology with zero Chern number and the other has non-trivial topology with nonzero Chern number. Physical origins and topological properties of two types of flat band are studied comparatively.

26 - Small Printed Log-Periodic Array, Matched with an Active Non-Foster Network

Fernando Albarracin Vargas, *Carlos III University in Madrid, Spain*
Francisco Javier Herraíz-Martinez, *Carlos III University in Madrid, Spain*
Daniel Segovia-Vargas, *Carlos III University in Madrid, Spain*

The design of a small printed-log-periodic antenna, loaded with an active matching network, for multiband applications is presented. A well-known, low-cost and low-profile antenna is re-engineered for including an additional impedance bandwidth in the lower UHF-band. The design method includes the use of the recently introduced sensitivity parameter Sens in order to find a suitable location for a transistor-based non-Foster network, realized with a Negative Impedance Converter (NIC).

2D planar MMs lacking in-plane mirror symmetry. However, realization of such asymmetric MMs in the high frequency region remains challenging since it is hard to precisely control the asymmetric geometry of the ultrasmall meta-atom. Moreover, another limiting factor of those MMs is their weak extrinsically 2D-chiral effect such as circular polarization conversion difference (CPCD). Here, we theoretically demonstrate that a highly symmetric metasurface (MS), also known as 2D planar MMs, can produce a dual-band strong extrinsic 2D chirality: CPCD in the THz region under off-normal incidence. Our MS consists of an array of circular holes penetrating through a metal/dielectric/metal (MDM) trilayer, where the holes occupy the sites of a rectangular lattice. The CPCD is due to the mutual orientation of circular holes array (CHA) and oblique incident wave. Meanwhile, we show that the CPCD in the single metal layer CHA disappears owing to the absence of magnetic dipolar moment that can significantly enhance chiral effects. The highly symmetric achiral MS with the large CPCD may be operated as flat lenses, chiral sensing and highly efficient polarization converters.

50 - Effective Diamagnetic Behaviour of 2D Magnonic Crystals

Roberto Zivieri, *Department of Physics and Earh Sciences, University of Ferrara, Italy*

In-plane magnetized two-dimensional binary magnonic crystals show an effective diamagnetic behaviour due to the formation of effective magnetic monopoles at the boundary between the two materials that orient the demagnetizing field parallel to the external field and to the magnetization.

51 - Nanopatterned Superconductors as Building Blocks for Fluxonic Metamaterials

Oleksandr V. Dobrovolskiy, *Goethe University Frankfurt am Main, Germany*
Valerij A. Shklovskij, *V. Karazin Kharkiv National University, Ukraine*
Ruslan V. Vovk, *V. Karazin Kharkiv National University, Ukraine*
Volodymyr Kruglyak, *University of Exeter, UK*
Michael Huth, *Goethe University Frankfurt am Main, Germany*

We demonstrate that nanopatterned superconducting microstrips can be used as building blocks for fluxonic metamaterials with intriguing microwave properties in the lower GHz range. The microstrips patterned with asymmetric grooves behave as microwave low-pass filters whose cutoff frequency can be tuned not only by the dc value but also by its polarity. For the microstrips with symmetric grooves a sine-to-triangular or a sine-to-rectangular pulse shape conversion is observed, depending on the dc value and the ac amplitude. A serial connection of different microstrips allows one to tailor discrete microwave loss levels that can be used for the development of high-frequency applications and multilevel excess-loss-based fluxonic devices.

Oral Sessions (Monday 19 – Afternoon 2)			
17:30-18:30	**Oral Session M3-A** **Bio-inspired advanced materials** **(special focused session)** Organizers: Nader Engheta; Giuseppe Strangi Chairs: Nader Engheta; Giuseppe Strangi	**Oral Session M3-B** **Commercialization of metamaterials** **(special focused session)** Organizers: George Eleftheriades; Ferran Martin; Tie Jun Cui Chairs: George Eleftheriades; Ferran Martin; Tie Jun Cui	**Oral Session M3-C** **Chiral structures** Chair: Nikolay Zheludev
	Imperial	**Imperial 2**	**Imperial 4**
17:30	**Mimicking and Interfacing Neuro-Biological Architectures with Nanostructured Materials** Invited **Francesco De Angelis**, *Istituto Italiano di Tecnologia, Italy* **Michele Dipalo**, *Istituto Italiano di Tecnologia, Italy* **Francesco Tantussi**, *Istituto Italiano di Tecnologia, Italy* **Valeria Caprettini**, *Istituto Italiano di Tecnologia, Italy* **Andrea Jacassi**, *Istituto Italiano di Tecnologia, Italy* **Victoria Shalabaeva**, *Istituto Italiano di Tecnologia, Italy* **Andrea Cerea**, *Istituto Italiano di Tecnologia, Italy* **Sara Perotto**, *Istituto Italiano di Tecnologia, Italy* In natural systems commonly appear periodic structures exhibiting macroscopic properties different from the ones on the single elements. Typical examples are butterfly wings, lotus leaves or complex neuronal. Here we describe results we achieved by combining plasmonic nanostructures with nature-inspired superhydrophobic metamaterials. Then, we will try to extend this concept to the recent development of electronic devices with neuromorphic architectures for future computing.	**Metamaterial Surface Antenna Technology: Commercialization Through Diffractive Metamaterials And Liquid Crystal Display Manufacturing** Invited **Ryan Stevenson**, *Kymeta Corporation, USA* **Mohsen Sazegar**, *Kymeta Corporation, USA* **Adam Bily**, *Echodyne Corporation, USA* **Mikala Johnson**, *Kymeta Corporation, USA* **Nathan Kundtz**, *Kymeta Corporation, USA* For mobile, broadband satellite communications applications a high-gain, scanning antenna is required. Kymeta is commercializing an electronically scanned, metamaterial antenna technology achieved through the use of diffractive metasurfaces and high-birefringence liquid crystals. Kymeta's technology is positioned for mass production by leveraging the manufacturing capabilities of the LC display industry.	**How Electromagnetic Chiral is a Chiral Object ?** **Ivan Fernandez-Corbaton**, *KIT, Germany* **Martin Fruehnert**, *KIT, Germany* **Carsten Rockstuhl**, *KIT, Germany* The common geometrical definition of chirality lacks meaningful upper bounds and the ability to rank objects according to their chirality. We introduce a definition for the electromagnetic chirality of an object which solves both these problems. We then study the electromagnetic properties of the objects that achieve the upper bound and show that they have promising applications. We discuss two of them: A two-fold resonantly enhanced and background free circular dichroism measurement setup and angle independent helicity filtering glasses.
17:45			**Electromagnetic Field Energy in Absorptive Chiral Metamaterial with Helical Elements** **Igor Semchenko**, *Gomel State University, Belarus* **Alexei Balmakou**, *Slovak University of Technology, Slovakia* **Sergei Khakhomov**, *Gomel State University, Belarus* **Sergei Tretyakov**, *Aalto University, Finland* Here we present theoretical results for estimation of electromagnetic field energy density in a dispersive lossy chiral metamaterial which consists of an array of helical resonators. The array interaction with a harmonic electromagnetic field of circularly polarized (CP) plane

			wave is studied depending on the sign of circular polarization. The generalized solution for the problem is found which is in good agreement with previous partial solutions obtained for split ring resonators, straight wires, and helices. Numerical postprocessing of the achieved theoretical findings revealed the optimal geometries of the helical lossy resonators for the highest interaction selectivity of them with resonant CP radiation.
18:00	**You see it, or you don't see it** Invited **Shu Yang**, *University of Pennsylvania, USA* Nature provides us fascinating examples with remarkable optical effects, including the dazzling iridescence on butterfly wings and dynamic underwater camouflage on Cephalopod skins that can change from transparency to pigmentation. Meanwhile, there have been tremendous interests in design of smart roofing, skylights, and architectural windows, which can block or reflect sunlight on scorching days, and return to a transparent state at a low lighting condition to improve light harvesting and capture free heat from the sun. Taking the cues from nature, I will discuss fabrication of tilted polymer pillar arrays on a wrinkled surface and assembly of nanoparticle films and their composites, which can achieve dramatic and reversible changes between three states, that is structural color display, opaqueness, and high transparency.	**Application of Metamaterials in Near Field UHF-RFID Readers** Invited **Jordi Bonache**, *Universitat Autónoma de Barcelona, Spain* **Gerard Zamora**, *Universitat Autónoma de Barcelona, Spain* **Ferran Paredes**, *Universitat Autónoma de Barcelona, Spain* **Simone Zuffanelli**, *Universitat Autónoma de Barcelona, Spain* **Pau Aguila**, *Universitat Autónoma de Barcelona, Spain* **Ferran Martin**, *Universitat Autónoma de Barcelona, Spain* In this work, we present an electromagnetic field confinement device based on metamaterials to be used in near field RFID readers. With this device, the confinement volume can be controlled, namely, it is possible to define a large area with an intense field without radiation leakage. The proposed device shows electric field components in the three spatial directions, ensuring the tag detection in different orientations.	**Probing Natural Optical Activity of Disordered Media** **Felipe Pinheiro**, *Instituto de Fisica, Universidade Federal do Rio de Janeiro, Brazil* **Vassili Fedotov**, *Optoelectronics Research Centre and Centre for Photonic Metamaterials, University of Southampton, UK* **Nikitas Papasimakis**, *Optoelectronics Research Centre and Centre for Photonic Metamaterials, University of Southampton, UK* **Nikolay Zheludev**, *Optoelectronics Research Centre and Centre for Photonic Metamaterials, University of Southampton, UK* We investigate natural optical activity of disordered systems composed of pointlike scatterers. We demonstrate that the histogram of the rotatory power is strongly dependent on the disorder strength, as disordered media are intrinsically chiral. We argue that the standard deviation of optical rotation can probe chirality in random media.
18:15			**Tailoring Local Optical Chirality in Helical Metamaterials** **Philipp Gutsche**, *Zuse Institute Berlin, Germany* **Raquel Mäusle**, *Zuse Institute Berlin, Germany* **Sven Burger**, *Zuse Institute Berlin and JCMwave, Germany* In this contribution we present results from a numerical study of light propagation in helical metamaterials. In particular, light interaction with hexagonal lattices of three intertwined tapered gold helices is studied. Regimes of tunable, local optical chirality enhancement and tunable, local field energy enhancement are identified.

18:30-19:30	**Welcome Reception**

Tuesday, 20th September

09:00-10:00	**Plenary Session 2** — **Imperial** Chair: Filiberto Bilotti **Topological Principles and Exceptional Point Physics Realized using Simple Meta-crystals** **C.T. Chan**, *Hong Kong University of Science and Technology, Hong Kong* Meta-crystals can have fairly complex band dispersions in the momentum space, allowing for the possibility of realizing topological phenomena such as Weyl points, synthetic gauge flux and topologically protected edge states. Likewise, "exceptional point" concepts can be demonstrated in simple acoustic systems.		
10:00-10:30	**Coffee Break**		
Oral Sessions (Tuesday 20 – Morning)			
10:30-12:30	**Oral Session T1-A** **RF and microwave metasurfaces** Chair: Themos Kallos	**Oral Session T1-B** **Plasmonics of metallic nanoparticles** Chair: Andrei Lavrinenko	**Oral Session T1-C** **Acoustics and mechanics III** Chair: Muamer Kadic
	Imperial	**Imperial 2**	**Imperial 4**
10:30	**Exact Polychromatic Metasurface Design: The GSTC Approach** **Nima Chamanara**, *polytechnique Montreal, Canada* **Yousef Vahabzadeh**, *polytechnique Montreal, Canada* **Karim Achouri**, *polytechnique Montreal, Canada* **Christophe Caloz**, *polytechnique Montreal, Canada* The generalized sheet transition conditions (GSTCs) have been recently leveraged for synthesizing metasurfaces transforming specified monochromatic incident waves in arbitrary fashions. This paper extends the technique to general polychromatic designs. The resulting polychromatic metasurfaces provide unprecedented control on the temporal and spatial frequency components of incident pulsed electromagnetic waves. They may find applications in spatial filters, spatial phasers, real-time Fourier transformers and real-time spectrum analyzers	**Isotropic 3D Optical Magnetism in Visible Light in a Self-Assempled Metamaterial** Invited **Philippe Barois**, *CNRS-University of Bordeaux, France* **Sergio Gomez-Graña**, *CNRS-University of Bordeaux, France* **Mona Treguer-Delapierre**, *CNRS-University of Bordeaux, France* **Etienne Duguet**, *CNRS-University of Bordeaux, France* **Jean-Baptiste Salmon**, *CNRS-University of Bordeaux, France* **Jacques Leng**, *CNRS-University of Bordeaux, France* **Vasyl Kravets**, *University of Manchester, UK* **Alexander Grigorenko**, *University of Manchester, UK* **Anirudh Peyyety**, *CNRS-University of Bordeaux, France* **Virginie Ponsinet**, *CNRS-University of Bordeaux, France*	**Homogenization of Sound Hard Metamaterials in the Time Domain** **Agnes Maurel**, *CNRS, Institut Langevin, France* **Jean-Jacques Marigo**, *LMS, Ecole Polytechnique, France* **Bruno Lombard**, *CNRS, LMA, France* We present a homogenization method based on a matched asymptotic expansion technique for sound hard materials structured at subwavelength scale. Considering the wave equation in the time domain, jump conditions are derived for the acoustic pressure and the normal velocity across an equivalent interface with non zero thickness. These jump conditions are implemented in a numerical scheme and compared to the results of the direct problem.

10:45	**Tailor the Functionalities of Metasurfaces Based on a Complete Phase Diagram** **Shaojie Ma**, *Department of Physics in Fudan University, China* Metal/insulator/metal metasurfaces have widely applications ranging from perfect absorption to phase modulation, but the mechanism of these functionalities are not yet fully understood. Here, based on a coupled-mode analysis, we establish a complete phase diagram through two simple parameters, which lays a solid basis for realizing functional and tunable photonic devices with such structures.	**Philippe Richetti**, *CNRS-University of Bordeaux, France* **Alexandre Baron**, *CNRS-University of Bordeaux, France* **Daniel Torrent-Marti**, *CNRS-University of Bordeaux, France* Raspberry-like plasmonic nanoclusters have been synthesized by nanochemistry and self-assembled into bulk metamaterials in microfluidic devices. The optical properties of the nanoclusters have been studied by polarization resolved light scattering prior to assembling. The scattering efficiencies of the electric and magnetic multipoles are unambiguously determined experimentally, in excellent agreement with numerical simulations. The residual degree of anisotropy inherent to the self-assembly process is measured. The effective magnetic permeability of the assembled material differs notably from 1 and shows no significant dependence on the direction of propagation.	**Broadband Topological Non-Reciprocity in Time-Floquet Metamaterials** **Romain Fleury**, *Ecole Polytechnique Federale de Lausanne (EPFL), Switzerland* **Alexander Khanikaev**, *The City University of New York, NY, United States of America* **Andrea Alu**, *The University of Texas at Austin, TX, United States of America* We introduce and discuss time-Floquet metamaterials, or artificial media possessing a double periodicity both in space and time. They can be obtained from a regular crystal by periodically modulating in time the physical properties of each unit cell, leading to a novel class of metamaterials where frequency is not conserved. By suitably breaking time-reversal symmetry, these classical systems can exhibit non-trivial topological properties that can be exploited to build novel, broadband nonreciprocal devices immune to defects and disorder both in their structure and in the modulation scheme. We discuss potential applications in acoustics and electromagnetism.
11:00	**Electromagnetically Induced Transparency Through Magnetic Field Interactions in Bilayered Enantiomeric Metasurfaces** **Elena Bochkova**, *IEF, CNRS, UMR 8622, University Paris Sud, University Paris-Saclay, France* **Shah Nawaz Burokur**, *LEME, EA 4416, Université Paris Ouest, France* **André de Lustrac**, *IEF, CNRS, UMR 8622, Univ Paris Sud, Université Paris-Saclay; Université Paris Ouest, France* **Anatole Lupu**, *IEF, CNRS, UMR 8622, Univ Paris Sud, Université Paris-Saclay; CNRS, Orsay, France* We demonstrate the possibility to achieve electromagnetically induced transparency by using magnetic field induced coupling between appropriate symmetry resonant enantiomeric elements in a bilayered metasurface arrangement. The considered mechanism is distinctly different from near-field coupling hybridization or retarded interaction far-field coupling. The low sensitivity of the spectral response to the variation of the separation distance between enantiomeric meta-atoms greatly relaxes fabrication constraints for the optical domain where such kind of resonances with sharp spectral features are highly	**3D DNA Plasmonics** **Na Liu**, *MPI for Intelligent Systems, Germany* Deterministic placement and dynamic manipulation of individual plasmonic nanoparticles with nanoscale precision feature an important step towards active nanoplasmonic devices with prescribed levels of performance and functionalities at optical frequencies. We demonstrate the precise organization and the controlled motion of nanoparticles by using the toolbox of DNA nanotechnology	**Enhancement of Stimulated Brillouin Scattering in Metamaterials** **Michael Smith**, *The University of Sydney, Australia* **Carel Martijn de Sterke**, *The University of Sydney, Australia* **Chris Poulton**, *University of Technology Sydney, Australia* **Mikhail Lapine**, *University of Technology Sydney, Australia* **Christian Wolff**, *University of Technology Sydney, Australia* **Boris Kuhlmey**, *The University of Sydney, Australia* We calculate the effective stimulated Brillouin scattering (SBS) gain coefficient for an all-dielectric cubic metamaterial. A complete methodology for calculating the effective optical, acoustic and optoacoustic parameters present in the gain coefficient is presented for the first time, and an order of magnitude enhancement in the gain coefficient is achieved.

	desirable for sensing applications.		
11:15	**Design of Ultra-flat Antennas Based on Modulated Metasurfaces** **Gabriele Minatti**, *University of Siena, Italy* **Francesco Caminita**, *Wave Up Srl, Italy* **Enrica Martini**, *Wave Up Srl, Italy* **Stefano Maci**, *University of Siena, Italy* This work presents design and analysis methods of planar antennas based on modulated metasurfaces (MTSs). These antennas operate on an interaction between a cylindrical surface wave (SW) excited by an isotropic radiator and an MTS offering a spatially modulated impedance boundary condition (IBC). The periodic modulation of the IBC transforms the SW launched by the feed into a leaky wave (LW), thus, generating a radiating aperture. This results in a lightweight and low profile structure, characterized by low losses and simple low-cost manufacturing. Furthermore, by acting on the impedance pattern it is possible to obtain a unique control of the phase and amplitude of the aperture field, thus, molding the radiation pattern.	**Plasmon-Exciton Interactions Using DNA Templates** **Eva-Maria Roller**, *Faculty of Physics and Center for NanoScience (CeNS), Ludwig-Maximilians-Universit¨at (LMU), Germany* **Christos Argyropoulos**, *Department of Electrical and Computer Engineering, University of Nebraska-Lincoln, USA* **Alexander Hoegele**, *Faculty of Physics and Center for NanoScience (CeNS), Ludwig-Maximilians-Universit¨at (LMU), Germany* **Tim Liedl**, *Faculty of Physics and Center for NanoScience (CeNS), Ludwig-Maximilians-Universit¨at (LMU), Germany* **Mauricio Pilo-Pais**, *Faculty of Physics and Center for NanoScience (CeNS), Ludwig-Maximilians-Universit¨at (LMU), Germany* We use the DNA origami technique to study interactions between plasmons and molecular excitons (J-aggregates). A DNA Origami 2-Layer square-lattice sheet was used to assemble nano-particle dimers with a fixed spacing of 5 nm. The assembled structures were then incubated in a dye solution known to form J-aggregates at high concentrations. The small gap between the gold particles produces a plasmonic hot-spot that exhibits enough field strength to observe plasmon-exciton coupling at room temperature and optical frequencies. Dark-field scattering spectroscopy was used to characterize the hybrid states, displaying a splitting up to 115 meV. Further detuning between the exciton absorption and the plasmon resonances was obtained by varying the NPs size between 30nm to 60nm while maintaining the gap size constant. This permitted us to fit a two-component coupled oscillator model and extract a coupling constant g of 80meV. The pre-programmability of the design to match the exciton of choice and the massive parallel assembly makes DNA-origami the perfect template to study plasmon-exciton interactions.	**Soft Acoustic Metaslabs for Sound Insulation** **Abdoulaye Ba**, *University of Bordeaux, France* **Kevin Zimny**, *University of Bordeaux, France* **Benoit Mascaro**, *Univerisity of Bordeaux, France* **Artem Kovalenko**, *University of Bordeaux, France* **Olivier Mondain**, *University of Bordeaux, France* **Thomas Brunet**, *Univerisity of Bordeaux, France* **Christophe Aristégui**, *Univerisity of Bordeaux, France* Acoustic properties of sub-wavelength panels composed of porous micro-beads is here investigated through ultrasonic experiments. Deep and wide minima observed in transmission-configuration measurements suggest interesting applications in terms of sound insulation.
11:30	**Broadband Transparent Metasurfaces for Full Phase Shift and Polarization Control** **Juan D. Baena**, *Universidad Nacional de Colombia, Colombia*	**Super-Spherical Core-Shell Nanoparticles: Nanostructured Materials Enabling Applications in the Visible Regime** **Davide Ramaccia**, *“RomaTre” University, Italy*	**Mechanical Motion and Spatiotemporal Modulation to Realize Non-Reciprocal and Active Metamaterials** **Dimitrios Sounas**, *The University of Texas at Austin, USA*

	Manuel Londoño, *Universidad Nacional de Colombia, Colombia* We have achieved a broadband transparent metasurface useful for full phase control and conversion from linear polarization to any elliptical polarization. This can be applied in the field of telecommunications to obtain circular polarized signals, taking advantage of that every other polarization state can be decomposed into two circular polarized signals, and thus achieving always a communication between antennas.	**S. Arcieri**, *“RomaTre” University, Italy* **A. Toscano**, *“RomaTre” University, Italy* **Fililberto Bilotti**, *“RomaTre” University, Italy* In this contribution, we present a non-conventional core-shell nanoparticle, named supersphere, for implementing optical devices whose performances cannot be easily achieved with conventional nanoparticles. Superspheres are solids with intermediate shape between a sphere and a cube, whose external boundaries are described by Lamè surface equation. Thanks to its particular shape, a core-shell supersphere resonates at a lower resonant frequency with respect to a conventional core-shell spherical nanoparticle with same electrical dimensions. Such a characteristic allows relaxing the fabrication constrains, i.e. extremely thin shells, typically required for making the conventional spherical core-shell nanoparticles to operate in the lowest region of the visible spectrum. Here, after having discussed the geometry and electrical response of a core-shell supersphere, we report some preliminary results on their successful employment in the implementation of three optical devices: a transparent screen, a biosensor and a mantle cloak.	**Li Quan**, *The University of Texas at Austin, USA* **Yakir Hadad**, *The University of Texas at Austin, USA* **Andrea Alu**, *The University of Texas at Austin, USA* We connect the two basic approaches of mechanical motion and spatiotemporal modulation for realizing moving media and show that they can both be derived from the same fundamental relativistic principles. We do this through examples of non-reciprocal structures, such as moving INZ media and rotating rings, and active structures, such as media in relative motion with each other for light generation. In the latter case, we discuss the relation of the spatiotemporal modulation approach with parametric down-conversion.
11:45	**Dynamic Handedness Switching in Planar Chiral Checkerboard Metasurfaces: Theory and Numerical Simulation** **Yoshiro Urade**, *Department of Electronic Science and Engineering, Kyoto University, Japan* **Yosuke Nakata**, *Center for Energy and Environmental Science, Shinshu University, Japan* **Toshihiro Nakanishi**, *Department of Electronic Science and Engineering, Kyoto University, Japan* **Masao Kitano**, *Department of Electronic Science and Engineering, Kyoto University, Japan* We demonstrate that the handedness of a planar chiral checkerboard metasurface can be switched by modulating local impedance of the metasurface structure. A theoretical analysis based on Babinet's principle and numerical simulation for the electromagnetic response of the metasurface are provided.	**Reconfigurable Metal-Dielectric Nanodimers as Component of Hybrid Nanophotonics** **Dmitry Zuev**, *ITMO University, Russia* **Sergey Makarov**, *ITMO University, Russia* **Valentin Milichko**, *ITMO University, Russia* **Sergey Starikov**, *Joint Institute for High Temperatures of the Russian Academy of Sciences, Russia* **Ivan Mukhin**, *St. Petersburg Academic University, Russia* **Ivan Morozov**, *St. Petersburg Academic University, Russia* **Alexander Krasnok**, *ITMO University, Russia* **Pavel Belov**, *ITMO University, Russia* We demonstrate a novel type of asymmetrical hybrid nanostructures fabricated via combination of conventional lithographical methods with fs laser reshaping at nanoscale. The method of such type structures fabrication makes possible accurate engineering both electric and magnetic optical resonances of the hybrid nanoparticle. We show tuning of scattering properties and considerable shift of the resonant transmittance spectral position on 250 nm in	**Acoustic Vortex Beam Generation Using a Compact Metamaterial Aperture** **Christina J. Naify**, *Naval Research Lab (USA), USA* **Charles A. Rohde**, *Naval Research Lab (USA), USA* **Theodore P. Martin**, *Naval Research Lab (USA), USA* **Michael Nicholas**, *Naval Research Lab (USA), USA* **Matthew D. Guild**, *Naval Research Lab (USA), USA* **Gregory J. Orris**, *Naval Research Lab (USA), USA* Vortex waves, which carry helical phase fronts, have found a wide range of applications from high-rate communications, to particle manipulation. Current methods to generate vortex waves include active arrays, or passive apertures such as metasurfaces. Here we present a metamaterial-based, passive aperture capable of generating a range of topologically-diverse vortex modes. Generation of both integer, and non-integer modes is demonstrated experimentally and analytically..

		the visible range.	
12:00	**Miniaturized Metasurface Using Interdigital Capacitors and Meandered Loop Slots** **Yunfei Cao**, *The University of Hong Kong, Hong Kong* A compact metasurface (MS) with a small volume of 0.0508λg×0.0508λg×0.0005λg (λg is the guided wavelength) is proposed. On the top layer of the substrate, the patch is loaded with several interdigital capacitors between the adjacent unit cells on the four sides to increase the equivalent capacitance, hence reducing the total size. A meandered loop slot is etched on the bottom layer of the substrate to introduce an additional inductance effect to decrease the resonance frequency further, and simultaneously increase the operating bandwidth. The operating frequency of the proposed MS further decreases by reducing the thickness of the substrate. So an ultra thin substrate is used in this design to reduce the total volume further..	**Transport of a Localized Surface Plasmon Through a Linear Array of Metal Nanoparticles: Forerunner and Normal Mode Contributions** **P. Jasper Compaijen**, *Zernike Insitutte for Advanced Materials, University of Groningen, Netherlands* **Victor A. Malyshev**, *Zernike Insitutte for Advanced Materials, University of Groningen, Netherlands* **Jasper Knoester**, *Zernike Insitutte for Advanced Materials, University of Groningen, Netherlands* We theoretically investigate the transport of a Localized Surface Plasmon through a linear chain of metal nanoparticles. Two co-existing signals propagating through the array are found: one, traveling with the group velocity of the surface plasmon polaritons of the system, and the other one, running with the speed of light (a Sommerfeld-like forerunner).	**PT Symmetric Scattering Using Passive Acoustic With Flow** **Yves Aurégan**, *Laboratoire d'Acoustique de l'Université du Maine, France* **Vincent Pagneux**, *Laboratoire d'Acoustique de l'Université du Maine, France* We show both theoretically and experimentally that an acoustical wave in an airflow duct going through a pair of diaphragms, one with gain and another with an equivalent amount of losses, displays all the features of a parity-time (*PT*) symmetric system.
12:15	**Frequency Tunable Metasurface for GNSS** **Yunfei Cao**, *The University of Hong Kong, Hong Kong* **John (Yiannis) C. Vardaxoglou**, *Loughborough University, U.K.* **S. W. Cheung**, *The University of Hong Kong, Hong Kong* **T. I. Yuk**, *The University of Hong Kong, Hong Kong* A compact frequency tunable MetaSurface (MS) for GNSS is proposed in this paper. The MS comprised of a double layer array with square conducting patches on one layer and meander line slots on the other. The unit cell has a total volume of 0.15λg×0.15λg×0.01λg (λg is the guided wavelength) where four varactor diodes are placed symmetrically across the meandered slot on the ground plane to achieve the frequency tunability. Because the meandered slot on the other side of the substrate is inductive, the operating frequency is reduced and the operating bandwidth is increased. A very efficient biasing circuit has been designed to control all the varactors where simulation results show that, by tuning the varactors from 4.08 pF to 0.95 pF, the operating frequency of the MS can be tuned from 1.08 to 1.61 GHz.	**Inhomogeneous Broadening in Non-interacting Nonlocal Plasmonic Ensembles** **Christos Tserkezis**, *Technical University of Denmark, Department of Photonics Engineering, Denmark* **Johan Rosenkrantz Maack**, *Technical University of Denmark, Department of Photonics Engineering, Denmark* **Zhaowei Liu**, *University of California, San Diego, Department of Electrical and Computer Engineering, U.S.A.* **Martijn Wubs**, *Technical University of Denmark, Department of Photonics Engineering and Center for Nanostructured Graphene, Denmark* **Niels Asger Mortensen**, *Technical University of Denmark, Department of Photonics Engineering and Center for Nanostructured Graphene, Denmark* The importance of inhomogeneous broadening due to the size dependence of plasmon resonances in few-nm metallic particle ensembles is investigated through different models describing the nonlocal optical response of plasmonic nanospheres.	**Gradient Index Devices for the Full Control of Elastic Waves in Plates** **Yabin Jin**, *Université de Lille 1, France* **Daniel Torrent**, *Université de Bordeaux, France* **Bahram Djafari-Rouhani**, *Université de Lille 1, France* We present a method for designing gradient index (GRIN) devices for elastic waves in plates based on Fourier homogenization of phononic crystals/acoustic metamaterials. The method allows the design of devices to control simultaneously the three fundamental Lamb modes, despite the fact that their dispersion relations are managed by different elastic constants. It is shown that by means of complex GRIN phononic crystals and thickness variations of the plate, it is possible to independently design the three refractive indexes of these Lamb modes, hence realizing their simultaneous control. The method is applied to the design of some GRIN devices such as a flat, Luneburg or Maxwell lens.

12:30-14:00	Lunch Break		
Oral Sessions (Tuesday 20 – Afternoon 1)			
14:00-16:00	**Oral Session T2-A** **Graphene and superconducting structures** Chair: Vassili Fedotov	**Oral Session T2-B** **Metasurfaces I** Chair: Alexander B. Yakovlev	**Oral Session T2-C** **Cloaking and transformation approaches I** Chair: Dimitrios Sounas
	Imperial	**Imperial 2**	**Imperial 4**
14:00	**Quantized Beam Shifts in Graphene** **Wilton Kort-Kamp**, *Los Alamos National Laboratory, USA* **Nikolai Sinitsyn**, *Los Alamos National Laboratory, USA* **Diego Dalvit**, *Los Alamos National Laboratory, USA* We predict quantized Imbert-Fedorov, Goos-Hänchen, and photonic spin Hall shifts for light beams impinging on a graphene systems in external magnetic fields. In the quantum Hall regime the Imbert-Fedorov and photonic spin Hall shifts are quantized in integer multiples of the fine structure constant α, while the Goos-Hänchen ones in multiples of α. **Media link(s):** See published paper at Phys. Rev. B 93, 081410(R) (2016).	**Giant Nonlinear Optical Activity from Planar Metasurfaces** Invited **Thomas Zentgraf**, *Department of Physics, University of Paderborn, Germany* **Guixin Li**, *Department of Physics, University of Paderborn, Germany* **Shumei Chen**, *School of Physics & Astronomy, University of Birmingham, UK* **Martin Weismann**, *Department of Electronic and Electrical Engineering, University College London, UK* **Bernhard Reineke**, *Department of Physics, University of Paderborn, Germany* **Ventsislav Kolev Valev**, *Department of Physics, University of Bath, UK* **Kok Wai Cheah**, *Department of Physics, Hong Kong Baptist University, Hong Kong* **Nicolae Coriolan Panoiu**, *Department of Electronic and Electrical Engineering, University College London, UK* **Shuang Zhang**, *School of Physics & Astronomy, University of Birmingham, UK* Second harmonic generation circular dichroism (CD) is more sensitive to the handedness of chiral materials than its linear optical counterpart. In this work, we show that 3D chiral structures are not necessary for introducing strong CD for harmonic generations. Specifically, we demonstrate giant CD for both second harmonic generation and third harmonic generation on suitably designed ultrathin plasmonic metasurfaces. It is experimentally and theoretically verified that the overwhelming contribution to this nonlinear CD is of achiral origin. The results shed new light on the origin of	**Electromagnetic Invisibility Cloaks in Relativistic Motion** **Jad C. Halimeh**, *Physics Department and Arnold Sommerfeld Center for Theoretical Physics, LMU München, Germany* **Robert T. Thompson**, *Department of Mathematics and Statistics, University of Otago, New Zealand* **Martin Wegener**, *Institute of Applied Physics and Institute of Nanotechnology, Karlsruhe Institute of Technology (KIT), Germany* We show that an ideal free-space invisibility cloak moving at relativistic speed does not work in general. We also show, however, that there are infinitely many special cases, for which the cloak continues to work, but cloaking becomes non-reciprocal. We illustrate our findings by ray-tracing calculations.
14:15	**Superconducting Transmission Lines with Pulse-Controlled Dispersion** **Sergey Shitov**, *National University for Science & Technology MISiS, Moscow / Kotel'nikov Institute of Radio Engineering and Electronics, Moscow, Russia* **Ayman Yahya**, *National University for Science & Technology MISiS, Moscow, Russia* **Alexey Ustinov**, *Physikalisches Institut, Karlsruhe Institute of Technology / National University for Science & Technology MISiS, Moscow, Germany / Russia* To control phase velocity in superconducting transmission lines using short electrical pulses, a few approaches are being developed. A new design is developed for left-to-right (L2R) and right-to-left (R2L)		**Ultrathin Carpet Cloak Based on Ring Resonators** **Bakhtiyar Orazbayev**, *Public University of Navarre, Spain* **Nasim Mohammadi Estakhri**, *The University of Texas at Austin, USA* **Miguel Beruete**, *Public University of Navarre, Spain* **Andrea Alù**, *The University of Texas at Austin, USA* In this work the design of an ultrathin carpet cloak based on a metasurface with ring resonators is demonstrated. The scattering from a triangular bump of a Gaussian beam is suppressed by manipulating the reflection phase along the edge of the bump. This is achieved by an array of closed ring resonators with varying radii. The object to hide can be placed under the bump on a flat ground

	tunable transmission lines based on a CPW with embedded paired resonators containing dc-SQUIDs, up to 40 cells, at frequencies up to 20 GHz. Characteristic impedance of new dispersive transmission lines is increased above 30 Ohm; a thin-film attenuator is integrated for suppression of standing waves. A stop-band is found for R2L line demonstrating slower phase velocity; this transmission gap is due to effect of shorter wavelength (up to 100 times) reaching electrical length of the paired resonators cell (70 μm). In case of L2R line with faster phase velocity, the transmission band can be almost flat, if simultaneous tuning of frequency for all paired resonators is provided. No negative phase velocity is found in the simulations; however, the increment of differential phase velocity is positive for R2L near edge of the stop-band and negative near the resonance for L2R case.	the nonlinear CD effect in achiral planar surfaces.	plane. The performance of the designed cloak in the near field and far field is numerically analyzed at the operation frequency and the successful concealing of the bump is confirmed. The presented cloak has a thin, lightweight design and can find applications in radar and antenna systems.
14:30	**Superconductive Resonator With Integrated Spirals Structure For Magnetic Metamaterial Applications** **Aleksandr Averkin**, *National University of Science and Technology MIS&S, Moscow, Russia* **Alexander Zhuravel**, *B. Verkin Institute for Low Temp. Physics and Engineering, NAS of Ukraine, Kharkov, Ukraine* **Valeriy Koshelets**, *Kotel'nikov Institute of Radio Engineering and Electronics, Moscow, Russia* **Lyudmila Filippenko**, *Kotel'nikov Institute of Radio Engineering and Electronics, Moscow, Russia* **Alexandre Karpov**, *National University of Science and Technology MIS&S, Moscow, Russia* **Alexey Ustinov**, *Physikalisches Institute, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany* We developed an ultra-compact superconductive microwave resonator with magnetic coupling, suitable for use as magnetic meta-atom in RF metamaterials. The resonator is made as a part of superconductive integrated microcircuit with two superposed superconductive spirals. The two superposed spirals are wounded in opposite directions and separated by SiO2 dielectric layer in a standard Nb process. The two-spiral structure behaves as a distributed resonator with exceptionally slow phase speed, exhibiting a number of resonant modes in RF transmission experiments. Achieved resonator's diameter to the wavelength rate λ/D is exceptionally high, about 14300. The lowest resonance frequency of twin-spiral resonator ~7 MHz is	**Flat Nonlinear Optics with Ultrathin Highly-Nonlinear Metasurfaces** Invited **N. Nookala**, *The University of Texas at Austin, USA* **J. Lee**, *The University of Texas at Austin, USA* **M. Tymchenko**, *The University of Texas at Austin, USA* **J.S. Gomez-Diaz**, *The University of Texas at Austin, USA* **F. Demmerle**, *Technical University of Munich, Germany* **G. Boehm**, *Technical University of Munich, Germany* **K. Lai**, *The University of Texas at Austin, USA* **G. Shvets**, *The University of Texas at Austin, USA* **M.-C. Amann**, *Technical University of Munich, USA* **A. Alu**, *The University of Texas at Austin, USA* **M.A. Belkin**, *The University of Texas at Austin, USA* Extending the 'flat optics' paradigm to the nonlinear optics faces important challenges, since, for any practical situation, we are required to simultaneously achieve sub-diffraction phase control and efficient frequency conversion in metasurfaces of sub-wavelength thickness. Here, we experimentally demonstrate giant nonlinear response and continuous phase control of the giant nonlinear response in metasurfaces based on plasmonic nanoresonators coupled to intersubband transitions in semiconductor multi-quantum wells. Over 0.075% of second-harmonic power conversion efficiency is achieved experimentally in a 400-nm-thick metasurface using 10 microns wavelength pump with 20 kW/cm2 intensity.	**Antenna-Based Carpet Cloak: a Possible Frequency and Angular Broadband Cloaking Technique** **Antonino Tobia** *Roma Tre University, Italy* **Davide Ramaccia**, *Roma Tre University, Italy* **Alessandro Toscano**, *Roma Tre University, Italy* **Filiberto Bilotti**, *Roma Tre University, Italy* In this contribution, we discuss a possible antenna-based cloak for overcoming the intrinsic narrow frequency and angular bandwidths of conventional metasurface-based cloaks. The idea is to use a fully passive antenna array to mimic the reflection from a ground plane even in presence of an electrically large metallic bump. Here, a triangular bump over a ground plane is cloaked covering both sides by a pair of conventional half-wavelength dipole arrays. Inspired by the Van Atta array configuration, we connect the antenna elements on one side to the other in order to restore the phase fronts as the bump were not present. The performances have been numerically evaluated, showing the ability of the proposed setup to mimic the reflection from a ground plane over the frequency operation band of the antenna elements. Wide angular bandwidth is achieved thanks to the self-adaptive nature of the proposed configuration.

	lowered by the factor of 21 compared to the single spiral resonator. The measured and HFSS simulated resonance frequencies are in a good agreement. Moreover, in experiment with cryogenic Laser scanning microscope (LSM), we confirmed HFSS simulated distribution of the RF currents of the first resonant modes.		
14:45	**Q: How many folded angels can we fit on the head of pin? A: 22+/-5** Invited **Itai Cohen**, *Cornell, USA* **Paul McEuen**, *Cornell, USA* **Marc Miskin**, *Cornell, USA* **Christian Santangelo**, *UMASS, USA* **Ryan Hayward**, *UMASS, USA* **Tom Hull**, *University of Western New England, USA* **Robert Lang**, *Affiliation, USA* **Jesse Silverberg**, *Cornell, USA* For centuries, origami, the Japanese art of paper folding, has been a powerful technique for transforming two dimensional sheets into beautiful three dimensional sculptures. Recently, origami has made its foray into a new realm, that of physics and engineering, where it has been revolutionizing our concept of materials design. In this talk I will describe the new design principles we are uncovering for determining the shape, mechanics, and transformations of origami structures along with their usefulness in areas as diverse as solar sail design, architecture, and even fashion. Arguably however, the greatest strength of this new paradigm is the fact that origami is intrinsically scalable. Thus sculptures built at one size can be shrunk down smaller and smaller. This begs the question: what is the smallest fold one can make? Or in other words how many folded angels can we fit on the head of a pin? The rest of this talk will take a deep dive into how origami has been marching smaller and smaller in size. From folding by hand, to self-folding through shape memory alloys and even folding via polymer layers, I will argue that the ultimate limit for scaling down origami is set by folding a sheet of atomic dimensions. I will conclude by showing this vision: realized in the folds of a single sheet of graphene.		**Advancements in Doppler Cloak Technology: Manipulation of Doppler Effect and Invisibility for Moving Objects** **Davide Ramaccia**, *Roma Tre University, Italy* **Dimitrios Sounas**, *University of Texas at Austin, USA* **Andrea Alù**, *University of Texas at Austin, USA* **Alessandro Toscano**, *Roma Tre University, Italy* **Filiberto Bilotti**, *Roma Tre University, Italy* In this contribution, we present some important advancements in Doppler cloak technology, which is based on the frequency mixing property of linear momentum-biased metamaterial, whose artificial permittivity function is modulated in space and time. The importance of such a technology is given by the possibility to manipulate the Doppler effect and restore the invisibility of cloaked object in relativistic motion. Here, we review the main characteristics of a conventional Doppler cloak, consisting of a system composed of a planar reflector covered by a spatio-temporally modulated slab. We demonstrate that such a scheme presents some drawbacks in terms of efficiency and, therefore, an enhanced version based on a momentum-biased parallel-plate medium is presented and discussed.
15:00		**Low-Loss and Lossy Optical Metasurfaces Based on Ellipsoidal Nanoparticles** **Alessio Monti**, *Niccolò Cusano University, Italy* **Alessandro Toscano**, *Roma Tre University, Italy* **Filiberto Bilotti**, *Roma Tre University, Italy* In this contribution, we describe the optical properties of bi-dimensional arrays of ellipsoidal nanoparticles and propose some potential applications. First, we analyze a 2D metasurface model able to rigorously characterize the optical behavior of these structures in terms of equivalent surface impedance. Then, we comment some of their possible applications ranging from the design of optical scattering cancellation devices up to the	**Antenna Engineering in the Framework of Transformation Optics and Metamaterials** Invited **Yang Hao**, *Queen Mary University of London, United Kingdom* Both concepts of Transformation Optics (TO) and metamaterials have been regarded as one of key enablers for future antenna engineering. Previously we presented a theoretical framework to design antennas via TO. In this paper, we will evaluate several different approaches including field transformation (FT) to manipulate electromagnetic waves for antenna applications. All antennas are designed analytically and validated through numerical simulations and

		realization of transparent screens. Full-wave simulations are provided to confirm the effectiveness of the analytical model.	measurements. In this paper, we intend to demonstrate that both TO and FT approaches have much wider engineering applications which link artificial materials and the control of electromagnetic waves through advanced additive manufacturing.
15:15	**Transparency of Layered Superconducting Structures in the Presence of DC Magnetic Field** **Tetiana Rokhmanova**, *O.Ya. Usikov Institute for Radiophysics and Electronics of the NAS of Ukraine, Ukraine* **Zakhar Maizelis**, *O.Ya. Usikov Institute for Radiophysics and Electronics of the NAS of Ukraine, Ukraine* **Stanislav Apostolov**, *O.Ya. Usikov Institute for Radiophysics and Electronics of the NAS of Ukraine, Ukraine* **Filipe Perez-Rodriguez**, *Benemerita Universidad Autonoma de Puebla, Mexico* **Nykolay Makarov**, *Benemerita Universidad Autonoma de Puebla, Mexico* **Valeriy Yampol'skii**, *O.Ya. Usikov Institute for Radiophysics and Electronics of the NAS of Ukraine, V.N. Karazin Kharkiv National University, Benemerita Universidad Autonoma de Puebla, Ukraine* The transparency of layered superconductors to terahertz transverse-electric waves in the presence of external static magnetic field is studied theoretically. We obtain the analytical expression for transmission coefficient and show that even relatively weak DC magnetic field can significantly affect the transparency of such structures	**Effective Medium Description of a Metasurface Composed of a Periodic Array of Nanoantennas Coupled to a Metallic Film** **Patrick Bowen**, *Duke University, USA* **Alexandre Baron**, *Duke University, USA* **David Smith**, *Duke University, USA* An effective medium theory of metasurfaces is presented, when the metasurface is placed close enough to a metal film such that the dipoles that comprise the metasurface couple to surface plasmon modes of the metal film. The effective polarizability is calculated by explicitly evaluating the infinite sum of fields from all the dipoles in the lattice.	
15:30	**Broadband Transparency in Macroscopic Quantum Superconducting Metamaterials** **Daimeng Zhang**, *University of Maryland, USA* **Melissa Trepanier**, *University of Maryland, USA* **Steven Anlage**, *University of Maryland, USA* We present experimental results and numerical simulations on a superconducting SQUID metamaterial with a unique broadband transparency behavior in the microwave range. Through rf flux tuning we show that the real part of the extracted effective permeability approaches 1.0 and the imaginary part is close to 0 in the transparency regime.	**Application of Metasurfaces for Magnetic Resonance Imaging** **Alena Shchelokova**, *ITMO University, Russia* **Alexey Slobozhanyuk**, *ITMO University, Australian National University, Russia, Australia* **Irina Melchakova**, *ITMO University, Russia* **Yuri Kivshar**, *ITMO University, Australian National University, Russia, Australia* **Pavel Belov**, *ITMO University, Russia* We demonstrate experimentally how to improve substantially the performance of magnetic resonance imaging (MRI) devices by employing unique properties of ultrathin metasurface resonators. We fabricate metasurfaces formed by arrays of nonmagnetic metallic wires and observe significantly enhanced signal-to-noise ratio by exciting particular modes of metasurface	**Cloaking Receiving and Transmitting Antennas: Theoretical Aspects and Applications** Invited **Alessio Monti**, *Niccolò Cusano University, Italy* **Jason Soric**, *University of Texas at Austin, USA* **Mirko Barbuto**, *Niccolò Cusano University, Italy* **Davide Ramaccia**, *Roma Tre University, Italy* **Stefano Vellucci**, *Roma Tre University, Italy* **Fabrizio Trotta**, *ELETTRONICA S.p.A., Italy* **Andrea Alù**, *University of Texas at Austin, USA* **Alessandro Toscano**, *Roma Tre University, Italy* **Filiberto Bilotti**, *Roma Tre University, Italy* In this contribution, we review our latest results about the unprecedented possibilities enabled by electromagnetic cloaking in antenna theory and applications. In particular, we show that, in the receiving regime, cloaking allows designing antennas exhibiting a minimum level of

		resonators.	scattering for a given level of absorbed power, whereas, in the transmitting one, cloaking enables the co-siting of different antennas in a confined region. Both full-wave and experimental results are presented to support the theoretical considerations.
15:45	**Active Graphene-Based Metasurfaces and Their Applications to Phase Modulation, Motion Sensing, and Polarization Control** **Gennady Shvets**, *UT-Austin, USA* We demonstrate that considerable phase control can be achieved by integrating a single-layer graphene (SLG) with a resonant plasmonic metasurface which contains nanoscale gaps. By concentrating the light's intensity inside the nanogaps, the metasurface dramatically increases the coupling of light to the SLG, thus enabling phase control of mid-infrared light through free-carrier injection into graphene. Specifically, using infrared interferometry, we show that the reflection phase can be changed by as much as 55deg. using field-effect control. Moreover, the amplitude of the reflected light remains essentially constant while the phase undergoes a 28deg. change, thus enabling the first graphene-based infrared phase modulator that can potentially operate at multi-gigahertz speed. Such non-mechanical phase modulation enables a new experimental technique, graphene-based laser interferometry, which we use to demonstrate motion detection with nanoscale precision. Finally, we demonstrate that, by the judicious choice of a strongly anisotropic metasurface, the graphene-controlled phase shift of light can be rendered polarization-dependent. We demonstrate that the polarization state (e.g., the ellipticity) of the reflected light can be by modulated by field-effect carrier injection into the SLG. These results pave the way for novel high-speed graphene-based optical devices and sensors such as polarimeters, ellipsometers, and frequency modulators.	**Experimental Demonstration of Optical Hybrid Surface Waves in Anisotropic Resonant Metasurfaces** **Dmitry Baranov**, *ITMO University, Nanophotonics and Metamaterials Department, Russia* **Radu Malureanu**, *Technical University of Denmark, DTU Fotonik, Denmark* **Osamu Takayama** *Technical University of Denmark, DTU Fotonik, Denmark* **Ivan Mukhin**, *ITMO University, Nanophotonics and Metamaterials Department, Russia* **Anton Samusev**, *ITMO University, Nanophotonics and Metamaterials Department, Russia* **Ivan Iorsh**, *ITMO University, Nanophotonics and Metamaterials Department, Russia* **Andrey Bogdanov**, *ITMO University, Nanophotonics and Metamaterials Department, Russia* **Andrei Lavrinenko**, *Technical University of Denmark, DTU Fotonik, Denmark* We experimentally demonstrate hybrid transverse electric and hybrid transverse magnetic surface waves supported by anisotropic resonant metasurface. We show that for quasi-TE-polarized surface waves a topological transition from elliptic to hyperbolic regime takes place.	
16:00-16:30	**Coffee Break**		

Oral Sessions (Tuesday 20 – Afternoon 2)			
16:30-18:30	**Oral Session T3-A** **Tunable and nonreciprocal metamaterials** Chair: Alex Schuchinsky	**Oral Session T3-B** **Optical effects** Chair: Andrea Alu	**Oral Session T3-C** **Cloaking and transformation approaches II** Chair: Nader Engheta
16:30	**Nonreciprocal Metamaterials: A Global Perspective** **Christophe Caloz**, *Polytechnique Montréal, Canada* **Sergei Tretyakov**, *Aalto University, Finland* Nonreciprocal metamaterials represent a vast and little explored field of physics and engineering. This paper, as a subset of [1], overviews fundamental principles and recent developments in this area.	**Structured Light in Linear and Nonlinear Engineered Media** Invited **Natalia Litchinitser**, *University at Buffalo, The State University of New York, USA* **Jingbo Sun**, *University at Buffalo, The State University of New York, USA* **Mikhail Shalaev**, *University at Buffalo, The State University of New York, USA* **Wiktor Walasik**, *University at Buffalo, The State University of New York, USA* **Salih Silahli**, *University at Buffalo, The State University of New York, USA* **Apra Pandey**, *CST, Inc., USA* We discuss fundamental optical phenomena at the interface of nonlinear and singular optics in artificial media, including theoretical and experimental studies of linear and nonlinear light-matter interactions of singular optical beams in metamaterials, colloidal suspensions, and gaseous media. We show that on the one hand, unique optical properties of metamaterials open unlimited prospects to "engineer" light, on the other hand, structured light beams, containing phase or polarization singularities enable new approaches to create complex photonic structures.	**Wavefront Shaping through Emulated Curved Space in Transformation Optics** Invited **Hui Liu**, *School of Physics, Nanjing University, China* We experimentally realized wavefront shaping by exploiting general relativity effects in transformation optics. We demonstrate beam shaping within waveguides with predesigned refractive index varying so as to create curved space environment for light. We use this technique to construct very narrow non-diffracting beams and shape-invariant beams accelerating on arbitrary trajectories.
16:45	**Phase Transitions in Dispersive Non-Hermitian Optical Systems** **Oksana Shramkova**, *CCQCN, University of Crete, Greece* **Konstantinos Makris**, *CCQCN, University of Crete, Greece* **Giorgos Tsironis**, *CCQCN, University of Crete, Greece* The optical properties of one-dimensional non-Hermitian system with dispersion are examined. The possibility of PT-symmetry realization by changing the parameters of the dispersive media with gain and loss is considered.		
17:00	**Thermally Controlled Terahertz Metamaterial Based on Nematic-to-Isotropic Phase Transition** **Rafal Kowerdziej**, *Military University of Technology, Poland* The thermally controlled metamaterial combined with a nematic liquid crystal layer is demonstrated experimentally in the terahertz spectrum. By increasing the temperature from 23°C to 110°C, a reversible transmittance shift of up to 7% was achieved at a frequency of approximately 0.65 THz. Thermally switchable metamaterial devices will play a vital role in the development of next-generation filtering and sensing	**Propagation of Optical Fields Through a Three-Dimensional Diffraction-Compensating Metamaterial** **Ville Kivijärvi**, *Aalto University, Finland* **Markus Nyman**, *Aalto University, Finland* **Andriy Shevchenko**, *Aalto University, Finland* **Matti Kaivola**, *Aalto University, Finland* We introduce a metamaterial design that eliminates optical diffraction for three-dimensional optical fields. The material is shown to provide divergence-free guidance of radially polarized Laguerre-Gaussian beams and distortion-free transfer of arbitrary images created by unpolarized or circularly polarized light. Also, it exhibits	**Omnidirectional Light Concentrators and Absorbers Revisited: Almost Flat Absorbers inside Almost Circular (Spherical) Lenses** **Ludmila Prokopeva**, *Novosibirsk State University, Novosibirsk, Russia* **Alexander Kildishev**, *School of Electrical and Computer Engineering, Birck Nanotechnology Center, Purdue University, USA* We extend our previously developed theory of a circular omnidirectional absorber – 'an optical black hole'. We introduce a new, elliptically flattened design that could have elliptic cylinder, oblate or prolate spheroidal

	components and devices.	exceptionally low optical absorption and reflection losses.	shapes. As a result, the absorbing core could now be flattened to a strip (elliptic cylinder) or a disk (oblate spheroid) and therefore match well-established planar fabrication techniques. First, we present a general and complete theoretical description that includes 3D oblique incidence, and then test the theory with ray-tracing and full-wave simulations of elliptic absorbers that confirm flawless performance at complete acceptance angles.
17:15	**Tunable Microwave Absorption Of Graphene-Polymer Heterostructures Deposited On A Epsilon-Near-Zero Metamaterial** **Michaël Lobet**, *UNamur, Belgium* **Michaël Sarrazin**, *UNamur, Belgium* Electrodynamics of graphene-PMMA hetero-structures on a slab of epsilon-near-zero metamaterial is theoretically worked out. Perfect absorption is achieved once electromagnetic impedance matching condition is fulfilled. Tunability of the absorption can be obtained using a voltage modulation of the effective conductivity of the device. For example, modulation of 40% of absorption/reflectance is shown using voltage beyond the breakdown voltage of the polymer layers.	**Non-Hermitian Microring Systems: PT-symmetric Lasers, Mode Management And Enhanced Emission Efficiency** **Matthias Heinrich**, *Friedrich-Schiller-University Jena, Institute of Applied Physics, Germany* **Hossein Hodaei**, *University of Central Florida, CREOL The College of Optics and Photonics, USA* **Mohammad-Ali Miri**, *The University of Texas at Austin, Department of Electrical and Computer Engineering, USA* **Absar U. Hassan**, *University of Central Florida, CREOL The College of Optics and Photonics, USA* **William E. Hayenga**, *University of Central Florida, CREOL The College of Optics and Photonics, USA* **Demetrios N. Christodoulides**, *University of Central Florida, CREOL The College of Optics and Photonics, USA* **Mercedeh Khajavikhan**, *University of Central Florida, CREOL The College of Optics and Photonics, USA* We provide an overview of our recent work on PT-symmetric microring lasers and present our newest theoretical findings and experimental results on mode control and lasing dynamics in such configurations. In contrast to conventional approaches, the exceptional-point dynamics arising from the complex interplay of gain and loss allow for the suppression of parasitic resonances with virtually no detrimental effects on the overall system efficiency. Finally, we show how PT-symmetrically structured active materials can serve as a powerful tool to tailor the modal content of lasing emissions from larger-area transversely multimoded architectures.	**Transient Regime of Dispersive Invisible Structures Designed from Transformation Optics** **Boris Gralak**, *CNRS - Institut Fresnel, France* **Sébastien Guenneau**, *CNRS - Institut Fresnel, France* A regularized version of transformation optics is used to design a simple invisible structure made of two anisotropic homogeneous layers. This metamaterial is illuminated in normal incidence by a causal source with sinusoidal time dependence that is switched on at an initial time. When frequency dispersion is introduced, the system generates transient electromagnetic fields in addition to the permanent electromagnetic fields corresponding to the perfect cloaking. An analytical expression of transient fields is established for long enough time. The space-time dependence of transient fields shows oscillations governed by the Bessel function J1 and an amplitude decreasing as the power.
17:30	**Optomechanical Guitar: Reconfiguring Metamaterials with Sub-wavelength Spatial Resolution** **Jun-Yu Ou**, *University of Southampton, United Kingdom*	**Mid-Infrared Twist Polarizer Metasurface Based on Spiral Architecture** **Ihar Faniayeu**, *Research Institute of Electronics, Shizuoka University, Japan*	**Non Spherically-Symmetric Absolute Optical Instruments** **Tomas Tyc**, *Department of Theoretical Physics and Astrophysics, Masaryk University, Czech Republic*

	Eric Plum, *University of Southampton, United Kingdom* **Nikolay I. Zheludev**, *University of Southampton, United Kingdom* Optomechanical metamaterials, where optical signals actuate unique elements of the nanostructure at their eigenfrequency, can be used to modulate metamaterials with sub-wavelength spatial resolution. We demonstrate the first all-optically addressable metadevice operating in the near-infrared.	**Viktar Asadchy**, *Department of Radio Science and Engineering, Aalto University, Finland* **Vygantas Mizeikis**, *Research Institute of Electronics, Shizuoka University, Japan* Twist polarizer metasurface based on spiral architecture was designed and tested using full-wave numerical simulations. Highly efficient polarization conversion between orthogonal input and output linearly polarized waves, low reflectance, transmission over 85%, and negligible ellipticity have been achieved for the resonance wavelength 5.57 um. The proposed twist polarizer was optimized for practical realisation using direct laser write lithography fabrication technique combined with subsequent metallization noble metals, such as gold or silver.	**HL Dao**, *Department of Electrical and Computer Engineering, National University of Singapore, Singapore* **Aaron Danner**, *Department of Electrical and Computer Engineering, National University of Singapore, Singapore* So far, almost all known absolute optical instruments have had a high symmetry. However, here we demonstrate a method of designing refractive index profiles that yield asymmetric absolute optical instruments. To do this, we employ the analogy between geometrical optics and classical mechanics and consider the situation that the problem separates in Cartesian coordinates. Our method can also be used for constructing the index profiles of most previously known absolute optical instruments.
17:45	**Towards Broadband Tunable non-Foster Radiating Systems** **Silvio Hrabar**, *University of Zagreb, Croatia* **Aleksandar Kricenko**, *University of Zagreb, Croatia* It is shown that inherent instability of the non-Foster reactance (usually considered as a serious drawback of broadband active metamaterials) becomes a very useful feature in the case of self-oscillating radiating structures.	**Efficient Directional Control of Scattered Field at Optical Frequency with Subwavelength Asymmetric Dielectric Dimers** **Toshihiko Shibanuma**, *The Blackett Laboratory, Department of Physics, Imperial College London, United Kingdom* **Pablo Albella**, *The Blackett Laboratory, Department of Physics, Imperial College London, United Kingdom* **Stefan Maier**, *The Blackett Laboratory, Department of Physics, Imperial College London, United Kingdom* We demonstrate that finely designed asymmetric dimer configurations of silicon nanoparticles can switch the direction of scattered electromagnetic field depending on the incident wavelength and/or polarization. The application of the proposed asymmetric nanoantennas is also explored as a light guiding block in optical nanocircuitry.	**Graphene as a Tunable Plasmonic Metasurface with Transformation Optics** **Paloma A Huidobro**, *Imperial College London, United Kingdom* **Matthias Kraft**, *Imperial College London, United Kingdom* **Steafn A Maier**, *Imperial College London, United Kingdom* **John B Pendry**, *Imperial College London, United Kingdom* We demonstrate a tunable plasmonic metasurface by considering a graphene sheet subject to a periodically patterned doping level. By extracting the effective conductivity of the sheet we characterize metasurfaces periodically modulated along one or two directions. In the first case, and making use of the analytical insight provided by transformation optics, we show an efficient control of THz radiation for one polarization. In the second case, we demonstrate a metasurface with an isotropic response that is independent of wave polarization and orientation.
18:00	**Study On One-way Guiding InSb Structures For THz Spectral Region** **Pavel Kwiecien**, *Czech Technical University in Prague, Faculty of Nuclear Sciences and Physical Engineering, Czech Republic* **Ivan Richter**, *Czech Technical University in Prague, Faculty of Nuclear Sciences and Physical Engineering,*	**Quasi-Waveguide Enhancement of Photoluminescence from Silicon Nanocrystals** **Sergey Dyakov**, *Skolkovo Institute of Science and Technology, Russia* Extinction and photoluminescence spectra are studied for a periodic array of gold nanowires deposited on top of	**A Microwave Imaging Method based on Transformation Electromagnetics** **Mustafa Kuzuoglu**, *Middle East Technical University, Turkey* **Ozlem Ozgun**, *Hacettepe University, Turkey* The purpose of this study is to combine the

	Czech Republic **Vladimír Kuzmiak**, *Institute of Photonics and Electronics of the Czech Academy of Sciences, Czech Republic* **Jiří Čtyroký**, *Institute of Photonics and Electronics of the Czech Academy of Sciences, Czech Republic* We have studied guiding structures based on the highly-dispersive polaritonic InSb semiconductor material, in the presence of external magnetic field. The Voigt configuration has been imposed to enable nonreciprocity bringing new phenomena in connection with magnetoplasmons. For that purpose, we have developed a numerical technique based on the magnetooptic aRCWA.	a dielectric substrate containing silicon nanocrystals. Quasiguided modes are observed in the substrate resulting in modification of optical properties of silicon nanocrystals. Our calculations of extinction and photoluminescence spectra are in good agreement with experimental results. The periodicity provides a powerful tool for achieving a high photoluminescence out-coupling efficiency of silicon nanocrystals.	transformation electromagnetics approach and the inverse algorithms for solving microwave imaging problems, especially in the context of imaging the shapes of complex objects. A suitable transformation medium is placed into the domain of interest by using the concepts of the transformation electromagnetics, and hence, expensive cost function evaluations can be performed by the finite element method with reduced computational load. Numerical examples are demonstrated to measure the performance of the proposed approach.
18:15	**Nonreciprocal Microwave Transmission Through A Single Metamolecule With Magnetism And Chirality On Coplanar Waveguide** **Toshiyuki Kodama**, *Graduate School of Materials Science Nara Institute of Science and Technology (NAIST), Japan* We performed broadband microwave spectroscopy of permalloy micro-coil, i.e., metamolecule, using coplanar waveguide and vector network analyzer. The metamolecule placed at the edge of the signal line showed a characteristic resonances. Interestingly, nonreciprocal microwave propagation was observed at the frequency of the Kittel-mode FMR.	**Optical Nanoantennas As Magnetic Nanoprobes For Enhancing Light-Matter Interaction** **Caner Guclu**, *University of California Irvine (UCI), USA* **Mehdi Veysi**, *University of California Irvine (UCI), United States* **Mahsa Darvishzadeh-Vercheie**, *University of California Irvine (UCI), United States* **Filippo Capolino**, *University of California Irvine (UCI), United States* A class of optical nanoantennas utilized as photoinduced magnetic nanoprobes is studied for enhancing magnetic near-field in a magnetic-dominant region with vanishing electric field. We examine the illumination of such magnetic nanoprobes that guarantees selective excitation of magnetic resonances, such as azimuthally electric polarized beams (APBs) which possess a strong longitudinal magnetic field on the beam axis where the electric field is ideally null. Magnetic nanoprobes whose magnetic resonances are selectively excited show a large magnetic near-field enhancement and large magnetic-to-electric-field contrast ratio. Such nanoprobes are the basis for the development of future magnetic-base spectroscopy and macroscopy systems.	**A Class of Invisible Graded Index Profiles and the Control of Electromagnetic Waves** **Benjamin Vial**, *Queen Mary, University of London, United Kingdom* **Yangjie Liu**, *Queen Mary, University of London, United Kingdom* **Simon Horsley**, *University of Exeter, United Kingdom* **Thomas Philbin**, *University of Exeter, United Kingdom* **Yang Hao**, *Queen Mary, University of London, United Kingdom* We propose a general methodology to manipulate the amplitude of an electromagnetic wave in a pre-specified way, without introducing any scattering. This leads to a whole class of isotropic spatially varying permittivity and permeability profiles that are invisible to incident waves. The theory is illustrated through various numerical examples, including the non-magnetic case. The implementation of the required material properties using metamaterials is discussed, as well as extensions of the method for controlling the phase of electromagnetic fields.

Wednesday, 21st September

09:00-10:00	**Plenary Session 3** — **Imperial** Chair: Alex Schuchinsky; Mark Spector **Electromagnetic Metamaterials: Science and Applications** **Anthony Grbic**, *University of Michigan, USA* This talk will review advances made by my team over the past few years in the emerging area of electromagnetic metasurfaces. The development of passive metasurfaces with electric, magnetic, as well as magneto-electric and electro-magnetic properties will be described, and their field tailoring properties and functionalities explained. In addition, the development of tunable, active, and non-reciprocal designs will be touched upon. The presentation will include two broad classes of metasurfaces. The first class of metasurfaces includes those that can manipulate electromagnetic wavefronts incident from free space. Such metasurfaces can tailor reflected and/or transmitted waves, acting as lenses and/or reflectors with unparalleled field control. The second class of metasurfaces that will be described includes metasurfaces that can guide or radiate waves. These metasurfaces act as either waveguiding structures or support traveling/leaky waves that radiate tailored far-field patterns.
10:00-10:30	**Coffee Break**

Oral Sessions (Wednesday 21 – Morning)

10:30-12:30	**Oral Session W1-A** **Nonlinear effects** Chair: Martin Wegener	**Oral Session W1-B** **Plasmonic metasurfaces** Chair: Andrey Miroshnichenko	**Oral Session W1-C** **Geometry and topology** Chair: C.T. Chan
	Imperial	**Imperial 2**	**Imperial 4**
10:30	**Nonlocality in Discrete Nonlinear Metamaterials** **Maxim Gorlach**, *ITMO University, Russia* **Pavel Belov**, *ITMO University, Russia* We report a theoretical model for calculating effective nonlinear susceptibilities of nonlinear metamaterials taking frequency and spatial dispersion into account. We study the impact of nonlocality on metamaterials nonlinear properties and highlight new physical effects arising in nonlinear metamaterials due to spatial dispersion.	**Coherent Control of Plasmonic Spin-Hall Effect** **Hui Liu**, *School of Physics, Nanjing University, China* We experimentally demonstrate coherent and independent control of SPP orbitals for the two opposite spins using multiple rings of nano-slots with properly designed orientations on a metasurface. This is a form of spin-enabled coherent control and provides a unique way in achieving tunable orbital motions in plasmonics.	**Photonic Topological Insulators and Their Applications: From Delay Lines to Nonreciprocal Waveguides** Invited **Gennady Shvets**, *UT-Austin, USA* Electromagnetic (EM) waves propagating through an inhomogeneous medium inevitably scatter whenever the mediums electromagnetic properties change on the scale of a single wavelength. This fundamental phenomenon constrains how optical structures are designed and interfaced with each other. Our earlier theoretical work indicates [1] that electromagnetic structures collectively known as photonic topological insulators (PTIs) can be employed to overcome this fundamental limitation, thereby paving the way to ultra-compact photonic structures that no longer have to be
10:45	**Nonlinear Second Order Effects Enhancement in Optical Helmholtz Resonators** **Sébastien Héron**, *MINAO - ONERA - The French Aerospace Lab, France*	**Effect of Lattice Geometry on Optical Transmission through Subwavelength Nanohole Arrays** **Arif E Cetin**, *Massachusetts Institute of Technology, USA*	

	Patrick Bouchon, *MINAO - ONERA - The French Aerospace Lab, France* **Paul Chevalier**, *MINAO - ONERA - The French Aerospace Lab, France* **Fabrice Pardo**, *MINAO - Laboratoire de Photonique et de Nanostructures (LPN-CNRS), France* **Arthur Baucour**, *MINAO - ONERA - The French Aerospace Lab, France* **Riad Haïdar**, *MINAO - ONERA - The French Aerospace Lab, France* Optical Helmholtz resonators display, at resonance, zero reflectivity and heavy concentration of the incoming electric field in a sub-wavelength volume. If filled with a non linear medium, this huge confinement leads to the creation of a great quantity of non linear polarization and thus of enhanced Second Harmonic Generation. It is further enhanced through the metallic grating behavior of the whole structure acting as a metasurface.	**Martin Dršata**, *Brno University of Technology, Czech Republic* **Yasa Ekşioğlu**, *Istanbul Kemerburgaz University, Turkey* **Jiří Petráček**, *Brno University of Technology, Czech Republic* We theoretically investigate refractive index sensors that employ plasmonic nanoholes arranged in a square and hexagonal periodic lattice. The hexagonal system supports narrower spectral response and larger figure-of-merit values. This lattice also exhibits larger spectral shifts caused by a dielectric film which covers the nanoholes, mimicking a biomolecular layer.	wavelength- scale smooth. Here I present the first experimental demonstration of a photonic structure that supports topologically protected surface electromagnetic waves (TPSWs) that are counterparts to the edge states between two quantum spin-Hall topological insulators in condensed matter. Unlike conventional guided EM waves that do not benefit from topological protection, TPSWs are shown to experience reflections-free time delays when detoured around sharply-curved paths, thus offering a unique paradigm for wave buffers and delay lines. The opportunities of using TPSWs as leaky wave antennas will also be discussed. I will also discuss how the photonic analogs of the quantum Hall and valley-Hall topological insulators can be realized and interfaced with each other. Such interface can be utilized for making a variety of non-reciprocal devices such as circulators. Finally, I will introduce the concept of a topologically protected photonic cavity and demonstrate how strong coupling of such cavities with passing TPSWs can be achieved without compromising directional coupling.
11:00	**Nonlinear Plasmonics at High Temperatures** **Yonatan Sivan**, *Ben-Gurion University, Israel* **Shi-Wei Chu**, *National University of Taiwan, Taiwan* We solve the Maxwell and heat equations self-consistently for metal nanoparticles under intense continuous wave (CW) illumination at visible wavelengths. Unlike previous studies, we rely on experimentally measured data for the metal permittivity at increasing temperature. We show that the thermal nonlinearity of the metal can lead to substantial deviations from the predictions of the linear model for the temperature and field distribution - up to $50%$ errors! Thus, our approach can explain the strong nonlinear scattering from metal nanoparticles observed experimentally. This modelling approach is essential for the identification of the underlying physical mechanism responsible for the thermo-optical nonlinearity of the metal and should be adopted in all applications of high temperature nonlinear plasmonics, especially for refractory metals, both for CW and pulsed illumination.	**Femtosecond plasmonic and photonic wavepackets on metasurfaces** Invited **Albert Polman**, *FOM Institute AMOLF, Netherlands* We use 30 keV electrons to create femtosecond plasmonic and photonic wave packets from metallic and dielectric metasurfaces, determining their polarization- and angle-resolved emission spectra, resonant modal field density of states and dispersion, and 3D tomographic field reconstructions.	**Unidirectional Propagation Controlled by Acoustic Metamaterials** Invited **Yanfeng Chen**, *Nanjing University, National Lab. of Solid-State Microstructures, China* **Cheng He**, *National Lab. of Solid-State Microstructures, Nanjing University, China* **Xu Ni**, *National Lab. of Solid-State Microstructures, Nanjing University, China* **Minghui Lu**, *National Lab. of Solid-State Microstructures, Nanjing University, China* In this talk, one-way propagation have been proposed to realize by some effects, such as nonreciprocal linear, nonlinear, phase shift and diffractive process in acoustic metamaterials.
11:15	**Nonlinear All-Dielectric Nanoantenna Reconfigured by Electron-Hole Plasma** **Denis Baranov**, *Moscow Institute of Physics and*		

	Technology, Russia **Sergey Makarov**, *ITMO University, Russia* *Alexander Krasnok, ITMO University, Russia* **Pavel Belov**, *ITMO University, Russia* Interplay of magnetic and electric dipole moments of a single dielectric nanoparticle completely governs its scattering properties in the optical range. The amplitudes and phases of the induced dipoles can be altered by varying permittivity of the nanoparticle via generation of electron-hole plasma. In this work, we show ultrafast operation time of a silicon nanoantenna controlled by electron-hole plasma, allowing for ultrafast variation of the excited dipole moments. Basing on the experimental results, we develop an analytical model describing transient response of a silicon nanoparticle to an intense laser pulse and show theoretically that plasma induced optical nonlinearity leads to ultrafast reconfiguration of the scattering power pattern. Our work provides a strategy to design ultracompact and fast all-optical switches, which can be applied for broad range of nonlinear nanophotonic devices.		
11:30	**Enhanced Quadratic and Cubic Optical Nonlinearities in Photonic Structures Containing Nanopatterned Graphene and other 2D Materials** Invited **Nicolae Panoiu**, UCL, *United Kingdom* **Martin Weismann**, *UCL, United Kingdom* Remarkable optical and electrical properties of graphene and other two-dimensional (2D) materials provide significant potential for novel optoelectronic applications and devices, many of which depend on nonlinear optical effects in these 2D materials. In this paper we use a theoretical and computational formalism we have recently developed to efficiently and accurately determine the linear and nonlinear optical response of nanostructured 2D materials embedded in periodic structures containing regular three-dimensional (3D) materials. We use the proposed method to demonstrate enhanced nonlinear optical interactions via resonant excitation of phase-matched nonlinear waveguide modes, enhanced nonlinearity of nanostructures containing graphene and other 2D nanomaterials, such as MoS2 and WSe2, and tunable Fano resonances in such periodically patterned photonic heteromaterials.	**Plasmonic Metasurface for Optical Applications in Demand** Invited **Pin Chieh Wu**, *National Taiwan University, Taiwan* **Wei Ting Chen**, *National Taiwan University, Taiwan* **Yao-Wei Huang**, *National Taiwan University, Taiwan* **Chun Yen Liao**, *National Taiwan University, Taiwan* **Wei-Yi Tsai**, *National Taiwan University, Taiwan* **Ai Qun Liu**, *Nanyang Technological University, Singapore* **Nikolay I. Zheludev**, *University of Southampton, United Kingdom* **Greg Sun**, *University of Massachusetts Boston, America* **Din Ping Tsai**, *Academia Sinica, Taiwan* A vertical split-ring resonator (VSRR) is introduced as the building block for plasmonic metasurface array. Due to its specific structural configuration, a couple of potential applications such as VSRR-based refractive-index sensor and beam steering are presented. Aluminum based plasmonic nano-rod will be subsequently utilized for the development of multicolor meta-hologram.	**Topological Bound States in Metamaterials** Invited **Mario Silveirinha**, *University of Lisbon, Portugal* For a fixed wave polarization epsilon-negative (ENG) materials and mu-negative (MNG) materials are topologically inequivalent. Here, it is shown that this property implies that strongly localized bound states are formed when an ENG cavity is opened-up in an MNG background.

12:00	**Electromagnetic Control of Qubits Through Quantum Breathers** Invited **George Tsironis**, *University of Crete, Greece* We investigate coherence properties of qubit lattices through two specific models. The first involves an uncoupled chain of cubits that interacts with an electromagnetic wave. We show that in the strong coupling regime the nonlinearity of the interaction induces traveling coherent modes in the form of breathers that propagate with a process similar to self-induced transparency. The second model involves qubit-qubit interaction of the type of the quantum Ising model. We ignore external interactions and show that a coherence wave of quantum fluctuations is induced through a sudden quench of the interactions into the ferromagnetic regime.	**~~Nanophotonics for Tailoring the Flow of Thermal Radiation~~** ~~Invited~~ WITHDRAWN **Ognjen Ilic**, *Massachusetts Institute of Technology, USA* **Peter Bermel**, *Purdue University, USA* **Marinko Jablan**, *University of Zagreb, Croatia* **Hrvoje Buljan**, *University of Zagreb, Croatia* **Gang Chen**, *Massachusetts Institute of Technology, USA* **John Joannopoulos**, *Massachusetts Institute of Technology, USA* **Ivan Celanovic**, *Massachusetts Institute of Technology, USA* **Marin Soljacic**, *Massachusetts Institute of Technology, USA* The ability of nanoscale photonic structures to manipulate electromagnetic waves offers unprecedented control over radiative processes and radiative energy exchange. Light emitted from hot objects can be of great utility, yet the broadband spectral nature of thermal radiation implies that a significant portion of the spectrum is usually wasted. In addition, there are fundamental constraints to the magnitude of thermally emitted power in the far field. Radiative energy transfer mediated by plasmon-polariton modes in graphene in the near field offers a tunable means to overcome the blackbody limit, potentially enabling thermal transistors and high-performance energy conversion. In the far-field, thermal emission from high-temperature emitters can be spectrally filtered by nanophotonic structures that enable light recycling. This approach may find applications in thermophotovoltaic energy conversion and lighting.	**Circuit-Based Magnetless Floquet Topological Insulator** **Mykhailo Tymchenko**, *The University of Texas at Austin, USA* **Andrea Alu**, *University of Texas at Austin, USA* We explore the design and realization of a topological Floquet insulator in the form of a graphenelike honeycomb network of wye resonators, in order to achieve non-reciprocal transport with zero backward reflection over a continuous frequency range. The topological insulator here consists of two domains, with different topological orders induced by a periodic spatio-temporal modulation of the resonance frequency in each branch of suitably arranged wye resonators, creating a form of local 'spinning'. The modulation in opposite directions breaks time-reversal symmetry in the lattice and produces a topologically protected edge state with a gapless dispersion crossing the bulk bandgap. The topologically protected edge states possess unique properties, such as one-way guiding, small group velocity dispersion, absence of backscattering, and immunity to structural disorder. Our analysis allows unveiling their peculiar propagation and confinement properties, and their inherent robustness to defects and loss.
12:15			**Metamaterials Based on Angularly Layered Cylinders** **Said El-Jallal**, *Université de Bordeaux - Centre de Recherche Paul Pascal, France* **Daniel Torrent**, *Université de Bordeaux - Centre de Recherche Paul Pascal, France* In this work, we study the possibility of obtaining doubly negative electromagnetic metamaterials by means of an array of angularly inhomogeneous cylinders, in which circular sectors of the cylinder are filled up alternatively by metallic and dielectric materials. It is shown that the cylinder behaves as a highly anisotropic cylindrical rod with extreme electromagnetic parameters, whose main effect is to degenerate all Mie resonances, so that the monopolar and dipolar modes are close enough to allow a doubly negative metamaterial.

<table>
<tr><td>12:30-14:00</td><td colspan="3">Lunch Break</td></tr>
<tr><td colspan="4">Oral Sessions (Wednesday 21 – Afternoon)</td></tr>
<tr><td>14:00-16:00</td><td>Oral Session W2-A
Exotic structures and effects
Chair: Filiberto Bilotti</td><td>Oral Session W2-B
Plasmonic sensing
Chair: Mikhail Lapine</td><td>Oral Session W2-C
Metasurfaces II
Chair: Min Qiu</td></tr>
<tr><td></td><td>Imperial</td><td>Imperial 2</td><td>Imperial 4</td></tr>
<tr><td>14:00</td><td>Light Absorption and Scattering by Metamaterial Thermal Black Hole
Stanislav Maslovski, Instituto de Telecomunicações, Universidade de Coimbra, Portugal
Interaction of Gaussian light beams with a spherical metamaterial thermal black hole (which is a an object that outperforms the Planck-Kirchhoff black body in absorption of light with a given frequency) is considered. At a given wavelength, such an object, while being optically large, has an effective absorption cross section significantly greater than its physical cross section. The Poynting vector distribution in the vicinity of such object under a few excitation scenarios is studied. It is found that the energy flow picture in the region beneath the effective event horizon of the metamaterial thermal black hole is very peculiar, with the energy flow trajectories collapsing at a couple of impact points on the physical surface of the metamaterial thermal black hole.</td><td rowspan="2">Metamaterial Based Nanobiosensors and Nanophotodetectors Invited
Ekmel Ozbay, Bilkent University, Turkey
We present how metamaterials can be used for nanobiosensors and nanophotodetector applications. We also report the design, fabrication, and measurement of a device comprising a tunable split ring resonator array on epitaxial graphene.</td><td>Angular Filtering with Double Layer Gradient Phase Metasurfaces
Arnold Kalvach, Budapest University of Technology and Economics, Hungary
Zsolt Szabó, Budapest University of Technology and Economics, Hungary
Gradient phase metasurfaces are used for angular filtering, exploiting that there exists a critical angle above which incident waves are totally reflected. Since the transmitted waves are refracted, a second metasurface is used to restore the original direction of propagation. The cutoff angle can be simply set by designing the phase gradient of the metasurfaces.</td></tr>
<tr><td>14:15</td><td>Reconfigurable Magnonic Metamaterial For Microwave Signal Processing
Steven Louis, Oakland University, USA
Ivan Lisenkov, Oakland University, USA
Sergey Nikitov, Institute of Radio-engineering and Electronics of RAS, Russia
Vasyl Tyberkevych, Oakland University, USA</td><td>Multi-level Information Encoding on Terahertz Metasurfaces
Ashish Chanana, University of Utah, USA
Andrew Paulsen, Massachussets Institute of Technology, USA
Ajay Nahata, University of Utah, USA
Metasurfaces have been shown to allow control of light</td></tr>
</table>

WEDNESDAY

	Andrei Slavin, *Oakland University, USA* We propose a reconfigurable magnonic metamaterial		using planar structures, which relies on the generalized laws of reflection and refraction. These designer
	based on an array of dipolarly-coupled magnetic nano-pillars having perpendicular shape anisotropy. The static magnetic ground state of such a metamaterial is antiferromagnetic (AFM), and a linear defect in the form of ferromagnetically (FM) ordered chain of nano-pillars can act as a waveguide supporting a strongly localized spin wave on the linear defect whose frequency is well-separated from the bulk spin wave spectrum of the metamaterial. The phase of this localized SW can be controlled by placing an additional point defect (a pillar with inverted magnetization direction) near the waveguide. In our case the phase shift is close to π radians, which corresponds to the operation of the phase inverter working without an external bias magnetic field. Since the phase shift is achieved by changing the orientation of magnetization of a single pillar, it is possible to dynamically control this phase shift. Also, by changing the orientation of the pillars placed further from the waveguide it is possible to vary the magnitude of the phase shift without significant changes in the spin wave amplitude.		imaging and holography applications, wherein the spatial modulation in amplitude and phase is achieved by selective assemblies of geometrically varying resonant and diffracting elements. We propose here a unique approach where information can be encrypted as spatial variation in conductivity of identical resonant elements. We achieved 9-level amplitude modulation using simple dipole unit cells and 64-bit encoding per bit using 3-color unit cells. The information can only be retrieved under terahertz radiation of appropriate frequency and along the intended polarization.
14:30	**Doppler Effect in Zero-index Metamaterials** **Jia Ran**, *Tongji University; Queen Mary University of London, United Kingdom* **Yewen Zhang**, *Tongji University, China* **Xiaodong Chen**, *Queen Mary, University of London;University of Electronic Science and Technology of China, United Kingdom* **Kai Fang**, *Tongji University, China* **Hong Chen**, *Tongji University, China* We observed the abnormal Doppler effect inside a reconfigurable balanced transmission line, which has zero index at the balanced frequency. By applying a digital signal controller, a moving reflective interface is built inside this transmission line. The normal, inverse and an unusual abnormal Doppler effects are observed at different frequencies, completing the full figure of Doppler effect.	**Nanoscale Constriction as a Source of Plasmons for Plasmonic Nanocircuitries** **Alexander Uskov**, *P. N. Lebedev Physical Institute; ITMO University, Russia* **Igor Smetanin**, *P. N. Lebedev Physical Institute, Russia* **Igor Protsenko**, *P. N. Lebedev Physical Institute, Russia* **Jacob Khurgin**, *Department of Electrical & Computer Engineering, John Hopkins University, USA* **Mickael Buret**, *Laboratoire Interdisciplinaire Carnot de Bourgogne, CNRS-UMR 6303, Université Bourgogne Franche-Comte, France* **Alexandre Bouhelier**, *Laboratoire Interdisciplinaire Carnot de Bourgogne, CNRS-UMR 6303, Université Bourgogne Franche-Comte, France* We investigate spontaneous light emission by electrons passing through a nanoscale metal constriction and find that the Purcell-enhanced emission is engendered by two distinct mechanisms. In the first mechanism emission is caused by electron colliding with the	**Surface Wave Routing of Beams by a Transparent Birefringent Metasurface** **Karim Achouri**, *Ecole Polytechnique de Montreal, Canada* A metasurface routing electromagnetic beams via surface waves from one point to another point of space is introduced. This metasurface is transparent and may simultaneously support generalized refraction for another orthogonal beam (birefringence). The metasurface is designed by the general surface susceptibility synthesis method and its operation is validated by finite difference analysis, both being based on generalized sheet boundary conditions.

		effective potential of the mesoscopic contact while the second mechanism involves collisions of electrons with the walls of the constriction. We find that multiple collisions with the walls can lead to the orders-of-magnitude higher light emission probability in comparison to a single collision with the effective potential	
14:45	**Magneto-induced Anisotropy in Periodic Metamaterials** **Yakov M. Strelniker**, *Department of Physics, Bar-Ilan University, IL-52900 Ramat-Gan, Israel, Israel* **David J. Bergman**, *Raymond and Beverly Sackler School of Physics and Astronomy, Tel Aviv University, IL-69978 Tel Aviv, Israel, Israel* When an applied magnetic field has an arbitrary direction with respect to the lattice axes of a periodically nano-structured metal-dielectric metamaterial, the effective permittivity tensor becomes anisotropic. This can be measured directly in case of the Voigt and Kerr effects, for which some general expressions are presented and discussed.	**Near and Far Field Interactions for Plexcitonic Coupling Enhancement in Aluminum Dimers Arrays** **Francesco Todisco**, *CNR Nanotec, Italy* **Marco Esposito**, *CNR Nanotec, Italy* **Milena De Giorgi**, *CNR Nanotec, Italy* **Giuseppe Gigli**, *CNR Nanotec, Italy* **Daniele Sanvitto**, *CNR Nanotec, Italy* We studied the generation of plasmonic surface lattice resonances in square arrays of aluminum dimers and their influence on the strong coupling with a molecular J-aggregate. We demonstrate that the dimer-gap plasmonic mode strongly enhances the light-matter interaction, and results in an higher Rabi splitting with respect to the short-axis mode of the dimer.	**Electron-Beam-Induced Directional THz Radiation from Graded Metallic Grating Metasurfaces** **Tatsunosuke Matsui**, *Mie University, Japan* **Kazuki Omura**, *Mie University, Japan* **Akiko Okajima**, *Mie University, Japan* We have numerically analyzed an electron-beam induced directional terahertz (THz) radiation from graded metallic grating structures with graded groove depths (GGD) or graded groove spacing (GGS) based on a simplified particle-in-cell finite-difference time-domain method. Directional THz radiations are obtained from GGDs. Airy beam-like directional THz beams are obtained from GGSs.
15:00	**Experiments On 3D Hall-Effect Metamaterials** Invited **Christian Kern**, *Institute of Applied Physics, Karlsruhe Institute of Technology, Germany* **Muamer Kadic**, *Institute of Applied Physics, Karlsruhe Institute of Technology, Germany* **Martin Wegener**, *Institute of Applied Physics, Karlsruhe Institute of Technology, Germany* We have recently shown theoretically that 3D metamaterials composed of only a single constituent material can lead to a sign inversion of the Hall effect with respect to the constituent material. Here, we present recent corresponding experiments, which validate this prediction.	**Ag Nanoparticle Decorated Graphene Oxide: Fluorescence Quenching and Surface Enhanced Raman Scattering** **John Gough**, *Trinity College Dublin, Ireland* **Katarzyna Siewerska**, *Trinity College Dublin, Ireland* **Sam Mehigan**, *Trinity College Dublin, Ireland* **Damien Hanlon**, *Trinity College Dublin, Ireland* **Claudia Backes**, *Trinity College Dublin, Ireland* **Zahra Gholamvand**, *Trinity College Dublin, Ireland* **Beata Szydloska**, *Trinity College Dublin, Ireland* **Werner Blau**, *Trinity College Dublin, Ireland* **Eithne McCabe**, *Trinity College Dublin, Ireland* **Louise Bradley**, *Trinity College Dublin, Ireland* The emission and Raman scattering properties of Rhodamine 6G, Rhodamine B and Sulforhodamine 101 were characterised on graphene oxide and Ag nanoparticle graphene oxide to examine the impact of fluorescence quenching on surface enhanced Raman scattering detection. Strong correlation is found between time-resolved fluorescence data and Raman scattering peak signal-to-noise ratios.	**Tuneable Liquid Crystal-Metamaterial Hybrids with Elasto-Mechanical Coupling** **Vassili Fedotov**, *Unversity of Southampton, United Kingdom* **Oleksandr Buchnev**, *Unversity of Southampton, United Kingdom* **Tom Frank**, *Unversity of Southampton, United Kingdom* **Nina Podoliak**, *Unversity of Southampton, United Kingdom* **Malgosia Kaczmarek**, *Unversity of Southampton, United Kingdom* **Liudi Jiang**, *Unversity of Southampton, United Kingdom* We demonstrate a new generation of nonlinear, dynamically tuneable artificial material systems – optical metamaterial hybrids that exploit elastic coupling of liquid crystals (the hybrids' functional component) with mechanically re-configurable fabric of the metamaterial hosts.

15:15		**SPR Sensor with Ultranarrow Magnetoplasmonic Resonance** **Daria Ignatyeva**, *Lomonosov Moscow State University, Faculty of Physics, RQC, Russia* **Pavel Kapralov**, *RQC, Russia* **Grigoriy Knyazev**, *Lomonosov Moscow State University, Faculty of Physics, RQC, Russia* **Olga Borovkova**, *RQC, Russia* **Sergey Sekatskii**, *École Polytechnique Fédérale de Lausanne, Institute of the Physics of Biological Systems, Switzerland* **Mohammad Nur-E-Alam**, *Edith Cowan University, Electron Science Research Institute, Australia* **Mikhail Vasiliev**, *Edith Cowan University, Electron Science Research Institute, Australia* **Kamal Alameh**, *Edith Cowan University, Electron Science Research Institute, Australia* **Vladimir Belotelov**, *Lomonosov Moscow State University, Faculty of Physics, RQC, Russia* We present results of experimental investigations of ultralong-range propagating magnetoplasmons in special heterostructure. Propagation distance of surface plasmon increases up to 35 μm due to inclusion of photonic crystal and it can be effectively controlled by magnetic field of 240 mT due to the presence of the magnetic layer.	**Metasystems for All-optical Recognition and Processing of Images and Data** **Maria Papaioannou**, *University of Southampton, United Kingdom* **Eric Plum**, *University of Southampton, United Kingdom* **Edward T. F. Rogers**, *University of Southampton, United Kingdom* **João Valente**, *University of Southampton, United Kingdom* **Nikolay I. Zheludev**, *University of Southampton, United Kingdom* All-optical image recognition and data processing is accomplished by engaging the effectively nonlinear coherent wave interaction on a thin absorbing metasurface. This approach relies on coherent perfect absorption and perfect transmission of matching image features and it is compatible with single-photon intensities and THz frame rates.
15:30	**Position-Independent Manipulation of Waves in Extreme-Parameter Metastructures** Invited **Yue Li**, *Tsinghua University, China* **Inigo Liberal**, *University of Pennsylvania, USA* **Nader Engheta**, *University of Pennsylvania, USA* Owing to the peculiarity of light-matter interaction in extreme-parameter materials and structures, certain aspects of fields and waves in such structures can be tailored independently of the positions of their constituent elements, thus providing unique flexibility and useful features in their designs. We discuss the results of our ongoing study on specialized position-independent wave manipulation in these metastructures.	**Sensing with Plasmonic DFB Laser** **Alexander V. Dorofeenko**, *ITAE RAS, FSUE VNIIA, MIPT, Russia* **Igor A. Nechepurenko**, *ITAE RAS, FSUE VNIIA, MIPT, Russia* **Alexander A. Zyablovsky**, *ITAE RAS, FSUE VNIIA, MIPT, Russia* **Eugeny S. Andrianov**, *ITAE RAS, FSUE VNIIA, MIPT, Russia* **Alexander A. Pukhov**, *ITAE RAS, FSUE VNIIA, MIPT, Russia* **Yurii E. Lozovik**, *ITAE RAS, FSUE VNIIA, MIPT, ISAN RAS, Russia* Plasmonic DFB laser based on CdSe quantum dot film with periodic array of silver nanoparticles is theoretically considered. The system is modeled by sequential calculation of modes and solution of a multimode	**Efficient Polarization Sorting with Gap-Plasmon Based Metasurfaces** Invited **Sergey I. Bozhevolnyi**, *University of Southern Denmark, Denmark* Our recent progress in development of metasurfaces based on arrays of gap-plasmon resonators is reviewed emphasizing various functionalities involving the manipulation of light polarization, including simultaneous determination of Stokes parameters. Latest studies on gap-plasmon based metasurfaces that randomize the reflected radiation are also presented.

		equation system, which takes into account spontaneous emission process. Sensing applications of this system are investigated, and high sensitivity to intracavity absorption is demonstrated.	
15:45		**Nanoparticle-Assisted STED Nanoscopy with Gold Nano-Spheres** **Aurelien Merkel**, *Laboratoire d'Acoustique de l'Université du Maine UMR-CNRS 6613, France* **Georgios Theocharis**, *Laboratoire d'Acoustique de l'Université du Maine UMR-CNRS 6613, France* **Olivier Richoux**, *Laboratoire d'Acoustique de l'Université du Maine UMR-CNRS 6613, France* **Vicent Romero-Garcia**, *Laboratoire d'Acoustique de l'Université du Maine UMR-CNRS 6613, France* **Vincent Pagneux**, *Laboratoire d'Acoustique de l'Université du Maine UMR-CNRS 6613, France* **Yonatan Sivan**, *Ben-Gurion University, Israel* **Nicolai Urban**, *Max Planck Institute for Biophysical Chemistry, Germany* **Stefan W. Hell**, *Max Planck Institute for Biophysical Chemistry, Germany* We show experimentally a 3-fold reduction of the intensity required to achieve sub-diffraction resolution in a stimulated-emission-depletion (STED) microscope using 60nm gold spheres coated with fluorophores. This provides a substantial minituarization of the NP-STED label compared with previous studies, and is an important step towards imaging of biological systems.	
16:00-17:30	**Coffee break and Poster Session II**		
16:00-17:30	**Poster Session II**		

1 - Numerical Modeling of the Planar Resonators Arrays for THz Band
Dusan Nespor, *BUT Brno, Czech Republic*

The article presents results of numerical modelling of planar resonators arrays deigned for THz frequencies for various boundary conditions and material parameters. The presented results have shown the possibilities of using finite element analysis for THz frequencies and infrared band resonators arrays designing.

2 - Studies of Giant Magnetoimpedance Effect in Soft Magnetic Microwires at

27 - Nanomechanically Reconfigurable All-dielectric Metasurfaces for Sub-GHz Optical Modulation

Artemios Karvounis, *University of Southampton, United Kingdom*
Jun-Yu Ou, *University of Southampton, University of Southampton*
Behrad Gholipour, *University of Southampton, University of Southampton*
Kevin F. MacDonald, *University of Southampton, University of Southampton*
Nikolay I Zheludev, *University of Southampton, University of Southampton*

Ultra-thin, free-standing, all-dielectric subwavelength-gratings and arrays of nano-

GHz Frequencies

Arcady Zhukov, *Dpto. de Fís. Mater., University of Basque Country (UPV/EHU) , Spain*
Mihail Ipatov, *Dpto. de Fís. Mater., University of Basque Country (UPV/EHU) , Spain*
Valentina Zhukova, *Dpto. de Fís. Mater., University of Basque Country (UPV/EHU) , Spain*

We studied Giant magnetoimpedance (GMI) effect and magnetic properties of various Co-rich amorphous microwires. We measured magnetic field dependences of the GMI ratio up to GHz frequency range and observed quite high GMI ratio in studied thin magnetic microwires even at GHz frequencies. We observed different values of the magnetic anisotropy field obtained from the hysteresis loops and the impedance curves. Observed dependences can be explained considering different magnetic anisotropy in the surface layers and in the inner part of metallic nucleus and skin depth effect. Features of high frequency GMI effect have been analyzed using FMR-like approximation

3 - Multi-qubit Quantum Phase Gates Based on Plasmonic Nanospheres

Jun Ren, *Beijing Institute of Technology, China*
Xiangdong Zhang, *Beijing Institute of Technology, China*

The Dicke effects resulting from the interaction between surface plasmons of nanospheres and quantum emitters have been investigated by using a Green's function approach. Based on such an investigation, we propose a scheme for a deterministic multi-qubit quantum phase gate in the environment of single sphere and nanosphere cluster.

4 - A Method to Enlarge Seismic Band Gaps by Optimizing the Local Resonances

Bogdan Ungureanu, *Aix Marseille Université, CNRS, Centrale Marseille, Institut Fresnel UMR 7249, France*
Boris Okorn, *Ruđer Bošković Institute, Croatia*
Silvio Hrabar, *University of Zagreb, Croatia*
Jordi Sancho-Parramon, *Ruđer Bošković Institute, Croatia*
Antonija Perić, *University of Zagreb, Croatia*

We analyze rotational and bending resonance modes with 3 different variations on ligament number and size. Inertial resonators induce low frequency band gaps, which are relevant for seismic protection in sedimentary basins. Another aspect of this work is that by varying the number and the thickness of ligaments, we achieve wider low-frequency band gaps, which is of interest for the whole metamaterial's community.

5 - The Role of Coulomb Interaction in Small Nanoparticle Spasers

Vitaliy Pustovit, *Materials and Manufacturing Directorate, Air Force Research Laboratory, USA*
Arkadi Chipouline, *Institute for Microelectrotechnics and Photonics, Technical University of Darmstadt, Germany*

cantilevers can act as resonant nanomechanically reconfigurable metasurfaces at telecommunication wavelengths. Actuation by electrostatic and optical forces delivers reversible reflectivity changes up to 20% and a giant sub-GHz frequency optomechanical nonlinearity.

28 - Using Directional Constants to Define the Out-of-Plane Coordinate Transformation in a Two-Dimensional Cloak

Fábio Gonçalves, *Federal University of Minas Gerais, Brazil*
Elson Silva, *Federal University of Minas Gerais, Brazil*
Renato Mesquita, *Federal University of Minas Gerais, Brazil*

An out-of-plane coordinate transformation can avoid singular materials in a two-dimensional cloak. Based on simulations of elliptical cylinders, in this paper we show that the use of two directional constants to define the out-of-plane stretching can result in anisotropic materials with lower values and yet with a better invisibility for a given incident wave direction.

29 - Non-Nearest Neighbours Interactions in SRR Chains

Alexander V. Dorofeenko, *ITAE RAS, FSUE VNIIA, MIPT, Russia*
Anton M. Pikalov, *MSU, Russia*
Alexey P. Vinogradov, *ITAE RAS, FSUE VNIIA, MIPT, Russia*
Alexander B. Granovsky, *MSU, ITAE RAS, Russia*

Split-ring resonator (SRR) axial chain is considered with the account of retardation and non-nearest neighbor interactions. In the case of the first element excitation, the appearance of nonexponential decay is revealed. The features of the Fourier transform of the current amplitude distribution in the chain are related to the solutions in the infinite chain. The nonexponential contribution is interpreted as a result of excitation of a family of damping solutions, which are found in the infinite chain.

30 - Metamaterials Inspired Dual-Wide Band CPW-Fed Antenna Using Split Ring Resonator Structure

Mahmoud Abdalla, *MTC College, Egypt*
Nour El-Sobky, *MSA University, Electronics and Communications Department, Giza, Egypt*
Moatz El-Gabry, *MSA University, Electronics and Communications Department, Giza, Egypt*

This paper presents a metamaterial inspired dual-wide band CPW-fed antenna using split-ring resonator structure. The antenna design is inspired from conventional circular monopole antenna to two split rings resonators. The antenna geometry was optimized to achieve two wide bands; the lower band covers the band 2.65 GHz to 3.25 GHz whereas the higher band covers the band 5 GHz to 7 GHz. The antenna dimensions were optimized for compact size (30 mm × 30 mm). The antenna radiation pattern was kept as omnidirectional in both bands. Full wave simulation and experimental measurements results are introduced with good matching between them.

Tigran Shahbazyan, *Jackson State University, USA*
Augustine Urbas, *Materials and Manufacturing Directorate, Air Force Research Laboratory, USA*

We study numerically the effect of mode mixing and direct dipole-dipole interactions between gain molecules on spasing in a small composite nanoparticles with a metallic core and a dye-doped dielectric shell. By combining Maxwell-Bloch equations with Green's function formalism, we calculate lasing frequency and threshold population inversion for various gain densities in the shell. We find that gain coupling to nonresonant plasmon modes has a negligible effect on spasing threshold. In contrast, the direct dipole-dipole coupling, by causing random shifts of gain molecules' excitation frequencies, hinders reaching the spasing threshold in small systems. We identify a region of parameter space in which spasing can occur considering these effects.

6 - Bio-inspired Seismic Metamaterials

Ronald Aznavourian, *Institut Fresnel - Aix Marseille Université, France*
Tania Puvirajesinghe, *C.R.C.M. - Institut Paoli-Calmettes, France*
Stephane Brule, *Dynamic Soil Laboratory - Menard, France*
Stefan Enoch, *Institut Fresnel - C.N.R.S., France*
Sebastien Guenneau, *Institut Fresnel - C.N.R.S., France*

We consider geometric transforms underpinning the design of cloaks in very soft soils structured with denser inclusions. We generate a class of bio-inspired cloaks deduced from mappings of the plane with morphing techniques, which allow us to rapidly deduce elastic wave patterns in bio-inspired cloaks from computations with FDTD simulations.

7 - On the Application of Snell's Law for Refracted Graphene Surface Plasmon Polariton Waves

Stamatis Amanatiadis, *Aristotle University of Thessaloniki, Greece*
Nikolaos Kantartzis, *Aristotle University of Thessaloniki, Greece*

The direction of refracted graphene surface plasmon polariton waves due to the variation of their effective index is estimated in the current work. After the extraction of the fundamental relationships for the propagation properties of a graphene surface wave, the effective index is derived and the well-known Snell's law is utilized. Moreover, the direction angle is obtained by means of a comprehensive numerical analysis, addressing an accurate finite-difference time-domain algorithm, which validates all theoretical estimations.

8 - Models of Graphene-Based Metamaterials for Drug Delivery

Tania Puvirajesinghe, *CRCM, Inserm, U1068, Marseille, France; Institut Paoli-Calmettes, Marseille, France; Aix-Marseille Université, Marseille, France. , France*

<p> We investigate the diffusion of a peptide drug through Graphene Oxide (GO) membranes that are modeled as a porous layered laminate constructed from flakes of

31 - Plasmonic Luminescence Enhancement By Metal Nanoparticles Embedded In Nanofibers

Radoslaw Jurga, *Istituto Italiano di Tecnologia, Italy*
Fabio Della Sala, *Istituto Italiano di Tecnologia, Italy*
Cristian Ciraci, *Istituto Italiano di Tecnologia, Italy*

We investigate how embedding a metal nanoparticle with an optical emitter in a fiber modifies its emission properties. By coupling the emitter to a metal nanoparticle, we show numerically that the emission rates and quantum yield are increased due to the combined effects of the confinement and the plasmonic enhancement.

32 - Dual Notching of UWB Antenna Using Double Inverse U-Shape Compact EBG Structure

Mahmoud Abdalla, *MTC College, Egypt*
Abdullah Al-Mohamadi, *MSA University, Electronics and Communications Department, Giza, Egypt*
Abdullah Moustafa, *MSA University, Electronics and Communications Department, Giza, Egypt*

This paper presents an ultra-wide-band monopole antenna integrated with a new configuration of electromagnetic band gap structures (EBGs). The operation frequency band of the ultra wide band antenna is 3.1 GHz-10.6 GHz whereas the dual rejected bands are 5.2 GHz and 5.8 GHz. These two notched bands are for wireless local area network. The new proposed EBG structure is composed of double inverse U-shape slotted patch and edge-located via. Using this new EBG, a high notching selectivity can be achieved for both bands. Compared to conventional mushroom like EBG structure, the proposed configuration of the EBG structure can reject dual band instead of single band and have smaller size by 72 %. The detailed theoretical study supported by electromagnetic full wave simulations and confirmed by experimental measurements is introduced.

33 - Orientation Dependence on the Focusing by Hyperbolic Crystals

Rair Macedo, *University of Glasgow, United Kingdom*
Thomas Dumelow, *Universidade do Estado do Rio Grande do Norte, Brazil*
Robert Stamps, *University of Glasgow, United Kingdom*

In this letter we demonstrate how the focusing in slab lenses with parallel sides made of a hyperbolic media can be highly affected by changes in the crystal's phonon polarization direction.

34 - Probing Enhancement of an Electric Field Perpendicular to an Optical Antenna Surface using SiC Surface Phonon Polaritons

Junichi Miyata, *Ritsumeikan University, Japan*
Yuhto Yamamoto, *Ritsumeikan University, Japan*
Yuhta Kunichika, *Ritsumeikan University, Japan*
Takahiro Kawano, *Ritsumeikan University, Japan*
Nobuyuki Umemori, *Ritsumeikan University, Japan*

GO and other polymer based materials. Our experiments employ a peptide drug and show a tunable non-linear dependence of the peptide concentration upon time. This is confirmed using numerical simulations with a diffusion equation accounting for the photothermal degradation of fluorophores and an effective percolation model. Applications include sustained drug delivery, which is associated with significant clinical advantages including fewer injections for patients, reduced side effects for the health of patients and reduction in the cost of drug intervention procedures.</p>

9 - Polarization conversion and circular dichroism induced by superwavelength lattice of chiral nanoholes

Ilya Zabkov, *Dukhov Research Institute of Automatics (VNIIA), Russia*
Vasily Klimov, *Dukhov Research Institute of Automatics (VNIIA), Russia*
Andrey Pavlov, *Dukhov Research Institute of Automatics (VNIIA), Russia*
Ruei-Cheng Shiu, *National Taiwan University, Taiwan*
Hsun-Chi Chan, *National Taiwan University, Taiwan*
Guang-Yu Guo, *National Taiwan University, Taiwan*

<p> Two-dimensional lattices of chiral nanoholes in a plasmonic film with lattice constants being slightly larger than light wavelength are proposed for effective control of polarization and spatial properties of light beams. Effective polarization conversion and strong circular dichroism in non-zero diffraction orders in these chiral metafilms are demonstrated by electromagnetic simulations.</p>

10 - Double-Negativity Issue for Dissipative Negative-Index Media

Thomas Brunet, *University of Bordeaux, France*
Olivier Poncelet, *University of Bordeaux, France*
Christophe Aristégui, *University of Bordeaux, France*

A criterion defining the sign of the acoustic index from those of the real and imaginary parts of the constitutive parameters of dissipative isotropic media, is established. We observe that the double negativity required for perfect media with a negative index is not necessary for dissipative metamaterials, for which single negativity of one of the two constitutive parameters may be sufficient.

11 - Nonlocal Effective Elastic Response Of 3D Al-Rubber Phononic Crystal

Anatolii Konovalenko, *Instituto de Física, Benemérita Universidad Autónoma de Puebla, Mexico*
Edahí Gutiérrez-Reyes, *Instituto de Física, Benemérita Universidad Autónoma de Puebla, Mexico*
Ana Lilia González, *Instituto de Física, Benemérita Universidad Autónoma de Puebla, Mexico*
Javier Flores-Méndez, *Facultad de Ciencias de la Electrónica, Benemérita Universidad Autónoma de Puebla, Mexico*
Felipe Pérez-Rodríguez, *Instituto de Física, Benemérita Universidad Autónoma de Puebla, Mexico*

A homogenization theory is used to calculate the dynamic mass density and the

Kenichi Kasahara, *Ritsumeikan University, Japan*
Nobuhiko Ozaki, *Wakayama university, Japan*
Naoki Ikeda, *National Institute for Materials Science, Japan*
Hirotaka Oosato, *National Institute for Materials Science, Japan*
Yoshimasa Sugimoto, *National Institute for Materials Science, Japan*

An electric field enhanced by a mid-infrared circular slot antenna with a thin Al2O3 layer was estimated by observing the intensity of surface phonon polariton signals arising from the SiC surface. Monitoring the surface phonon polariton intensity with varying Al2O3 layer thicknesses allowed measurement of increasing perpendicular fields.

35 - Engineering For Acoustic And Elastic Metamaterials

Mehul Makwana, *Multiwave Technologies AG, Switzerland*
Tryfon Antonakakis, *Multiwave Technologies AG, Switzerland*

Metamaterial design is hindered by lengthy computational time and a plethora of possible microstructures. Modelling a structured material is expensive in terms of computing memory, time and cost. One needs to have the right structure or topology combined with the adequate materials responding to engineering requirements of permittivity, permeability, or elastic wave velocities. Multiwaves software has the ability to compute these effective parameters and and as a result we are able to design structured media with desired properties. We have developed algorithms in the fields of homogenisation reducing metamaterial analysis to a single cell. To demonstrate the capabilities of our algorithms we elucidate one of our post-processing algorithms, high frequency homogenisation, by examining two case studies applicable to acoustic and elastic metamaterials. Using high-frequency homogenisation, in addition to other algorithms, the entire design process is accelerated by several orders of magnitude and is abstract enough to be applied to the discovery of novel metamaterials.

36 - Density-near-zero Acoustic Metamaterials based on Membrane Network

Ying Cheng, *School of Physics, Nanjing University, China*
Dajian Wu, *School of Physics and Technology, Nanjing Normal University, China*
Xuewei Wu, *School of Physics, Nanjing University, China*
Xiaojun Liu, *School of Physics, Nanjing University, China*

A two-dimensional density-near-zero acoustic metamaterial based on membrane network structure is presented. The membrane structure is modeled as a network of inductors and capacitors, and the retrieved effective mass density is close to zero at the resonance frequency. The membrane-network has the ability to control sound transmission such as cloaking.

37 - Isotropic Transformation Materials for the Controlling of Flexural Waves in Plates

Jin Hu, *Beijing Institute of Technology, China*
Jing Chen, *Beijing Institute of Technology, China*

The local affine transformation based method has been applied to the controlling of the dispersion relation for modes in a 3D phononic crystal composed of two materials with high elastic contrast. It is shown that the elastic metamaterial response is in general non local, i.e. depends on the direction and magnitude of the wave vector. The dynamic effective elastic parameters for a homogenized Al-rubber phononic crystal are calculated and analyzed. It is found that strong dynamic mass-density anisotropy appears because of the form of the inclusion and distinct frequency dependence of the effective metamaterial parameters for longitudinal and transverse modes.

12 - Strong Mangetic Response in Photoexcited Graphene Metasurfaces

Yuancheng Fan, *Northwestern Polytechnical University, China*
Nian-hai Shen, *Iowa State University, United States*
Fuli Zhang, *Northwestern Polytechnical University, China*
Costas Soukoulis, *Iowa State University, United States*

Metamaterials with resonant elements are of great interest in the manipulation of light. However, the enhanced energy dissipation associated in metamaterials caused by the resonant nature of meta-atoms and the intrinsic loss of metals obstructs it from practical application in extraordinary manipulation on the flow of light. It is highly desirable to achieve loss compensated resonance to take further advantages in boosting light-matter interactoins. In this talk, we will show that the plasmonic resonance in graphene based metasurface can be boosted with photoexcitation in graphene, even for the difficultly excited magnetic resonance case. It is shown thatremarkable modulations on the transmission through and absorption in the split ring resonators patterned graphene metasurfaces can be achieved under proper quasi-Fermi energy. Our results will have potential applications with strong light-graphene interactions based on active/dynamical plasmonic excitations in graphene metasurfaces.

13 - Double Fano Resonance with Externally Driven Subradiant Mode

Yeon Ui Lee, *Ewha Womans University, Korea (South)*
Jeong Weon Wu, *Ewha Womans University, Korea (South)*

We observe that a dark mode is not necessarily prerequisite for an asymmetric Fano resonance to take place in plasmonic structures. Double Fano resonances are experimentally and theoretically observed where a common subradiant driven oscillator is coupled with two superradiant oscillators. The extinction spectrum of the composite metamaterial exhibits coherent effect based on double Fano resonances.

14 - Nano-Scale Optical Beam Manipulating by Illusion Optics

David Margousi, *Azad University of Shahre-rey, Iran*
Hamed Reza Shoorian, *University of Torbat-e-Heydarieh, Iran*
Mohsen Nazari Far, *Itech Company, Iran*
Zahra Amin, *University of Tehran, Iran*

In the presence of an illusion device, the effective permittivity and permeability is remotely modulated, and electromagnetic plane-waves can penetrate into a metal slab without any physical changes or damages in the original structure. Moreover,

flexural waves in plates and the isotropic transformation material properties are analytically derived in the conformal transformation mappings. A flexural waves beam bender is designed as a sample and the numerical simulations verify that it can control the wave propagation direction well in the plates.

38 - Low-cost Multi-layer Graphene for Linear/non-linear Metasurface Applications

Zoran Eres, *Rudjer Boskovic Institute, Croatia*
Silvio Hrabar, *University of Zagreb, Croatia*

This paper presents an update on recently introduced low-cost CVD reactor for graphene synthesis in metamaterial research. Apart from previously reported synthesis of single-layer graphene, it has been shown possible to produce large area multi-layer graphene, as well.

39 - Illusion Optics: The Optical Transformation of An Object location

Viktoriia Gill, *ITMO University, Russia*
Anna Vozianova, *ITMO University, Russia*
Mikhail Khodzitsky, *ITMO University, Russia*

This work extends the concept of cloaking as a special form of illusion to the wider realm of illusion optics. We propose to use transformation optics to generate an illusion such that an arbitrary object appears to another location of our choice. This is achieved by using of the medium with the angle dependent tensors of permittivity and permeability. The radar illusion device using artificial materials in the terahertz frequency range was designed.

40 - Eaton's Removable Tsunami Wall

Sang-Hoon Kim, *Mokpo National Maritime University, Korea (South)*

A removable tsunami wall which appears only when tsunami occurs is proposed theoretically. It is an array of acoustic Eaton lenses, each of which is composed of expandable rubber balloons. The rotating property of the lens reduces the pressure of the water wave by the canceling tsunami method. The diameter of the lens is larger than the wavelength of the tsunami near the coast or order of km. Before a tsunami, the balloons are buried underground in shallow water near the coast in folded or rounded form. On alarm of a tsunami, water and air are pumped into the balloons to expand and erect the wall to the sea level within in a few hours. After the tsunami, the water and air are released from the balloons, and then are buried back underground for reuse by electric power.

41 - Effect of Retardation on Surface-Enhanced Raman Optical Activity

Tong Wu, *Beijing Institute of Technology, China*
Xiangdong Zhang, *Beijing Institute of Technology, China*

We extend Bouř's work by taking the retardation effect of the incident plane wave into consideration. We find this effect is crucial in simulating surface-enhanced Raman nano-optical plasmonic lenses constructed in this way can benefit from the mobility feature and can be shifted along the main structure by only moving the illusion device which has great potential practical applications in optical devices such as filters, blockers, photonic integration laser splitting, and interferometers.

15 - A PDMS Photonic Crystal Slab for THz Sensing

Gian Paolo Papari, *Dipartimento di Fisica , Italy*
Genni Testa, *Istituto per il Rilevamento Elettromagnetico dell'Ambiente National Research Council IREA - CNR, Via Diocleziano 328, Italy*
Romeo Bernini, *Istituto per il Rilevamento Elettromagnetico dell'Ambiente National Research Council IREA - CNR, Via Diocleziano 328, Italy*
Antonello Andreone, *Dipartimento di Fisica , Italy*

Electromagnetic properties of a photonic crystal slab in the shape of a two dimensional periodic lattice of polydimethylsiloxane (PDMS) rods with square symmetry is investigated through the use of THz time domain spectroscopy. The fit of the transmission through a full wave simulation give insights on the guided mechanism responsible for the onset of a resonance at about f_0 = 1.57THz. The device can be exploited for enhanced sensing experiments of different organic/biological substances as supported by full wave simulations.

16 - Enhanced Nonlinear Response From Real Plasmas Via Resonator Structures

Dylan Pederson, *The University of Texas at Austin, USA*
Konstantinos Kourtzanidis, *The University of Texas at Austin, USA*
Laxminarayan Raja, *The University of Texas at Austin, USA*

Using real plasmas combined with resonators such as the split ring resonator (SRR) is known to show enhanced second harmonic generator due to plasma nonlinearities. However, standard electromagnetic modeling of plasmas as a Drude material does not capture this inherent nonlinearity. We analyze the coupling between plasmas and resonators in order to identify situations in which nonlinear plasma response can become important, and the Drude model breaks down.

17 - Propagation of Transverse Plasmonic Modes in Graphene-Covered Nanowires

Dmitry Kuzmin, *Chelyabinsk State University, Russia*
Igor Bychkov, *Chelyabinsk State University, Russia*
Vladimir Shavrov, *Kotel'nikov Institute of Radio Engineering and Electronics of RAS, Russia*

Here, we present results of our investigation of transverse electric plasmonic modes propagating in graphene-covered nanowires. These weakly localized modes may be supported by the structure at certain relation between core radius, frequency and difference of permittivity of the core and the outer medium. The frequency range of these modes vary with the chemical potential of graphene (its carrier concentration), which may be tuned by gate voltage or chemical doping. Results may be used for

optical activity(SEROA). According to our numerical calculation, ignoring this retardation effect results in the calculated SEROA intensities much weaker than those without the approximation.

42 - Plasmonic Modes of Cylindrical Spiral Graphene Waveguide

Dmitry Kuzmin, *Chelyabinsk State University, Russia*
Igor Bychkov, *Chelyabinsk State University, Russia*
Vladimir Shavrov, *Kotel'nikov Institute of Radio Engineering and Electronics of RAS, Russia*

We present results of theoretical investigation of plasmonic modes of cylindrical spiral graphene waveguide. The graphene-based metasurface approach has been used for description of proposed structure. The possibility of giant high-order modes rotation along cylinder axis has been shown. Proposed structure may be interesting in context of non-reciprocal plasmonic devices and plasmons manipulation.

43 - Homogenization Methods: from Thick to Thin Metamaterials

Jean-Jacques Marigo, *CNRS, LMS, France*
Agnes Maurel, *CNRS, Institut Langevin, France*

We present a homogenization method for thin metamaterials based on a matched asymptotic expansion technique. We show that a metamaterial with thickness e and periodicity h can be replaced by an equivalent interface associated to effective jump conditions. The method is validated by comparison with direct numerics and results are compared to the results given by the classical homogenization of layered media. The interface homogenization is shown to be accurate for ke,kh<1 while the classical homogenization applies for kh<1, e>h.

44 - Self-Oscillations in the Optical Response of a Semiconductor Quantum Dot -- Metal Nanoparticle Heterodimer

Bintoro S. Nugroho, *(1) Zernike Insitutte for Advanced Materials, University of Groningen, (2) Universitas Tanjungpura, (1) Netherlands, (2) Indonesia*
Alexander A. Iskandar, *Institut Teknologi Bandung, Indonesia*
Victor A. Malyshev, *Zernike Insitutte for Advanced Materials, University of Groningen, The Netherlands*
Jasper Knoester, *Zernike Insitutte for Advanced Materials, University of Groningen, The Netherlands*

We theoretically investigate the nonlinear optical response of a nanohybrid comprising a semiconductor quantum dot strongly coupled to a metal nanoparticle. We show that the composite can exhibit self-oscillations under continuous single-wave excitation. In this regime, the system represents a tunable nanogenerator of a train of ultrashort pulses.

45 - Quantum Coherence In A Qubit Chain Induced By Electromagnetic Pulses

Nikolaos Lazarides, *University of Crete, Greece*
Zoran Ivic, *University of Belgrade, Serbia*

numerous optics and plasmonics applications.

18 - A Compact Double-Frequency Rejection Filter by Combining Spoof Surface Plasmons and Metamaterial Resonators

Qian Zhang, *Southeast University, China*
Tie Jun Cui, *Southeast University, China*

Recurring to rectangular split-ring resonators (SRRs) etched on metal part of spoof surface plasmon polariton (SPP) waveguide made of single-side corrugated metallic strip, we propose a compact double-frequency rejection filter. The complementary SRRs (CSRRs) can be excited by the SPP electric-field component perpendicular to the metal surface, achieving signal suppressions. The simulated results demonstrate excellent filtering performance of the proposed device, which has important effect on developing the integrated plasmonic devices and circuits at microwave and terahertz frequencies.

19 - Three-Dimensional Patterning of ZnO Nanostructures

Maria Farsari, *FORTH, Greece*
Argyro Giakoumaki, *FORTH, Greece*
George Kenanakis, *FORTH, Greece*
Argiro Klini, *FORTH, Greece*
Zacharias Viskadourakis, *University of Crete, Greece*
Alexandros Selimis, *FORTH, Greece*

We report on a method for preparing fully three-dimensional ZnO nanorod structures based on a combination of two laser techniques and low temperature hydrothermal growth. 3D structures are firstly fabricated employing Multiphoton Lithography. They are subsequently covered by a Zinc layer using Pulsed Laser Deposition; this layer acts as a seed for the growth of ZnO nanorods by Aqueous Chemical Growth. The resulting structures are covered uniformly by nanorods and are electrically conductive.

20 - Active Plasmonic Coupling of Metallic Nanoparticles With Dye

Moheb Abdelaziz, *Aalto University, Finland*
Mehdi Keshavarz Hedayati, *University of Kiel, Germany*
Mady Elbahri, *Aalto University, Finland*

The plasmonic coupling of photoactive molecules and random arrangements of metal nanoparticles on a transparent substrate is demonstrated. It was observed that the triggering of the molecules by UV irradiation shift the plasmon resonance of the gold nanoparticles. In fact, UV irradiation of metal nanoclusters covered with thin layer of Spirooxazine doped polystyrene split the resonance dip in transmission spectra in which the wavelengths difference between the photo-induced divided dips can reach up to 80nm. The origin of the observation attributed to the coupling of the activated molecule resonance with that of the localized plasmon of the nanoparticles. The possibility of the dynamic control of the coupling between the particles and molecules

George Tsironis, *University of Crete, Greece*

Superconducting qubits are at the heart of quantum information processing schemes. It is demonstrated that quantum coherence, in the form of population inversion pulses, is induced by self-induced transparent electromagnetic pulses propagating in superconducting metamaterials comprising charge qubits. Confirmation of that effect may open a pathway to powerful quantum computing.

46 - Extraordinary Optical Transmission Through Hole Arrays Covered by Metal Block

Bo Huang, *Jinan University, China*
Zhi Luo, *Jinan University, China*
Huidong Yang, *Jinan University, China*
Guannan He, *South China Normal University, China*

This study confirms the role of the SPP mode in the EOT effect, but the actually enhances mechanisms can different. We found that decreasing the gap heights and increasing the block side will shift the transmission peak to longer wavelengths. this phenomenon is difficult to explain with SPP alone, but the coupling mechanism or resonance model give us a simple tool to explains that phenomenon. Our research has potential applications in many fields, such as chemical sensing, optical filters, etc.

47 - Effect of Annealing on GMI Effect of Co-rich Amorphous Microwires

Valentina Zhukova, *Dpto. de Fís. Mater., University of Basque Country (UPV/EHU) , Spain*
Mihail Ipatov, *Dpto. de Fís. Mater., University of Basque Country (UPV/EHU) , Spain*
Arcady Zhukov, *Dpto. de Fís. Mater., University of Basque Country (UPV/EHU) , Spain*

We studied Giant magnetoimpedance (GMI) effect and magnetic properties of $Co_{69.2}Fe_{4.1}B_{11.8}Si_{13.8}C_{1.1}$ amorphous as-prepared and annealed microwires. We observed that these properties can be tuned by heat treatment. High GMI effect has been observed in as-prepared Co-rich microwires. Annealing affects both affects fdiagonal and off-diagonal GMI components.

48 - Design of a Dual-Band Metamaterial Absorber in Wlan Bands With High Stability over Incidence Angle and Polarization

Fulya Bagci, *Ankara University, Turkey*
Francisco Medina, *University of Sevilla, Spain*

A dual-band metamaterial absorber for two wireless local area network frequencies is proposed based on a practical and systematic methodology that involves equivalent circuit modelling prior to full-wave electromagnetic optimization. The proposed absorber exhibits almost unity absorptions and a robust characteristic for different incidence angles under different polarizations.

49 - Graphene-Dielectric-Metal Tunable THz Perfect Absorber

Charalampos P. Mavidis, *Institute of Electronic Structure and Laser, FORTH, and*

can pave the way for application of plasmonic system in new optoelectronic devices.

21 - Extension of the Contour Integral Method for the Modeling of TE Scattering in Two-Dimensional Photonic Structures Using the Duality Principle

Jan Birger Preibisch, *Technische Universität Hamburg-Harburg, Germany*
Christian Schuster, *Technische Universität Hamburg-Harburg, Germany*

The Contour Integral Method (CIM) is a numerically efficient modeling technique for planar or infinitely extended two-dimensional (2-D) structures. In the optical regime, the CIM has already been adapted and applied for the modeling of TMz0-mode scattering in photonic crystals. In this work the dual case of TEz0-mode scattering is addressed. Making use of the duality principle, expressions for the behavior of the TEz0-mode can be derived from the system matrices associated with the TMz0-mode. This allows to reuse use formulas and program code written for the TMz0-mode with minimal adjustments. The results are validated by comparison to full-wave simulations.

22 - Efficient Derivative-free Global Optimization of Multilayer Plasmonic Structure for Narrow Bandwidth Color Filters

Katherine Fountaine, *NGNext, Northrop Grumman Aerospace Systems, USA*
Dagny Fleischman, *California Institute of Technology, USA*
Harry Atwater, *California Institute of Technology, USA*
Luke Sweatlock, *NGNext, Northrop Grumman Aerospace Systems, USA*

We apply numerical methods in combination with full-field simulations to optimize transmission properties of multilayer plasmonic color filters using a multi-objective figure of merit over a five-dimensional parameter space and compare the numerically-optimized designs to an expert analytic design. Algorithm selection and figure of merit design are both critical to the effectiveness of numerical optimization.

23 - Tunable THz Modulators Based On The Toroidal Metamaterials Concept

Kristina Schegoleva, *National University of Science and Technology MISiS, Russia*
Alexey Basharin, *National University of Science and Technology MISiS, Russia*

We present tunable metamaterials with toroidal dipolar moment for THz applications. We suppose that equivalent schemes of our theoretical modeling can be applied as modulators allowing to tune the amplitude, phase and frequency of the transmitted THz radiation.

24 - Toroidal Dipole Moment Of General Non-Radiating Source

Nikita Nemkov, *The National University of Science and Technology MISiS, The laboratory for superconducting metamaterials, Russia*
Alexey Basharin, *The National University of Science and Technology MISiS, The laboratory for superconducting metamaterials, Russia*

There exist peculiar charge-current configurations which in spite of their type-dependence produce no radiation fields. Most studied case is that of the point

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M. Kafesaki, *Institute of Electronic Structure and Laser, FORTH, Crete, and Department of Materials Science and Technology, University of Crete, Greece*
Eleftherios N. Economou, *Institute of Electronic Structure and Laser, FORTH, Crete, and Department of Physics, University of Crete, Greece*
C. M. Soukoulis, *Institute of Electronic Structure and Laser, FORTH, Crete, and Ames Laboratory and Department of Physics and Astronomy, Iowa State University, Greece, USA*

We report a tunable THz perfect absorber comprised of a single unpatterned graphene sheet separated by a dielectric layer from a metallic back-reflector. By tuning the Fermi level of the graphene layer, the absorption of the structure varies from low values up to unity, depending also on the thickness and the permittivity of the dielectric layer.

50 - Fabrication and Characterization of Meta-Atoms and Three-Dimensional Plasmonic Nanostructures

Rossella Grillo, *University of Geneva, Switzerland*
Thomas Bürgi, *University of Geneva, Switzerland*

Using bottom-up technique, three-dimensional plasmonic nanostructures were synthesized and characterized. Such structures are sufficiently small to be perceived as an individual object in the far field and exhibit strong and isotropic magnetic response in the visible spectral domain.

51 - Modified Perfectly Matched Layers in Finite-Difference Time-Domain Schemes for the Efficient Truncation of Propagating Graphene Surface Waves

Stamatis Amanatiadis, *Aristotle University of Thessaloniki, Greece*
Christos Liaskos, *Foundation of Research and Technology, Greece*
Maria Kafesaki, *Foundation of Research and Technology/University of Crete, Greece*
Nikolaos Kantartzis, *Aristotle University of Thessaloniki, Greece*

The extension of the perfectly matched layer (PML) for the effective absorption of propagating graphene surface waves in finite-difference time-domain (FDTD) schemes is developed in this paper. Graphene is accurately modelled through its surface conductivity and is imported in the FDTD algorithm as a surface boundary condition. Also, the conventional PML equations are properly modified to include graphene's contribution. The validity of the proposed technique is numerically investigated in order to prove its noteworthy performance.

52 - An Amplification of the Magneto-Optical Effects in the Magneto-Plasmonic Structures with Gain

Olga Borovkova, *RQC, Russia*
Andrey Kalish, *RQC and M.V. Lomonosov Moscow State University, Russia*
Grigoriy Knyazev, *RQC and M.V. Lomonosov Moscow State University, Russia*
Pavel Kapralov, *RQC, Russia*

	anapole, a system of destructively interfering toroidal and electric point dipoles. We show that in fact any non-radiating source can be represented as an assembly of the point anapoles. In particular this implies a simple relation between the toroidal and electric dipole moments for arbitrary non-radiating source. We argue that this observation might be important to understand properties of certain physical systems and give explicit examples. **25 - Reconfigurable Terahertz Metamaterials with Germanium Telluride** **Christopher Kodama**, *Air Force Institute of Technology, USA* **Ronald Coutu**, *Air Force Institute of Technology, USA* **Michael Havrilla**, *Air Force Institute of Technology, USA* We present a reconfigurable, terahertz (THz) range split-ring resonator (SRR) design using the phase-change material germanium telluride (GeTe). GeTe is a chalcogenide material which undergoes a nonvolatile transition from an amorphous insulating phase to a conductive, crystalline phase at approximately 200 ºC. This nonvolatile change can be reversed with the application of sharp electrical or optical pulses. Using thin films of GeTe as switchable interconnects, SRRs can be made to be reconfigurable in multiple ways. Using a simple GeTe-incorporated SRR structure, we demonstrate both amplitude modification and resonant frequency shifting of an SRR's resonant response. **26 - The Theory of Two-Dimensional Distribute Feedback Laser Which Take Into Account the Process of Spontaneous Emission in the Gain Medium and Modes Competition** **Alexander Zyablovsky**, *All-Russia research institute of automatics, Russia* **Eugeny Andrianov**, *All-Russia research institute of automatics, Russia* **Igor Nechepurenko**, *All-Russia research institute of automatics, Russia* **Alexander Dorofeenko**, *All-Russia research institute of automatics, Russia* **Alexey Vinogradov**, *All-Russia research institute of automatics, Russia* **Alexander Pukhov**, *All-Russia research institute of automatics, Russia* **Alexander Lisyansky**, *Department of Physics of the Division of Mathematics and Natural Sciences, Queens College of the City University of New York, USA* We consider lasing in the plasmon distributed feedback laser. For this, we derive equations of DFB laser, which take into account the process of spontaneous emission in the gain medium and modes competition. We find dependence number of photons in the laser modes of lasing on the intensity of pumping and on the gain coefficient. We show that intensity of lasing nonmonotonically depends on gain coefficient of amplifying medium.	**Vladimir Belotelov**, *RQC and M.V. Lomonosov Moscow State University, Russia* Amplification of the transverse MO intensity effect in the magneto-plasmonic nanostructures with gain is reported. Ferromagnetic dielectric doped with the rear-earth ions plays the role of gain material. Loss compensation leads to the amplification of the SPP, and to the significant rise of a Q-factor of magneto-optical resonance in transmission. **53 - Perfect Electromagnetic Absorbers and Sensors Based on Surface Plasmon Polaritons** **Giorgos Perrakis**, *University of Crete and Institute of Electronic Structure and Laser, Foundation for Research and Technology, Greece* **George Kenanakis**, *Institute of Electronic Structure and Laser, Foundation for Research and Technology, Greece* **Maria Kafesaki**, *University of Crete, Department of Material Science, and Institute of Electronic Structure and Laser, Foundation for Research and Technology, Voutes, 71110, Heraklion, Greece, Grecce* **Costas Soukoulis**, *Ames Laboratory and Department of Physics and Astronomy, Iowa State University, and Institute of Electronic Structure and Laser, Foundation for Research and Technology, Greece* **Eleftherios Economou**, *Institute of Electronic Structure and Laser, Foundation for Research and Technology, Greece* In this work we study theoretically and verify experimentally perfect electromagnetic wave absorption based on surface plasmon polaritons in nanostructured one-dimensional binary metallic gratings. The perfect absorption can be tuned with the grating geometrical features and the structures can offer a great platform for sensing applications. **54 - Thin Wideband Infrared Metamaterial Absorber with Coplanar Metallic Patches of Different Sizes** **Kadir Üstün**, *Middle East Technical University, Turkey* **Gönül Turhan-Sayan**, *Middle East Technical University, Turkey* We propose and numerically analyze thin metamaterial structures designed to operate in Long Wave Infrared Region. With a thin design, one of the proposed structures attains absorptance values higher than 80 percent in the wavelength region from 8.14 µm to 11.59 µm.
17:30-19:00	**10th Anniversary Event**	
17:30-	**10th Anniversary Special Session**	

19:00	Organizers: Filiberto Bilotti; Alex Schuchinsky Chair: Filiberto Bilotti; Alex Schuchinsky
17:30	**Metamaterials Congress Series: Origins and History** Invited **Sergei Tretyakov**, *Aalto University, Finland* **Filiberto Bilotti**, *"Roma Tre" University, Italy* **Alexander Schuchinsky**, *Belfast, United Kingdom* This abstract is a short review of the history of the Metamaterials Congress Series, written on the occasion of its tenth anniversary.
17:50	**10 Years Metamaterials Congress: Status and Breadth of the Field** Invited **Martin Wegener**, *Institute of Applied Physics, Karlsruhe Institute of Technology, Germany* We review the status of the field on the occasion of the 10th Metamaterials Congress. While the Congress has largely focused on electromagnetic metamaterials in its early editions, it has a broader scope today, also including mechanics, thermodynamics, and transport. We emphasize that 3D printing inspires metamaterials – and vice versa.
18:10	**Everything You Always Wanted To Know About The Future Of Metamaterials, But Were Afraid To Ask** Invited **Nikolay Zheludev**, *University of Southampton, United Kingdom* Metamaterials were first developed as artificial media structured on a size scale smaller than the wavelength of external stimuli. They showed novel, now well-understood electromagnetic properties, such as negative index of refraction or optical magnetism, allowing devices such as optical cloaks and super-resolution lenses. Tuneable, nonlinear, switchable, gain-assisted, sensor and quantum metamaterials appeared and dramatically increased the potential for device integration of metamaterial technology, which is now widely researched. The next challenge is to develop metamaterials with on-demand optical properties that may be independently controlled at any given point in space and at any moment of time. This will allow not only modulation of light's intensity or phase, but will offer control of the wavefront and the nearfield of electromagnetic radiation, thus enabling reconfigurable electromagnetic space and multi-channel data processing in meta-systems. Developing randomly accessible photonic metamaterials with individual meta-molecules controlled at will is a huge challenge. Here, the meta-molecules shall be sub-wavelength optical switches with a fraction of square micron footprint and a physical volume of only about 10-19 m3. To have impact on telecommunications technologies such switches must be fast and consume energy at a level not prohibitive to their mass deployment. However, there are emerging technologies that can deliver not only meta-molecular level switching controlled by electric or magnetic signals, but also switching with light. These are nano-optomechanical, phase-change and coherent control technologies. The talk will overview advances in new materials enabling advances metamaterials and emerging switching technologies.
18:30	**The Next Ten Years** Invited **Nader Engheta**, *University of Pennsylvania, USA* On the occasion of 10th anniversary of this conference series, we look into the future to speculate how the field of metamaterials may evolve and how this conference series may play its key role in the next ten years.
19:00-20:00	**Break**
20:00-23:00	**Gala Dinner**

Thursday, September 22

Oral Sessions (Thursday 22 – Morning 1)			
09:00-10:30	**Oral Session Th1-A** **Metasurface applications** Chair: Yang Hao	**Oral Session Th1-B** **Plasmonics** Chair: Nikolay Zheludev	**Oral Session Th1-C** **Seismic metamaterials** **(special focused session)** Organizer: Sebastien Guenneau; Stephane Brule Chair: Sebastien Guenneau; Stephane Brule
	Imperial	**Imperial 2**	**Imperial 4**
09:00	**Multifunctional Cascaded Metasurfaces** **Viktar Asadchy**, *Aalto University, Finland* **Amr Elsakka**, *Aalto University, Finland* **Ihar Faniayeu**, *Shizuoka University, Japan* **Svetlana Tcvetkova**, *Aalto University, Finland* **Sergei Tretyakov**, *Aalto University, Finland* In this talk, design and realization of a single-layer meta-transmitarray which provides a certain functionality in a narrow frequency band while remains reflectionless (transparent) elsewhere is presented. Realization of such transmitarrays would allow integrating several metasurfaces in a cascade that performs different functionalities at different frequencies, opening a door for various new applications. In the presentation we will show results for fabricated structures as well as a cascade consisting of three independent metasurfaces for general control over reflection, transmission and absorption.	**Novel Physical Phenomena Based on Plasmon Hot Spots** Invited **Xiangdong Zhang**, *Beijing Institute of Technology, China* **Jun Ren**, *Beijing Institute of Technology, China* We report recent research progress on the strong coupling between an ensemble of quantum emitters (QEs) or chiral molecules and plasmon in the nanoparticle cluster, including strong interaction between chiral molecules and orbital angular momentum of photon, multi-qubit entanglement for two-level QEs, resonant energy transfer and so on.	**Seismic Surface Waves Attenuation by Buried Resonators** **Antonio Palermo**, *University of Bologna, Italy* **Sebastian Krödel**, *ETH, Switzerland* *Alessandro Marzani, University of Bologna, Italy* **Chiara Daraio**, *ETH, Switzerland* We propose to use arrays of resonant structures buried around sensitive locations as protection against surface seismic waves. The resonant structures consist of concrete tubes containing a steel mass suspended by soft bearings. We verify their design numerically and on a scaled experimental campaign. The arrays attenuate and redirect Rayleigh waves within the [1-10Hz] frequency range.
09:15	**Phase Gradient Discontinuity Metasurface with Intertwined Spiral Arrays** **Andrea Vallecchi**, *University of Oxford, UK* **Simon Hubert**, *Université catholique de Louvain, Belgium* **Alex Schuchinsky**, *UK* **Cristophe Craeye**, *Université catholique de Louvain* A reflect-type metasurface with phase gradient discontinuity is proposed. It is made of intertwined spirals loaded with inductors. An initial design is developed		**Conversion and Reflection of Rayleigh Waves with the Seismic Metawedge** invited **Andrea Colombi**, *Imperial College London, UK* **Philippe Roux**, *ISTerre, France* **Daniel Colquitt**, *University of Liverpool, UK* **Richard Craster**, *Imperial College London, UK* **Sebastien Gunenneau**, *Institut Fresnel, France* By combining concepts from elasticity, photonics and metamaterials, we present a seismic metasurface capable to convert or reflect seismic Rayleigh waves

	based on the phase response of uniform arrays under the locally periodic assumption. Calculations are accelerated using the periodic method of moments. Macro-cells, containing 70 identical micro-cells with different loads, are analysed using the Array Scanning Method. So far, only a fraction of the reflected power goes into the desired non-specular Floquet mode.		propagating in a sedimentary ground. The metasurface is obtained with an array of trees, with their height gradually decreasing to form a wedge-like profile, “the metawedge”. Local resonance phenomena between trees and ground, combined with the spatially varying profile of the wedge give rise to a twofold behavior depending on the incidence direction of the wavefront: (1) Rayleigh to shear wave conversion or (2) Rayleigh wave reflection.
09:30	**Molecular Detection With Terahertz Waves Based On Absorption-Induced Transparency Metamaterials** **Sergio G Rodrigo**, *Universidad de Zaragoza-CUD and CSIC-ICMA, Spain* **Luis Martín-Moreno**, *CSIC-ICMA and Universidad de Zaragoza, Spain* A system based on absorption-induced transparency (AIT) for the detection of spectral signatures of chemical compounds at Terahertz regime is presented. The system consists on a holey metal film whereby the presence of a given substance provokes the appearance of spectral features induced by the molecular specimen. The presence of a target chemical compound would be thus revealed as a strong drop in reflectivity measurements. We theoretically predict the AIT based system would serve to detect amounts of hydrocyanic acid at low rate concentrations.	**Direct Writing of Truly Three-Dimensional Optical Nanostructures by Focused Electron Beam Induced Deposition** **Katja Hoeflich**, *Institute of Nanoarchitectures for Energy Conversion, Helmholtz-Zentrum Berlin für Materialien und Energie, Germany* **Pawel Wozniak**, *Max Planck Institute for the Science of Light, Germany* *Caspar Haverkamp, Institute of Nanoarchitectures for Energy Conversion, Helmholtz-Zentrum Berlin für Materialien und Energie, Germany* **Peter Banzer**, *Max Planck Institute for the Science of Light, Germany* *Gerd Leuchs, Institute of Optics, Information and Photonics, Friedrich-Alexander-Universität Erlangen-Nuremberg, Germany* **Silke Christiansen**, *Institute of Nanoarchitectures for Energy Conversion, Helmholtz-Zentrum Berlin für Materialien und Energie, Germany* Direct writing using a focused electron beam provides fast and flexible fabrication of truly three-dimensional nanostructures with geometrical features below 50 nm. This presentation shows how the resulting composite nanostructures can be optically described, optimized and utilized for nano-optical applications.	
09:45	**Metasurface-enabled Pyroelectric Detection of 140 GHz Radiation with Strong Polarization Discrimination** **Sergei A. Kuznetsov** , *Novosibirsk State University, Russian Federation* **Miguel Navarro-Cia**, *University of Birmingham, UK* **Andrey G. Paulish**, *Institute of Semiconductor Physics SB RAS, Russian Federation* **Andrey V. Arzhannikov**, *Novosibirsk State University, Russian Federation* A pyroelectric infrared sensor is transformed into a	**3D Chiral Plasmonic Metamaterials Fabricated by Direct Laser Writing: The Twisted Omega Particle** **Ioanna Sakellari**, *4th Physics Institute, University of Stuttgart, Germany* **Xinghui Yin**, *4th Physics Institute, University of Stuttgart, Germany* **Maxim Nesterov**, *4th Physics Institute, University of Stuttgart, Germany* **Konstantina Terzaki**, *Institute of Electronic Structure and Laser - Foundation for Research and Technology, Greece* **Aggelos Xomalis**, *Institute of Electronic Structure and*	**Seismic Metamaterials in Civil Engineering** Invited **Stephane Brule**, *Menard, France* **Sebastien Guenneau**, *Institut Fresnel, France* **Stefan Enoch**, *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. The possibility of imagining a seismic 2D or 3D metamaterial made of a grid of inclusions or empty boreholes in the soil, interacting with a part of the earthquake signal is becoming realistic.

	polarization-selective millimeter-wave detector by integrating to it a metasurface absorber, which is 136 times thinner then the operating wavelength. The detector keeps high values of the response speed and sensitivity to polarized mm-wave radiation changed insignificantly against the regime of IR detection	*Laser - Foundation for Research and Technology, Greece* **Maria Farsari**, *Institute of Electronic Structure and Laser - Foundation for Research and Technology, Greece* **Harald Giessen**, *4th Physics Institute, University of Stuttgart, Germany* The plasmonic version of a 3D chiral meta-atom which consists of a loop-wire structure, or the so-called twisted omega particle, is experimentally and theoretically studied. Direct Laser Writing in combination with electroless silver plating is employed for the fabrication of such 3D chiral meta-atoms with feature sizes below the diffraction limit.	
10:00	**A Phase-tunable, Liquid Crystal-based Metasurface** **Amanda Couch**, *University of Michigan, USA* **Anthony Grbic**, *University of Michigan, USA* The dielectric anisotropy of liquid crystals is used to design a metasurface that acts as a phase-tunable reflector. An equivalent circuit is developed for the metasurface which closely models its simulation performance. The design and fabrication procedure for the metasurface is discussed. An experimental prototype demonstrates 186° of phase swing.	**Infrared Waveguided Graded-index Plasmonic Lens on SOI in TE Mode** **Yulong Fan**, *IEF-University of Paris Sud, France* **Anatole Lupu**, *IEF-University of Paris Sud, France* **Andre de Lustrac**, *IEF-University of Paris Sud, France* In this study we describe the design, the simulation and the characterization of a waveguided plasmonic lens on SOI. The lens is made of gold nanowires on a SOI waveguide. A thin silicon dioxide layer separates the gold nanowires from the SOI waveguide. This lens is made of a gradient index corresponding to the effective index of the gold wires on the silicon waveguide. Simulations and characterizations demonstrate that this device can be very efficient to focalize light at infrared wavelength.	
10:15	**Stability of Metasurface-Based Parity-Time Symmetric Systems** **Josip Loncar**, *University of Zagreb, Croatia* **Silvio Hrabar**, *University of Zagreb, Croatia* This study reports stability analysis of previously proposed parity-time symmetric system model based on mixed umped/distributed network by finding pole locations in complex frequency domain.	**Radiation Properties of Micro-structured Media via a Spatial Map of Green's Tensor** **Parry Y. Chen**, *Tel Aviv University, Israel* **David J. Bergman**, *Tel Aviv University, Israel* **Yonatan Sivan**, *Ben Gurion University, Israel* The spatial variation of Green's tensor of micro-structured media in both source and detector position and orientation over all 3D space on arbitrarily fine grid is obtained without repeated simulation. Total radiated fields even for arbitrary extended sources are simulated by simply projecting onto the structure's source-free eigenmodes. Eigenmodes of complex arrangements of scatterers can be constructed from individual eigenmodes semi-analytically, and total simulation time is only a few seconds for cylinder clusters. Maxwell	**Design Aspects of Seismic Metamaterials** **Giovanni Finocchio**, *University of Messina, Italy* **Orazio Casablanca**, *University of Messina, Italy* **Francesca Garesci**, *University of Messina, Italy* **Bruno Azzerboni**, *University of Messina, Italy* **Massimo Chiappini**, *Istituto Nazionale di Geofisica e Vulcanologia, Italy* Seismic Metamaterials (SM) can be used to filter secondary earthquake waves showing theoretically higher potential than traditional seismic insulators and passive energy dissipation systems. Here, we shows two crucial aspects in the design of the SM. In particular, the use of six order SMs allows to push the beginning of the band-gap at lower frequencies as compared to fourth order SMs. From a modeling point of view, we used the

		equations are solved rigorously, thus circumventing implementation and interpretation issues associated with quasi-normal eigenmode methods. Rapidly converging results are obtained, facilitating analytic calculations involving Green's tensor, such as radiative heat transfer and van der Waals forces.	Preisach model to include in the computation of the resonance frequency of the soil deposit the effect of the mechanical hysteresis. Our results, indicate a path towards the design of low frequency SMs.
10:30-11:00	**Coffee Break**		
Oral Sessions (Thursday 22 – Morning 2)			
11:00-12:30	**Oral Session Th2-A** **Microwave metamaterial devices** Chair: Anthony Grbic	**Oral Session Th2-B** **Plasmonics: Particle phenomena** Chair: Pavel Belov	**Oral Session Th2-C** **Theory and modelling** Chair: Mario Silveirinha
	Imperial	**Imperial 2**	**Imperial 4**
11:00	**Experimental Demonstration of Superdirectivity for Coupled Dimers of Meta-Atoms** Invited **Anna Radkovskaya**, *M. V. Lomonosov Moscow State University, Russia* **Andrea Vallecchi**, *University of Oxford, UK* *Lianbo Li, University of Oxford, UK* **Grahame Faulkner**, *University of Oxford, UK* *Chris Stevens, University of Oxford, UK* **Ekaterina Shamonina**, *University of Oxford, UK* A century-long quest for realizing superdirective antennas has got a new lease of life with the advent of metamaterials: Arrays of coupled meta-atoms capable of carrying slow short-wavelength magneto-inductive waves were shown to be promising candidates for realizing rapidly varying current distributions required for superdirectivity. This paper provides an overview of our work towards realizing a genuine superdirective meta-array, with only one element being driven. In particular, we report on our most recent experimental, numerical and analytical results, which, for the first time to our knowledge, confirm superdirective end-fire directivity reaching the maximum theoretical value. We formulate the conditions for superdirectivity in terms of shape and size of the meta-atoms and discuss implications of our results for future work on superdirective metamaterials.	**Leaky Modes of Domino Nanoparticles and Their Light-trapping Implications** **Pavel Voroshilov**, *ITMO University, Russia* *Constantin Simovski, Aalto University, Finland* Previously, we have revealed an efficient light trapping performed by arrays of cross-like substantially thick metal nanoantennas. This light trapping implied a broad spectrum of solar light concentrated in a subwavelength depth of the semiconductor substrate. However, the physics underlying this effect was not investigated. In the present paper, we show that our arrays support so-called leaky domino-modes, responsible for the broadband resonant absorption in the substrate. We have thoroughly studied the main properties of these modes, which turned out to be very unusual for the optical frequency range.	**Efficient Integral Equation Analysis of Scattering by a Metamaterial Grating Assisted Slab** **Nikolaos Tsitsas**, *Aristotle University of Thessaloniki, Department of Informatics, Greece* Plane wave scattering by a dielectric slab on which has been etched an infinitely periodic metamaterial grating is analyzed by means of semi-analytical integral equation techniques. The grating slab's operation as a frequency filter as well as the effect of the grating's parameters on the diffracted fields are investigated for a grating composed of an epsilon-near-zero (ENZ) material.
11:15		**Anomalous Spectral Shifts in Extreme Plasmonic Nano-Cavities** **Angela Demetriadou**, *Imperial College London, UK* **Anna Lombardi**, *University of Cambridge, UK* **Jan Mertens**, *University of Cambridge, UK* **Ortwin Hess**, *Imperial College London, UK* **Javier Aizpurua**, *Centro de Fisica de Materiales, Spain* **Jeremy Baumberg**, *University of Cambridge, UK*	**Field Decomposition For Analysis Of Hyperbolic Media** **Michael Havrilla**, *Air Force Institute of Technology, USA* A field decomposition of Maxwell's equations for uniaxial hyperbolic media based on the 2D Helmholtz theorem is provided. This decomposition is particularly useful since it produces TE and TM field sets that are orthogonal, allows for identification of two independent scalar

		Nanoplasmonics have the ability to confine light in sub-wavelength cavities, with recent nano-fabrication developments allowing for the realization of nanometer and sub-nanometer plasmonic cavities. We show that for such extremely small nano-cavities, the correlation between the field enhancement resonance and the radiative (far-field) resonance breaks down. This dissociation dominated the excitation and interference of higher-order modes in these nano-cavities. We discuss and demonstrate the impact of this anomalous spectral behaviour for the strong coupling of quantum emitters with plasmonic nano-cavities, where it is imperative to have nano-sized cavities.	potential formulations, provides substantial mathematical simplification, enhances physical insight, eases boundary condition enforcement and has a trivial field recovery process. An example involving a parallel-plate waveguide filled with hyperbolic media is given to demonstrate the technique.
11:30	**Programmable Magnetoinductive Devices** **Jan Paszkiewicz**, *University of Oxford, UK* **Ekaterina Shamonina**, *University of Oxford, UK* **Christopher Stevens**, *University of Oxford, UK* A design for a programmable magnetoinductive waveguide where the impedance of each cell can be set to one of two values by an electronic signal is presented. A 1D magnetoinductive waveguide using such cells is verified experimentally and used to demonstrate an electronically programmable transfer function. Extension of the concept to 2D devices and creating programmable RF systems is discussed.	**Interaction between a Nanoantenna Dimer and Orbital Angular Momentum Light** **Sang Soon Oh**, *Imperial College London, UK* **Ortwin Hess**, *Imperial College London, UK* **Jamie Michael Fitzgerald**, *Imperial College London, UK* **Richard Kerber**, *University of Münster, Germany* **Doris Reiter E.**, *University of Münster, Germany* We demonstrate that both parallel and anti-parallel orbital angular momentum light can be used to excite the dark mode of dimer nanoanteanna. We further develop an electric dipole radiation model which reproduces the numerically found results very well.	**Full-Wave Simulation of Semi-Infinite Metamaterial** **Denis Tihon**, *Université Catholique de Louvain, ICTEAM institute, Belgium* **Christophe Craeye**, *Université Catholique de Louvain, ICTEAM institute, Belgium* We present a method that can be used to model a semi-infinite metamaterial using full-wave simulations based on the Method of Moments. First, the impedance matrices describing one layer of the metamaterial are transformed in ordre to obtain the response of a semi-infinite metamaterial. Then, the fields within the first layers of the structure are computed recursively.
11:45	**Wireless Power Transfer System Based on Ceramic Resonators** Invited **Polina Kapitanova**, *ITMO University, Russia* *Mingzhao Song, ITMO University, Russia* **Ivan Iorsh**, *ITMO University, Russia* **Pavel Belov**, *ITMO University, Russia* An original approach to near field magnetic resonance wireless power transfer using high permittivity dielectric resonators is proposed. The results of numerical simulation and experimental investigation of the wireless power transfer systems based on ceramic resonators with the permittivity e=80 are reported.	**Maximum Optical Force and Torque on Multipolar Meta-atoms** **Aso Rahimzadegan**, *Institute of Theoretical Solid State Phsics, Karlsruhe Institute of Technology, Germany* **Rasoul Alaee**, *Institute of Theoretical Solid State Phsics, Karlsruhe Institute of Technology, Germany* **Ahvand Jalali**, *Department of Electrical and Electronic Engineering, University of Melbourne, Australia* **Carsten Rockstuhl**, *Institute of Theoretical Solid State Physics & Institute of Nanotechnology, Karlsruhe Institute of Technology, Germany* Optical forces provide unprecedented control on the spatial motion of particles.However, there exist upper bounds for the achievable force and torque depending on the induced multipole moment. In this contribution, we derive theoretically the upper limits for the possible optical force and torque while considering spectrally	**Discrete and Continuous Spectrum Analysis: an Alternative Perspective on Subwavelength Imaging** **Francisco Mesa**, *University of Seville, Spain* **Ali Forouzmand,** *University of Mississippi, USA* **Alexander B. Yakovlev**, *University of Mississippi, USA* **George W. Hanson**, *University of Wisconsin-Milwaukee, USA* **Francisco Medina**, *University of Seville, Spain* **R. Rodríguez-Berral**, *University of Seville, Spain* In this paper, we establish a general framework for understanding subwavelength imaging by means of complex-plane analysis of the Sommerfeld integral for a magnetic line source over a subwavelength imaging lens. The Sommerfeld integral of the transmitted field is calculated in terms of discrete and continuous spectra. This spectral decomposition makes it possible to achieve physical insight regarding the imaging mechanisms.

		isolated scattering resonances of an isotropic meta-atom that is illuminated by a plane wave. We show how and to which extent these bounds can be surpassed by exploiting constructive interference between different multipolar contributions. Particle swarm optimization is used to maximize the accelerability and rotatability of a meta-atom exemplarily.	Results are presented for a stack of silver slabs, an isolated wire-medium (WM) slab, and for a WM loaded with graphene sheets (GSs) and graphene patches (GPs).
12:00		**Plasmonic Gap Resonances between a Single Gold Nanorod and Films** [Invited] **Xingxing Chen**, *Zhejiang University, China* *Yu-Hui Chen, University of Otago, New Zealand* **Richard J. Blaikie**, *University of Otago, New Zealand* **Boyang Ding**, *University of Otago, New Zealand* **Min Qiu**, *Zhejiang University, China* The plasmonic resonances in individual gold nanorods nanoscopically coupled to a gold film with different gap spacing have been experimentally and theoretically investigated. The spectral shapes of single nanoparticle can be significantly modified as the gap distance changes in the sub-30 nm domain.	**Theory of Coupled Waveguides With Modal Degeneracies and Gain** **Mohamed Othman**, *University of California, Irvine, USA* **Filippo Capolino**, *University of California, Irvine, USA* We investigate the novel characteristics of coupled waveguides exhibiting eigenmode degeneracies and gain. We study a particular degeneracy of eigenmodes at which the state eigenvectors coalesce a condition named exceptional degeneracy. We explore the theory of such coupled-waveguides with exceptional points of degeneracies (EPD) using a generic coupled transmission-line (CTL) approach. We show that giant enhancement in the local density of states (LDOS) occurs in finite length resonators with second and fourth order degeneracies. We also demonstrate the possibility of low threshold generation (lasing) in such cavities. The developed framework provides a promising performance boost for several applications including low-threshold lasers, highly efficient high microwave power sources, and sensors.
12:15	**W-band Hybrid Wood Zone Plate Fishnet Metalens** **Bakhtiyar Orazbayev**, *Public University of Navarre, Spain* **Miguel Navarro-Cía**, *University of Birmingham, UK* **Miguel Beruete**, *Public University of Navarre, Spain* We present here the design, fabrication and numerical as well as experimental results of a lowprofile hybrid Wood zone plate fishnet metamaterial lens working at f = 99 GHz. The fishnet metamaterial with effective refractive index close to zero (n = 0.51) acts as an anti-reflecting layer as well as a beam shaper, increasing the overall efficiency while maintaining low profile, low cost and ease of manufacturing. The measurements are in good agreement with simulation results and demonstrate a focal length FL = 22.8 mm (7.5 λ0). In a lens antenna configuration a gain of 16.6 dB was measured at the operation frequency. This lens has a low-cost and		**Impact of a Conducting Medium on the Coupling of Meta-Atoms** **Andrea Vallecchi**, *University of Oxford, UK* **Son Chu**, *University of Oxford, UK* **Chris Stevens**, *University of Oxford, UK* **Ekaterina Shamonina**, *University of Oxford, UK* We have studied analytically, numerically and experimentally the effect of conducting material upon the mutual inductance between two coils yielding thereby the attenuation of magnetoinductive (MI) waves. It is shown among others that the expression for plane wave attenuation, used in the literature, has only limited validity. Our results will be relevant for the design and optimisation of MI waveguide links in conducting media in general and particularly when the attenuation is caused by soil conductivity. The results will also help medical diagnosis in problems where parts of the human

	compact design, and may find applications in integrated lens antenna systems.		body are imaged.
12:30-14:00	**Lunch Break**		
Oral Sessions (Thursday 22 – Afternoon 1)			
14:00-16:00	**Oral Session Th3-A** **Toroidal and multi-polar electrodynamics** Chair: Eleftherios Economou	**Oral Session Th3-B** **Novel plasmonic materials** Chair: Sergey Bozhevolnyi	**Oral Session Th3-C** **Advanced optical structures** Chair: Natalia Litchinitser
	Imperial	**Imperial 2**	**Imperial 4**
14:00	**Electromagnetic Doughnuts: Localized & Propagating Toroidal Excitations Enabled By Metamaterials** [Invited] **Tim Raybould**, *University of Southampton, UK* **Vassili Savinov**, *University of Southampton, UK* **Nikitas Papasimakis**, *University of Southampton, UK* **Vassili Fedotov**, *University of Southampton, UK* **Nikolay Zheludev**, *University of Southampton, UK* The toroidal dipole is a localized electromagnetic excitation, distinct from the magnetic and electric dipoles. While the electric dipole can be understood as a pair of opposite charges and the magnetic dipole as a current loop, the toroidal dipole corresponds to currents flowing on the surface of a torus. Toroidal dipoles provide physically significant contributions to the basic characteristics of matter including absorption, dispersion and optical activity. Toroidal excitations also exist in free space as spatially and temporally localized electromagnetic pulses propagating at the speed of light and interacting with matter. We review recent experimental observations of resonant toroidal dipole excitations in metamaterials and the discovery of anapoles, non-radiating charge-current configurations involving toroidal dipoles. While certain fundamental and practical aspects of toroidal electrodynamics remain open for the moment, we envision that exploitation of toroidal excitations can have important implications for the fields of photonics, sensing, energy and information.	**Zirconium Nitride as Emerging Material for Durable Photonic Devices and On-chip Plasmonics** **Urcan Guler**, *Nano Meta Technologies, USA* **Krishnakali Chaudhuri**, *Purdue University, USA* **Aveek Dutta**, *Purdue University, USA* **Harsha Reddy**, *Purdue University, USA* **Amr Shaltout**, *Purdue University, USA* **Soham Saha**, *Purdue University, USA* **Nathaniel Kinsey**, *Purdue University, USA* **Vladimir Shalaev**, *Purdue University, USA* **Alexandra Boltasseva**, *Purdue University, USA* Transition metal nitrides provide a unique set of material properties combining extremely high melting points, chemical resistance and CMOS compatibility together with plasmonic properties in the visible and infrared regions of the electromagnetic spectrum. Here, we study zirconium nitride as an emerging material for durable photonic devices and on-chip plasmonics. Ultra-smooth, ultra-thin zirconium nitride films are investigated for use as plasmonic waveguides, metasurfaces and high temperature sensors.	**Advanced Effective Medium Approximation For Subwavelength Multilayers To Overcome Maxwell-Garnet Approach Breakdown** **Vladislav Popov**, *Belarusian State University, Belarus* **Andrey Novitsky**, *Belarusian State University, Belarus* We develop a more precise definition of effective medium approximation for subwavelength multilayer structures. It allows to overcome anomalous behavior of the ordinary Maxwell-Garnet effective medium for all-dielectric multilayers, investigated theoretically and observed experimentally.
14:15		**All-chalcogenide Phase-Change Plasmonics** **Behrad Gholipour**, *University of Southampton, UK* *Artemios Karvounis, University of Southampton, UK* **Jun Yin**, *Nanyang Technological University, Singapore* **Cesare Soci, Nanyang Technological University, Singapore** **Kevin F. MacDonald, University of Southampton, UK**	**Optical Dispersion Models for Graphene: Integration-Free Formulations** **Ludmila Prokopeva**, *Novosibirsk State University, Novosibirsk, Russia* **Zhaxylyk Kudyshev**, *Skoltech, Skolkovo, Russia* **Alexander Kildishev**, *School of Electrical and Computer Enginering, Birck Nanotechnology Center, Purdue*

		Nikolay I. Zheludev, University of Southampton, UK We demonstrate that chalcogenide phase-change media provide a uniquely reconfigurable platform for nanostructured photonic metamaterials, which can be reversibly switched in non-volatile fashion between plasmonic and non-plasmonic states. Amorphous germanium antimony telluride is a transparent dielectric, but in the crystalline phase it presents a negative value of ε1 (real part of relative permittivity) and supports plasmonic resonances in the ultraviolet-visible spectral range.	*University, USA* Kubo's formalism for graphene surface conductivity is so far the most popular technique to model graphene in optics. However, its original integral form makes it inefficient for numerical evaluation and coupling to electromagnetic solvers since numerical integration shall be employed. In this paper we propose a Kubo-equivalent integration-free formulation for the computationally efficient modeling of the surface conductivity of graphene in time and frequency domains.
14:30	**Exact Multipolar Moments of a Localized Electric Current Distribution** **Ivan Fernandez-Corbaton**, *KIT, Germany* *Stefan Nanz, KIT, Germany* **Rasoul Alaee**, *KIT, Germany* **Carsten Rockstuhl**, *KIT, Germany* The multipolar decomposition of current distributions is used in many branches of physics. In particular, it is used to study the properties of meta-atoms. Here we present new exact expressions for the dipolar and quadrupolar moments of a localized electric current distribution. The typical integrals for the dipolar and quadrupolar moments of electromagnetically small sources are recovered as the lowest order terms of the new expressions in a series expansion with respect to the size of the source. All the higher order terms can be easily obtained. Formally, the new exact expressions are only marginally more complex than their lowest order approximations.	**Plasmons of Hot-Carrier Graphene** **A. Freddie Page**, *Imperial College London, UK* **Fouad Ballout**, *Imperial College London, UK* **Ortwin Hess**, *Imperial College London, UK* **Joachim Hamm**, *Imperial College London, UK* Graphene, as a 2D semi-metal, is able to support surface plasmon modes. These plasmons interact, scattering the electrons in graphene, by way of emission and absorption. For electrons in thermal equilibrium, the energy scale of the optical response can be tuned by setting the Fermi level via external gate voltage. However, for non-equilibrium cases, such as photo-excitation, plasmons can become amplified through stimulated emission. We present how the non-local sheet conductivity can be calculated for graphene in non-equilibrium cases, how this affects the plasmon dispersion, as well as absorption and emission rates, and how the plasmon channel contributes to carrier relaxtion.	**Resonant Visible Light Modulation With Graphene** **Renwen Yu**, *ICFO - Institut de Ciencies Fotoniques, Spain* **Valerio Pruneri**, *ICFO - Institut de Ciencies Fotoniques, ICREA - Institució Catalana de Recerca i Estudis Avançats, Spain* **Javier García de Abajo**, *ICFO - Institut de Ciencies Fotoniques, ICREA - Institució Catalana de Recerca i Estudis Avançats, Spain* No fundamental limit appears to prevent us from designing wavelength-sized devices capable of controlling the light phase and intensity at terahertz speeds in those spectral ranges. Here we have proposed a solution based upon graphene for fast modulation and switching of light at visible and near-infrared (vis-NIR) frequencies which is of utmost importance for optical signal processing and sensing technologies.
14:45	**Observation of Anapole with Dielectric Nanoparticles** **Invited** **Andrey Miroshnichenko**, *Australian National University, Australia* Nonradiating current configurations attract attention of physicists for many years as possible models of stable atoms. One intriguing example of such a nonradiating source is known as "anapole", which can be viewed as a composition of electric and toroidal dipole moments, resulting in destructive interference of the radiation fields. Here we demonstrate experimentally that dielectric nanoparticles can exhibit a radiationless anapole mode in visible.	**Active Modulation Of Visible Light With Graphene-Loaded Ultrathin Metal Plasmonic Antennas** **Renwen Yu**, *ICFO - Institut de Ciencies Fotoniques, Spain* **Valerio Pruneri**, *ICFO - Institut de Ciencies Fotoniques, ICREA - Institució Catalana de Recerca i Estudis Avançats, Spain* **Javier García de Abajo**, *ICFO - Institut de Ciencies Fotoniques, ICREA - Institució Catalana de Recerca i Estudis Avançats, Spain* Electro-opticalmodulationofvisibleandnear-infraredlightisimportantforawide variety of applications, ranging from communications to sensing and smart	**Singular Asymptotics of Surface-Plasmon Resonance** **Ory Schnitzer**, *Imperial College London, UK* **Vincenzo Giannini**, *Imperial College London, UK* **Richard V. Craster**, *Imperial College London, UK* **Stefan A. Maier**, *Imperial College London, UK* Scale disparities are omnipresent in the study of surface-plasmon resonance. We demonstrate how the paradigm of singular perturbation theory facilitates intuitive physical descriptions along with systematic asymptotic formulae. In particular, we shall consider the asymptotics of multiple-scale nanometallic configurations, field confinement and enhancement, and hydrodynamic

		windows. However, currently available approaches result in rather bulky devices, suffer from low integrability, and can hardly operate at the low power consumption and fast switching rates of microelectronic drivers. Here we show that planar nanostructures patterned in ultrathin metal-graphene hybrid films sustain highly tunable plasmons in the visible and near-infrared spectral regions.	nonlocality.
15:00		**Surface Plasmons on Highly Doped InP** **Mohammad Esmail Aryaee Panah**, *Technical University of Denmark, Denmark* **Luisa Ottaviano**, *Technical University of Denmark, Denmark* **Elizaveta Semenova**, *Technical University of Denmark, Denmark* **Andrei Lavrinenko**, *Technical University of Denmark, Denmark* Silicon doped InP is grown by metal-organic vapor phase epitaxy (MOVPE) using optimized growth parameters to achieve high free carrier concentration. Reflectance of the grown sample in mid-IR range is measured using FTIR and the result is used to retrieve the parameters of the dielectric function. The derived dielectric function is used to simulate the excitation of surface plasmons by a diffraction grating made of the grown material. The grating structure is fabricated using standard nanofabrication techniques. Spectral features from the grating agree well with the simulations and show spp coupling at predicted angles of incidence and wavelengths.	**Graphene-Dielectric Metamaterial for Beam Steering** **Bakhtiyar Orazbayev**, *Public University of Navarre, Spain* **Miguel Beruete**, *Public University of Navarre, Spain* **Irina Khromova**, *King's College London, United Kingdom* This work presents the designs of tunable mid-infrared (MIR) beam steering devices based on multilayer graphene-dielectric metamaterials. A tunable beam steering is achieved by changing the chemical potential of each graphene layer and, therefore, the effective refractive index of the metamaterial. Three different beam steerer concepts with a wide range of output angles (up to approximately 70°) are discussed. The proposed graphene-based tunable beam steering can be used in tunable transmitter/receiver modules for infrared imaging and sensing.
15:15	**Ensembles of Polaritonic Rods: Toroidal Modes and Evolution with Rod Separation** **Anna Tasolamprou**, *IESL - FORTH, Greece* **Odysseas Tsilipakos**, *IESL-FORTH, Greece* **Maria Kafesaki**, *IESL-FORTH & Department of Materials Science and Technology, University of Crete, Greece* **Costas Soukoulis**, *IESL-FORTH & Ames Laboratory and Department of Physics and Astronomy, Iowa State University, Greece & USA* **Eleftherios Economou**, *IESL - FORTH & Department of Physics, University of Crete, Greece* The optical modes supported by ensembles of	**Shape Memory Plasmonic Metamaterial** **Masanori Tsuruta**, *University of Southampton, UK* **João Valente**, *University of Southampton, UK* **Behrad Gholipour**, *University of Southampton, UK* **Kevin F. MacDonald**, *University of Southampton, UK* **Eric Plum**, *University of Southampton, UK* **Nikolay I. Zheludev**, *University of Southampton, UK* We demonstrate the first shape-memory-alloy-based reconfigurable metamaterial. The structural elements of such metamaterials deform with hysteresis in response to heating and cooling, resulting in non-volatile switching of the shape memory metamaterial's optical properties.	**Complex Media for Optical Manipulation: A Graded-index Optical Dimer** **Alireza Akbarzadeh**, *Institute of Electronic Structure and Laser, Foundation for Research & Technology-Hellas, Greece* **Thomas Koschny**, *Ames Laboratory and Department of Physics and Astronomy, Iowa State University, USA* **Maria Kafesaki**, *Institute of Electronic Structure and Laser, Foundation for Research & Technology-Hellas, Greece* **Eleftherios Economou**, *Institute of Electronic Structure and Laser, Foundation for Research & Technology-Hellas, Greece*

	polaritonic rods with toroidal topology are thoroughly investigated. In each case, the toroidal mode is identified and the evolution of mode frequencies with rod separation is examined. The study is conducted by means of finite-element based eigenvalue simulations, complemented with coupled mode theory.		**Costas Soukoulis**, *Ames Laboratory and Department of Physics and Astronomy, Iowa State University, USA* We present an optical dimer consisting of two graded-index lenses. We determine the lens profiles and we show that if they are aligned along a collimated light beam, the shining beam bonds them while they are suspended at a distance from each other. We invoke the force tracing technique to obtain the forces applied on the lenses and consequently we solve the equations of motion to verify the functionality of the dimer. Furthermore, we consider the sensitivity of the designed dimer to the lateral misalignments and we show that the restoring forces stabilize the dimer. Different features of the dimer and the detailed analysis accompanied by the time-flying animations will be illustrated. The introduced dimer is a viable setup which can be employed for various practical purposes such as particle trapping, sensing and imaging.
15:30	**All-dielectric Toroidal Metamaterials Based on Water** **Ivan Stenishchev**, *National University of Science and Technology MISiS, Russia* **Alexey Basharin**, *National University of Science and Technology MISiS, Russia* We theoretically and experimentally demonstrate in microwave frequency range toroidal dipole response in metamaterials based on clusters of cylindrical particles. Instead of expensive ceramic elements in experiment we used distilled water whose permittivity at room temperature is about 80, while the dielectric loss tangent is not large at frequencies up to 4 GHz.	**Replacing Metals with Alternative Plasmonic Substances in Plasmonics and Metamaterials: is it a good idea?** Invited **Jacob Khurgin**, *Johns Hopkins University, USA* Metals, which dominate the fields of plasmonics and metamaterials suffer from large ohmic losses. New plasmonic materials, such as doped oxides and nitrides, have smaller material loss, and using them in place of metals carries a promise of reduced-loss plasmonic and metamaterial structures, with sharper resonances and higher field concentration. This promise is put to a rigorous analytical test in this work and it is revealed that having low material loss is not sufficient to have a reduced modal loss in plasmonic structures, unless the plasma frequency is significantly higher than the operational frequency. Using examples of nanoparticle plasmons and gap plasmons one comes to the conclusion that even in the mid-infrared spectrum metals continue to hold advantage over the alternative media. The new materials may still find application niche where the high absorption loss is beneficial, e.g. in medicine and thermal photovoltaics.	**~~New Material Platforms and Metasurface Designs for Quantum Nanophotonics~~** Invited Withdrawn **Vladimir M. Shalaev**, *Purdue University, USA* **Mikhail Y. Shalaginov**, *Purdue University, USA* **Simeon Bogdanov**, *Purdue University, USA* **Rohith Chandrasekar**, *Purdue University, USA* **Zhuoxian Wang**, *Purdue University, USA* **Vadim V. Vorobyov**, *Russian Quantum Center, Russia* **Jing Liu**, *South Dakota School of Mines & Technology, USA* **Xiangeng Meng**, *Purdue University, USA* **Alexei S. Lagutchev**, *Purdue University, USA* **Alexander V. Kildishev**, *Purdue University, USA* **Joseph Irudayaraj**, *Purdue University, USA* **Alexandra Boltasseva**, *Purdue University, USA* **Alexey V. Akimov**, *Texas A&M University, USA* Building integrated optical interfaces for quantum systems is a challenging task in the field of quantum photonics. In this talk, we present our recent progress in controlling the emission properties of nitrogen-vacancy centers in nanodiamonds using hyperbolic metamaterials. Further, we discuss how Purcell enhancement of the optical transition affects the optical readout of the NV center spin-state. These findings can be helpful for engineering integrated quantum registers with room-temperature operation. We propose hyperbolic metasurfaces as the next generation of plasmonic light-matter interface for quantum emitters.
15:45	**Extremely High Q-Factor Toroidal Metamaterials** **Alexey Basharin**, *National University of Science and Technology MISIS, Russia* **Vitaliy Chuguevskiy**, *Voronezh state technical University, Russia* **Nikita Volsky**, *National University of Science and Technology MISIS, Russia* **Maria Kafesaki**, *Foundation for Research and Technology Hellas (FORTH), and University of Crete, Greece* **Eleftherios Economou**, *Foundation for Research and Technology Hellas (FORTH), and University of Crete, Greece* **Alexey Ustinov**, *National University of Science and*		

	Technology MISIS, Physikalisches Institut, Karlsruhe Institute of Technology, Russia, Germany We demonstrate that, owing to the unique topology of the toroidal dipolar mode, its electric/magnetic field can be spatially confined within subwavelength, externally accessible regions of the metamolecules, which makes the toroidal planar metamaterials a viable platform for high Q-factor resonators due to interfering toroidal and other dipolar modes in metamolecules.		Finally, we present our recent advances in constructing nanolaser systems based on hyperbolic media.
16:00-16:30	**Coffee Break**		
Oral Sessions (Thursday 22 – Afternoon 2)			
16:30-18:00	**Oral session Th4-A** **Antennas, from microwaves to optics** Chair: Ekaterina Shamonina	**Oral session Th4-B** **New effects** Chair: Alessio Monti	**Oral session Th4-C** **Homogenization** Chair: Stanislav Maslovski
	Imperial	**Imperial 2**	**Imperial 4**
16:30	**Microwave Metamaterial Lens Antennas and Engineering Applications** **TieJun Cui**, *Southeast university, China* Metamaterials can be used to design and realize high-performance microwave lens antennas. Here, we report several types of metamaterial lenses which could tailor the radiation features such as the far-field pattern, gain, side-lobe level, bandwidth, and beam-scanning angles with high performance. Such metamaterial lens antennas have found wide engineering applications.	**Lateral Radiative Drag forces, Caused by Electromagnetic Fluctuations Nearby a Slab of Asymmetric Anisotropic Absorbing Material: Prediction of the Effect** **Igor Nefedov**, *Aalto University, Finland* New effect of lateral drag forces, appeared due to fluctuations of electromagnetic field near a flat interface of unmoved finite-thickness layer of absorbing anisotropic medium, is predicted. Anisotropy axis has to be tilted with respect to the slab boundaries both of which are open. Spatial spectra of fluctuating electromagnetic fields are different for the positive and negative transverse wave vector components that results in appearance of lateral component of the Poynting vector, integrated over a whole spatial spectrum. This effect is analogous to van der Waals interaction between a small particle, moving nearby a flat absorptive surface, where the forward-backward symmetry is broken due to the particle movement. Likewise quantum, non-contact friction, appears between surfaces of two absorptive moving bodies. However, the most interesting in our case is that the drag forces appear without any external	**Locally Resonant Metamaterials Beyond Homogenization: Subwavelength Control of Waves, Slow Waves and Negative Index Media** Invited **Geoffroy Lerosey**, *Institut Langevin - CNRS & ESPCI Paris, France* We propose to consider metamaterials beyond the usual homogenization paradigm and show various applications of the approach. In particular, we prove that tailoring them locally allows a complete control of wave propagation at the deep subwavelength scales. Similarly, we demonstrate that spatially structured metamaterials - metamaterial crystals- can present amazing new properties.

		effects such as movement of a slab or a particle, as well as current excitation, just only due to electromagnetic fluctuations. This effect becomes huge for hyperbolic materials with tilted anisotropy axes.	
16:45	**Tilted Beam SLA 3D-Printed "Bull's Eye" Antenna Working at 96 GHz** **Unai Beaskoetxea**, *Public University of Navarre, Spain* **Stefano Maci**, *University of Siena, Italy* **Miguel Navarro-Cía**, *University of Birmingham, UK* **Miguel Beruete**, *Public University of Navarre, Spain* The versatility and utility of metallic corrugated leaky wave antennas have been time and again proved along several works. However, the weight of a purely metal structure can be a drawback for certain applications, such as satellite communications or similar purposes, where the employment of light devices is an essential requirement. In this work, it is demonstrated the feasibility of a 3D-printed structure which offers radiation features comparable to those presented by classical metallic antennas. Measurements and simulations show an overall good agreement, displaying a gain of 17 dB with a 3.5º beamwidth and -10 dB side lobe level at 96 GHz for an elliptical Bull's Eye antenna with a tilted beam pointing at 16.5º. Experimental and numerical results are substantiated by the theoretical analysis of optimum off-axis beaming and a step-by-step design and manufacturing procedure.	**Novel Lasers Based on Resonant Dark States** **Sotiris Droulias**, *Institute of Electronic Structure and Laser, Foundation for Research and Technology Hellas, Greece* **Aditya Jain**, *Ames Laboratory and Department of Physics and Astronomy, Iowa State University, USA* **Thomas Koschny**, *Ames Laboratory and Department of Physics and Astronomy, Iowa State University, USA* **Costas M. Soukoulis**, *Ames Laboratory and Department of Physics and Astronomy, Iowa State University, USA* We propose a metamaterial laser system in which the Q factor is controlled independently of the energy storage mechanism and, hence, coupling of the oscillating mode energy to radiation can be tuned at will. Our proposed system offers many other features, such as directionality, subwavelength integration and simple layer-by-layer fabrication.	
17:00	**Nanoresotron – Novel Concept of Optical Nanoantenna Excitation Through the Dissipative Instability of DC Current** **Igor Smetanin**, *P. N. Lebedev Physical Institute, Russia* **Alexander Bouhelier**, *Laboratoire Interdisciplinaire Carnot de Bourgogne, Université Bourgogne Franche-Comte, France* **Igor Protsenko**, *P. N. Lebedev Physical Institute, RussiaAlexander Uskov, P. N. Lebedev Physical Institute, ITMO University, Russia* We propose a novel physical mechanism for the excitation of optical nanoantenna which utilizes the dissipative instability of DC electric current in the quantum well. Realization of this approach in nanoplasmonics can lead to a new device – nanoresotron.	**Conjugately-Matched Uniaxial Metamaterials Make Extremely Efficient Absorbers, Emitters, and Reflectors** **Costas Valagiannopoulos**, *Nazarbayev University, Kazakhstan* **Constantin Simovski**, *Aalto University, Finland* **Sergei Tretyakov**, *Aalto University, Finland* The speed with which electromagnetic energy can be wirelessly transferred from a source to the user is a crucial parameter for performance of a large number of electronic and photonic devices. In this presentation we determine the constituent parameters of a medium which supports theoretically infinite energy concentration close to a medium sample surface; such a material combines properties of Perfectly Matched Layers (PML) and Double-Negative (DNG) media. It realizes conjugate	**Nonlocality in Uniaxially Polarizable Media and Cubic Metamaterials** **Pavel Belov**, *ITMO University, Russia* **Maxim Gorlach**, *ITMO University, Russia* We highlight the impact of spatial dispersion effects on metamaterials electromagnetic properties. We revisit the problem of artificial magnetism in uniaxially polarizable media and prove that such structures can not be consistently described in terms of local permittivity and permeability tensors. Furthermore, we discuss the phenomenon of spatial-dispersioninduced birefringence inmetamaterialswith cubic symmetry and compare themeasuredmagnitude of the effect with that known for natural crystals. Our results suggest that spatial dispersion in metamaterials turns out to be much more pronounced than in natural materials.

		matching with free space for every possible mode including, most importantly, all evanescent modes. We show that extremely high-amplitude resonating fields in the vicinity of a conjugately matched body can create large far-field radiation with the use of randomly placed particles which play the role of emission "vessels".	
17:15	**Modeling Holographic Metamaterial Antennas in a Planar Waveguide Using the Discrete Dipole Approximation** **Patrick Bowen**, *Duke University, USA* **Erik Shipton**, *Kymeta Corporation, USA* *Adam Bily, USA* **David Smith**, *Duke University, USA* **Nathan Kundtz**, *Kymeta Corporation, USA* We develop an approach to modeling holographic metamaterial antennas coupled to a planar waveguide feed structure using the Discrete Dipole Approximation. This fast and accurate approach offers many advantages over modeling the metamaterial as a homogenized material, and is validated against full-wave simulations.	**Quantum Many-Body Theory of Nonlocal Electromagnetic Response at a Planar Metallo-Dielectric Interface** **Fouad Ballout**, *Imperial College London, UK* **Joachim M. Hamm**, *Imperial College London, UK* **Ortwin Hess**, *Imperial College London, UK* We present on the basis of the jellium model a quantum field theory of surface-plasmon polaritons (SPPs) in which they emerge as extended objects as a result of an inhomogeneous condensation of bosons around a topological singularity describing the surface. The benefit of this approach lies in relating the electromagnetic fields belonging to such a macroscopic quantum state with the surface topology and nonlocal response function (i.e. the retarded photon self-energy) of the delimited electron gas sustaining that state.	**On the Deviation of Metamaterial Spheres from Effective Medium** **Mikhail Lapine**, *University of Technology Sydney, Australia* **Christopher Poulton**, *University of Technology Sydney, Australia* **Ross McPhedran**, *University of Sydney, Australia* We analyse convergence of actual properties of finite subwavelength metamaterial samples towards effective medium predictions. We show that the convergence is rather slow and it is likely that hundreds of thousands of individual meta-atoms must be assembled for matching the properties of the resulting structure to those of a bulk material.
17:30	**Metasurfaces for Perfect and Full Control of Refraction and Reflection** **Viktar Asadchy**, *Aalto University, Finland* **Mohammad Albooyeh**, *Aalto University, Finland* **Svetlana Tcvetkova**, *Aalto University, Finland* **Younes Ra'di**, *Aalto University and University of Michigan, Finland and USA* **Sergei Tretyakov**, *Aalto University, Finland* In this talk we present and discuss a new general approach to the synthesis of metasurfaces for full control of transmitted and reflected fields. The method is based on the use of an equivalent impedance matrix which connects the tangential field components at the two sides on the metasurface. Finding the impedance matrix components, we are able to synthesise metasurfaces which perfectly realize the desired response. We will explain possible alternative physical realizations and reveal the crucial role of bianisotropic coupling to achieve full control of transmission through perfectly matched metasurfaces. This abstract summarizes our results on metasurfaces for perfect refraction into an	**Spacetime Metamaterial Engineering** Invited **Christophe Caloz**, *Polytechnique Montréal, Canada* The paper presents recent metamaterial developments in the author's group. These developments are presented in a holistic perspective where novel direct or/and inverse space or/and time bianisotropic metamaterial properties are shown to enable unprecedented devices. Seven distinct classes of metamaterial structures and applications are described.	**A Local Thickness Dependent Permittivity Model for Nonlocal Bounded Wire Medium Structures** **Maziar Hedayati**, *University of Mississippi, USA* **Alexander B. Yakovlev**, *University of Mississippi, USA* **Mario G. Silveirinha**, *University of Lisbon, Portugal* **George W. Hanson**, *University of Wisconsin-Milwaukee, USA* A thickness dependent permittivity is derived in closed form for bounded wire-medium structures with electrically short wires. The model takes into account spatial dispersion (as an average per length of the wires) and the effect of the boundary. The thickness dependent permittivity is comprised of local bulk and boundary dependent terms, the latter including the effect of spatial nonlocality. The results are obtained for different electrically short wire-medium topologies which possess strong spatial dispersion, demonstrating good agreement with nonlocal homogenization model results.

	arbitrary direction.		
17:45	**Metasurfaces with Engineered Reflection and Transmission: Optimal Designs through Coupled-Mode Analysis** **Dimitrios Sounas**, *The University of Texas at Austin, USA* **Nasim Mohammadi Estakhri**, *The University of Texas at Austin, USA* **Andrea Alu**, *The University of Texas at Austin, USA* We develop an alternative description to surface impedance for gradient metasurfaces based on coupled-mode theory and provide an explanation for the large bandwidth of such structures. Our theory shows that broadband anomalous reflection and transmission, does not necessarily require the use of spatial gradients, but they can be achieved through suitably designed periodic arrays of resonant particles. In addition to their theoretical importance, our results can be important for the design of efficient metasurfaces with specified frequency response.		**Circuit Modeling of Nonlocal Bounded Wire-Medium Structures** **Maziar Hedayati**, *University of Mississippi, USA* **Alexander B. Yakovlev**, *University of Mississippi, USA* **Mario G. Silveirinha**, *University of Lisbon, Portugal* **George W. Hanson**, *University of Wisconsin-Milwaukee, USA* A circuit model is presented for nonlocal wire-medium (WM) structures with a new type of local permittivity (thickness dependent permittivity). This local permittivity is derived in closed form for bounded wire-medium structures with electrically short wires that takes into account spatial dispersion (as an average per length of the wires) and the effect of the boundary. The results are obtained in terms of the transmission/reflection response of the two-sided WM topologies which possess strong spatial dispersion, demonstrating good agreement with nonlocal homogenization model results.
18:00-18:30	***Closing Cerenomy***		

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