ROME, 16-21 SEPTEMBER 2019

METAMATERIALS

13TH INTERNATIONAL CONGRESS ON

ARTIFICIAL MATERIALS FOR NOVEL WAVE PHENOMENA

ROMA TRE UNIVERSITÀ DEGLI STUDI

UNIVERSITÀ NICCOLÒ CUSANO

METAMATERIALS CONGRESS

metamorphose

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Proceedings

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President Message

It is a great honor and pleasure for me to serve the Virtual Institute for Artificial Electromagnetic Materials and Metamaterials (METAMORPHOSE VI) as the new President. Our institute spun off several years ago, when I was still a graduate student, from a European collaboration among the leaders of the metamaterials community. As a student in Rome at that time, I have fond memories of the early stages of this society, and its roots into a series of earlier engaging activities in the research areas of chiral and bianisotropic materials. Originally led by Prof. S. Tretyakov, and then by Prof. F. Bilotti, over the years our institute has nicely evolved into the professional society of reference in the field of metamaterials, bringing together the leading groups in the field, and driving the evolution of our technical activities, from being mostly focused on electromagnetic, low-frequency artificial materials, to a diverse and multi-disciplinary society with interests spanning from nano-optics to acoustics, from radio-frequencies to mechanics and even seismic and matter waves.

Our institute is proud to sponsor since its inception the leading conference in the field, now at its 13th edition, the International Conference on Artificial Materials for Novel Wave Phenomena, and a series of doctoral Schools on Metamaterials, that have been setting the page for the next generation of scientists interested in entering this exciting field of science. It is the first time that the President of our Institute is based outside of Europe, and next year our Conference will also be hosted for the first time in North America. The hope is to extend the boundaries of Metamorphose beyond Europe, engaging more actively the strong metamaterials communities in America, Asia and in other parts of the world, and connect them in stronger terms with the many activities in Europe. I look forward to working with the past Presidents, following their footsteps, and with all of you to further grow our society and steer it in new directions to reflect the evolution of this exciting field of science and technology. I am very honored to serve this active scientific community in this role, and I hope to contribute to the next steps of its growth. I wish you an exciting conference in Rome, and look forward to seeing all of you next year in New York.

Andrea Alù
Metamorphose VI
president

Preface

On behalf of the Technical Program Committee (TPC), it is my great pleasure to welcome you to the 2019 edition of the Metamaterials Congress and to outline its technical program. The Congress has established itself as one of the premiere international and interdisciplinary forums on metamaterials and metasurfaces. Today it not only comprises the latest results from microwaves and optics, but also from acoustics, (quantum) mechanics, and transport.

The technical sessions are structured along four parallel tracks, which have been formed on the basis of a total of 317 submissions. The tracks comprise 53 invited talks, 17 (upgraded) extended oral talks, and 164 regular oral talks. Integrated into these tracks are special symposia on “metamaterials and electromagnetic heat transport”, “metamaterials for life science applications”, “time-varying metamaterials”, “topological band gaps in metamaterials”, as well as a Physical Review symposium. These oral sessions will be complemented by a poster session with 72 presentations. Each morning of the four Congress days will begin with a plenary presentation given by a distinguished leader in the field. This year, we are fortunate to welcome (in the sequence of appearance) Chiara Daraio, Emil Prodan, Daniel Sievenpiper, and Isabelle Staude.

I should like to take this opportunity to thank all the TPC members listed on the Congress website for their hard work and dedication to the Congress. Furthermore, I should like to thank all of the 53 reviewers, who provided their reports within the tight deadline imposed by the Congress schedule.

I wish you all a pleasant and fruitful stay in Rome.

Martin Wegener
Chair of the Technical
Program Committee

Welcome Message

On behalf of the Local Organizing Committee, it is my great pleasure to wish you a warm welcome to the 13th International Congress on Artificial Materials for Novel Wave Phenomena, co-organised by the Virtual Institute for Artificial Electromagnetic Materials and Metamaterials (METAMORPHOSE VI), "Roma Tre" University and "Niccolò Cusano" University. We are very honoured to again host the Conference in Rome, twelve years after the memorable inaugural edition dated back to 2007. Over these years, the Metamaterials' Congress series has crossed its original boundaries and established itself as the leading and natural forum for a broad class of scientists working on artificial materials and their applications in electromagnetism/optics, acoustics/mechanics, transport, and multi-physics.

Welcome to the Eternal City, one of the cradles of Western civilization. The venue of this Conference edition is about 10 minutes far from some of the most important attractions, such as the Vatican City, Mausoleum of Hadrian, Trevi Fountain, and Colosseum.

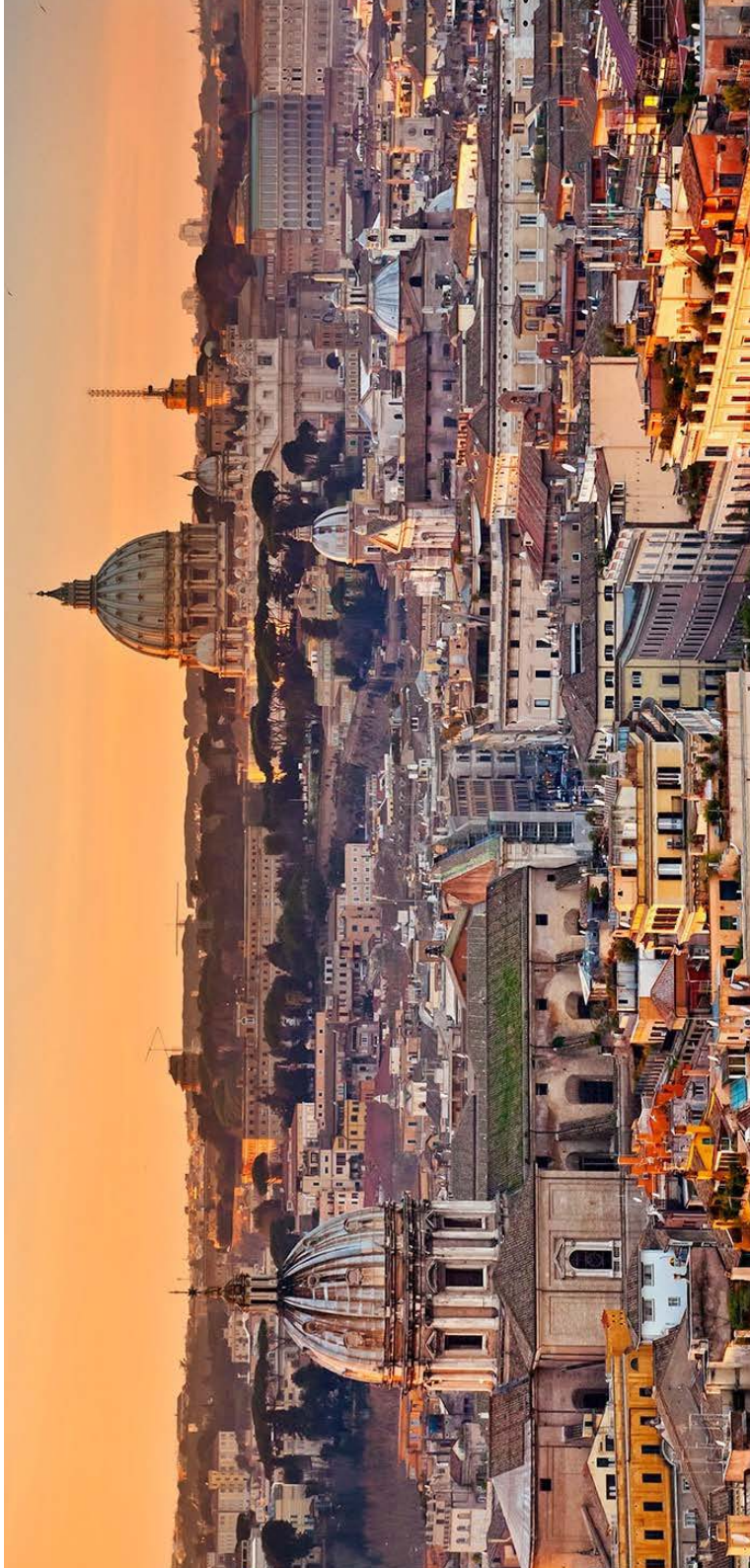
The Technical Program Committee has prepared an exciting programme including plenary, invited, oral, and poster presentations selected on the basis of novelty and importance. Scientific workshops and training sessions are also scheduled during the Conference days.

As usual, the Conference is followed by another exciting edition of the European Doctoral School on Metamaterials where pioneers and leading experts in metamaterials will discuss some of the latest advancements of this ever expanding research field. The school, hosted by "Niccolò Cusano" University, is focused on emerging engineered artificial materials whose electromagnetic, optical, and acoustic properties are dynamically controlled in space, time, and phase.

All the Congress delegates are invited to join the welcome reception that will take place on Monday 16th September at the Congress venue, right after the end of the sessions. Take a chance to enjoy a friendly atmosphere, meeting old friends, and creating new contacts. The Congress Dinner will take place on Wednesday 18th September at Villa dei Quintili, a magnificent historical residence with 200 years of history. The tickets for the Social Dinner are still available at the registration desk.

Finally, I would like to express my sincere gratitude to the two successive Presidents of Metamorphose VI, Profs. Filiberto Bilotti and Andrea Alù, and to the TPC Chair, Prof. Martin Wegener, for their invaluable and continuous support. I would also like to thank all our sponsors, exhibitors, committee members, colleagues and friends who have helped with the Congress organisation and make this edition possible.

Alessio Monti,
General Chair



PROGRAM

Monday 16 September

8:30 Registration

8:45 Opening ceremony

9:00 Plenary Session I

10:00 Coffee

10:30

A1	B1	C1	D1
Ss: Topological band gaps in metamaterials I	Ss: Metamaterials and electromagnetic heat transport II	Active and Non-Hermitian systems	Antenna and absorber applications I

12:30 Lunch

14:00

A2	B2	C2	D2
Plasmonics I	RF and microwave metamaterials I	Fabrication and experiment I	Transformational approaches

15:30 Coffee

16:00

A3	B3	C3	D3
Ss: Topological band gaps in metamaterials II	Acoustical and mechanical metamaterials I	Non-linear, tunable and reconfigurable metamaterials I	RF and microwave metamaterials II

18:00 Special Event and Welcome Reception

20:00

Tuesday 17 September

Plenary Session II

Coffee

A4	B4	C4	D4
Ss: Time-varying metamaterials I	Ss: Metamaterials and electromagnetic heat transport II	Optical metamaterials I	Antenna and absorber applications of metamaterials II

Lunch

A5	B5	C5	
Optical metrology and imaging	Chiral and bianisotropic metamaterials	Ss: Metamaterials for life-science applications I	

Coffee

A6	B6	C6	D6
Plasmonics II	Acoustical and mechanical metamaterials II	Physical Review Journals Symposium	Modelling I

Meet-and-greet the Physical Review

19:00

Wednesday 18 September

9:00 Plenary Session III

10:00 Coffee

10:30

A7	B7	C7	D7
Ss: Topological band gaps in metamaterials III	Non-linear, tunable and reconfigurable MTM II	Millimetre wave and microwave metamaterials	Homogenization

12:30 Lunch

14:00 Coffee + POSTER SESSION

15:30 Coffee

16:00

A8		C8	D8
Ss: Ttopological band gaps in metamaterials IV		Non-reciprocal metamaterials I	Optical metamaterials II

17:30

18:00

18:30

19:00 Gala Dinner

22:30

Thursday 19 September

Plenary session IV

Coffee

A9	B9	C9	D9
Ss: Time-varying metamaterials II	Acoustical and mechanical metamaterials III	Cloaking	Ss: Metamaterials for life-science applications II

Lunch

A10	B10	C10	D10
Fabrication and experiment II	Non-reciprocal metamaterials II	Extreme parameters	Modelling II

Coffee

A11	B11	C11	D11
Plasmonics III	Ss: Time-varying metamaterials III	Acoustical and mechanical metamaterials IV	Optical metamaterials III

Closing Ceremony

MONDAY

8:30 Registration

8:45 Opening ceremony
Hall: A

9:00 Plenary session I

10:00 Coffee

	Hall A	Hall B	Hall C	Hall D
10:30	A1	B1	C1	D1
	Special session: Topological band gaps in meta-materials I	*Special session: Meta-materials and electro-magnetic heat transport I*	*Active and Non-Hermitian systems*	*Antenna and absorber applications*

12:30 Lunch

14:00	A2	B2	C2	D2
	Plasmonics I	*RF and microwave meta-materials I*	*Fabrication and experiment I*	*Transformational approaches*

15:30 Coffee

16:00	A3	B3	C3	D3
	Special session: Topological band gaps in meta-materials II	*Acoustical and mechanical meta-materials I*	*Non-linear, tunable and reconfigurable meta-materials I*	*RF and microwave meta-materials II*

18:00 Special Event and Welcome Reception
20:00

Plenary session I

Hall: A **Chair:** Martin Wegener

9:00 Bulk-Boundary Correspondence in Periodic, Disordered and Aperiodic Topological Meta-Materials

Emil Prodan
Yeshiva University, New York (USA)

Quite often, the bulk-boundary principle is formulated as the emergence of topological boundary modes when a topological meta-material is cut in half. A principle, however, becomes useful when it contains the mechanism that explains the observations made in the statement. Surprisingly, not many are aware that such formulation of the bulk-boundary principle is in fact available. It goes as follows: For each class of the periodic table of topological phases, one can explicitly define a bulk as well as a boundary topological invariant and the two are equal. This statement is applied as it follows: Since the boundary invariant is computed from the boundary modes, a non-zero value of the bulk invariant automatically implies the existence of the boundary modes, because otherwise the boundary invariant, hence also the bulk one, will be zero. In this talk I will demonstrate with plenty of examples how this principle works for the traditional classes of topological meta-materials and how one can easily extend the principle in new settings, such those of quasi-periodic and quasi-crystalline meta-materials .

A1 Special session: Topological band gaps in metamaterials

Hall: A **Chairs:** Francesco Monticone

10:30 Odd elasticity (Invited)

Vincenzo Vitelli [The James Franck Institute, USA]

Hooke's law states that the forces or stresses experienced by an elastic object are proportional to the applied deformations or strains. The number of coefficients of proportionality between stress and strain, i.e., the elastic moduli, is constrained by energy conservation. In this talk, we lift this restriction and generalize linear elasticity to active media with non-conservative microscopic interactions that violate mechanical reciprocity. This generalized framework, which we dub odd elasticity, reveals that two additional moduli can exist in a two-dimensional isotropic solid with active bonds. Such an odd-elastic solid can be regarded as a distributed engine: work is locally extracted, or injected, during quasi-static cycles of deformation. Using continuum equations, coarse-grained microscopic models, and numerical simulations, we uncover phenomena ranging from activity-induced auxetic behavior to wave propagation powered by self-sustained active elastic cycles. Besides providing insights beyond existing hydrodynamic theories of active solids, odd elasticity suggests design principles for emergent autonomous materials.

11:00 New Phases of Matter Observed with Architectured Materials: From Higher-Order Topological Insulators to Chiral Landau Levels for Phonons (Invited)

Sebastian Huber, Valerio Peri, Marc Serra-Garcia, Roman Süsstrunk, Tom Larsen, Luis G. Villanueva, Osama R. Bilal, and Roni Ilan [ETH Zurich and EPF Lausanne, Switzerland, and Caltech, USA, and Tel Aviv University, Israel]

Phonons can serve two interesting purposes. On hand, we can design materials with interesting functionalities such as waveguiding, tailored thermal transport or the processing of classical and quantum information. On the other hand, the high control over fabrication allows us to explore new phases of matter in an efficient way. Here, we are are presenting recent results where we observed the first higher order topological insulator and made use of concepts from high-energy particle physics to create a three-dimensional uni-directional channel.

11:30 Resonant Laser-Beam Scanner based on Topologically Protected Twist Edge-States of Three-Dimensional Chiral Metamaterials

Julian Köpfler, Tobias Frenzel, Muamer Kadic, Jörg Schmalian, and Martin Wegener [Karlsruhe Institute of Technology, Germany, and Université de Bourgogne Franche-Comté, France]

We design a chain of alternating three-dimensional (3D) chiral elastic microstructure cells. The finite chain exhibits topologically protected and hence robust twist edge-states. The arrangement can be used as a scalable resonant mechanical laser-beam scanner.

11:45 A Two-Dimensional Su-Schrieffer-Heeger Acoustic Network: Experimental Observation of Topological Edge Waves

Liyang Zheng [LAUM, France]

We demonstrate experimentally and theoretically an acoustic realisation of 2D SSH model in a simple network. A discrete model is developed to study the sound wave propagation, which leads to the 2D SSH Hamiltonian. By designing an acoustic network, we experimentally observe the existence of topological edge waves.

12:00 Topological Edge Modes And Elastic Wave Pumping Leveraging Phononics Waveguides

Emanuele Riva, Matheus Inguaggiato Nora Rosa , Massimo Ruzzene , and Gabriele Cazzulani [Politecnico di Milano, Italy, and Georgia Institute of Technology, USA]

In this manuscript we report topological pumping in spatially modulated plates. We show that topological edge modes are supported at one boundary, depending on the modulation phase. When this parameter is varied along the second dimension, the edge state transforms from left to right localized, therefore pumping energy from one edge to the other.

12:15 Feedback Induced Robotic Topological Insulator

Ananya Ghatak [University of Amsterdam, Netherlands]

We investigate topological behaviour of a staggered 1-D mass-spring chain added to some external feedback. This type of staggered mass-spring system generally known as Kane-Lubensky (KL) chain and can show topology. With the feedback, the classical system mimics a non-Hermitian quantum system which is of special interest as such systems govern new and exotic physical properties which may or may not have direct analogues in the Hermitian counterparts. We see that the feedback induced KL-chain shows new exotic topological phases which. With the increasing feedback strength, the end states (topological states) switches from left to right and then again right left side on the chain owing to some robotic emergence. This switching is also indicated by the different winding properties of eigenvalues and/or eigenfunctions of the system in its quantum analogue. Our model is simple and can be directly studied in laboratories.

B1 Special session:
Metamaterials and electromagnetic heat transport I

Hall: B **Chairs:** Juan Carlos Cuevas

10:30 Flying Micro-Lightsails: Optical Levitation and Propulsion of Nanostructured Ultralight Macroscopic Objects (Invited)

Ognjen Ilic, Ramon Gao, Cora Went , Artur Davoyan, Joeson Wong, William Whitney, Michelle Sherrott, Deep Jariwala, Michael D. Kelzenberg, and Harry A. Atwater [California Institute of Technology, USA]

We explore nanophotonic design of materials, thermal management, and self-stabilizing optical manipulation, levitation and propulsion of lightweight macroscopic (i.e., mm, cm, or even meter-scale) micro-lightsails via radiation pressure. We consider the materials characteristics required to realize robust, thermally stable building blocks, and find that stable trajectories for dynamic motion of macro-objects can be achieved by controlling the anisotropy of light scattering along the object surface.

11:00 Plasmonic Photodetector driven by Plasmonic Local Heat (Invited)

Wakana Kubo [Tokyo University of Agriculture and Technology, Japan]

We propose a new type of plsmonic photodetector driven by plasmonic local heat. Plasmonic photo-thermoelectric effect is one of the photoelectric conversion that plasmonic local heat is converted into electric current via Seebeck effect of a thermoelectric material.

11:30 An ultra-thin colored textile for dual-mode radiative heating (Invited)

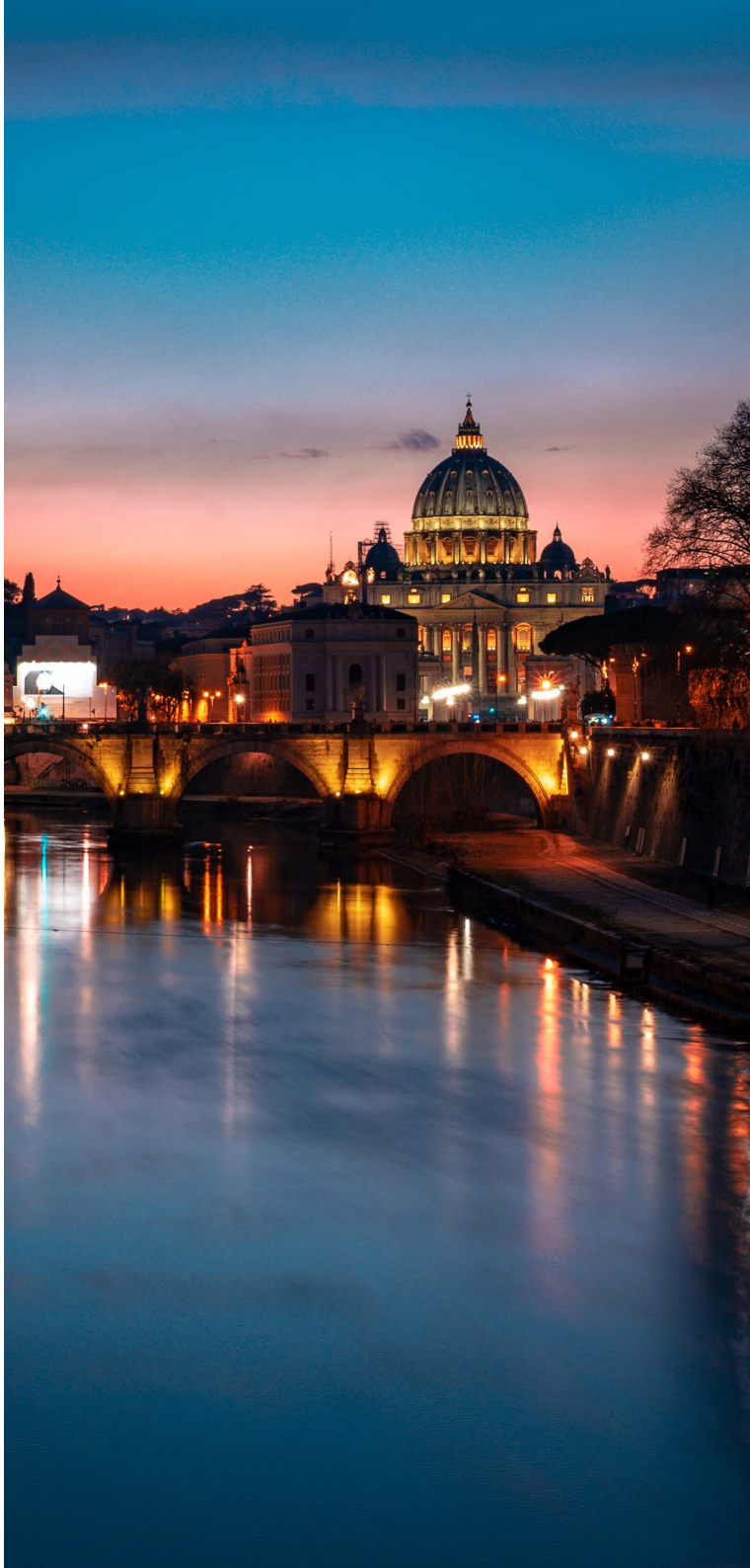
Min Qiu [Westlake University, China]

Personal thermal management, especially heating up the space around human body, consumes a huge amount of global resources. While traditional methods (such as room heaters) for personal heating are mostly energy-wasting and eco-unfriendly, ultra-thin textile with localized heating ability has recently gained significant attention. To date, passive radiative heating textiles are designed exclusively for indoor scenario and the coloration remains challenging. Herein, we report a colored nanophotonic structure textile (~16 μm thickness) with localized heating ability for both indoor and outdoor environments: (a) active heating by selectively absorbing sunlight and turning it into heat (maximum absorbance ~ 50%) and (b) passive heating by suppressing radiative heat loss with a low-emissivity outer surface (infrared emissivity ~ 10%). This textile enables a 3.8°C temperature enhancement of the artificial skin in indoor environment and a 6.3°C temperature enhancement under sunlight compared with 2-mm-thick black sweatshirt, as well as excellent aesthetics, wearability and manufacturability. This colored textile with simultaneous active and passive heating abilities is effective for personal thermal management, and paves an innovative way to the sustainable development of society.

12:00 Passive Photonic Thermostat: Radiative Thermal Management in Phase-Change Nanostructures (Extended)

Wilton Kort-Kamp , Shobita Kramadhati , Abul Azad, Matthew Reiten, Diego Dalvit [Los Alamos National Laboratory, USA]

In the last years, metasurfaces have attracted much attention due to the We propose a passive radiative thermostat based on phase-change photonic nanostructures for thermal regulation at room temperature. By self-adjusting their visible to mid-IR absorptivity and emissivity responses depending on the environment temperature, the proposed devices use the sky to cool or heat with respect to ambient, maintaining an equilibrium temperature approximately locked within the phase transition region.



C1 Active and Non-Hermitian systems

Hall: C **Chairs:** Vincenzo Galdi

10:30 Spectral Singularities in Non-Hermitian Cylindrical Geometries

Massimo Moccia, Giuseppe Castaldi, Andrea Alù and Vincenzo Galdi [University of Sannio, Italy, and University of New York, USA]

Spectral singularities are zero-width resonances associated to real-frequency poles in the scattering operator, which can occur in non-Hermitian structures characterized by suitable spatial distributions of gain and loss. Here, we study this phenomenon in connection with cylindrical structures, and address its exploitation for the tailoring and control of the scattering response.

10:45 Active Polarization and Wave Front Control of Terahertz Waves Using Graphene Metasurfaces

Haoyang Zhou [Fudan University, China]

Although metasurface has offered a new way of controlling the Terahertz (THz) waves, it is still a big challenge to achieve practical meta-devices with tunable functionalizes. Here, we present gated-controlled ultrathin graphene metasurface with switchable reflection polarization and propagating direction in the THz regime (with working frequency 0.37 THz). Such a flexible control is enabled by using meta-atoms with tunable polarization conversion rate (PCR) as the building blocks, so that both phase and polarization state of the total reflected waves can be controlled by graphene gate-voltage. Our proposal set a solid platform for the THz wave manipulation devices, and can be populated to various applications, such as active tunable meta-lenses, vortex phase plates and dynamic holography.

11:00 Scattering of Partially Coherent Radiation From PT-Symmetric 1D Periodic Structures

Solange Bessa Cavalcanti, and Paulo Brandão [Instituto de Física, Universidade Federal de Alagoas, Brazil]

In this work, we focus on studying the temporal dynamics of a V-type Recently, a new class of artificial optical materials based on media with a balance between loss an gain regions has been pursued intensely both theoretically and experimentally, due to the notion of parity-time (PT) symmetric structures, that is, a system that is invariant under the simultaneous symmetry transformations of spatial inversion and time reversal. Translated into optics, within the context of Helmholtz equation, it means that the complex refractive index satisfies the condition, $n(r) = n^*(-r)$. However, all the studies up to now have not exploited the random nature of the optical field and how it may influence the scattering process. Therefore, here, we have generalized the study of scattering of partially coherent radiation from a periodic system, to a particular one that happens to be invariant under the action of PT symmetry operation. The far-field spectral density profiles illustrate the strong dependency on the gain/loss profile of the scatterer. They exhibit partial absence of grating diffraction order when the coherence degree is high. Otherwise, i.e, in case of low coherence the diffraction order disappears.

11:15 Coherent Control of Scattering in Non-Hermitian PT-Symmetrical Systems

Zarko Sakotic, Alex Krasnok , Norbert Cselyuszka, Nikolina Jankovic, and Andrea Alú [University of Novi Sad, Serbia, and CUNY Advanced Science Research Center, USA]

Concepts of coherent perfect absorption, i.e., the time-reversed laser and coherent virtual absorption, are capable of all-optical light manipulation. In this work, we demonstrate how the concept of coherent excitation can pave the way to light scattering control in an extreme fashion in non-Hermitian PT-symmetrical systems supporting an embedded eigenstate.

11:30 Dielectric Nanoantennas And Metasurfaces With Active And Tunable Functionalities (Invited)

*Arseniy Kuznetsov [Institute of Materials Research and Engineering, A*STAR, Singapore]*

Two new paradigms in the field of dielectric nanoantennas and metasurfaces will be discussed. The first is based on active nanoantennas, made of active semiconductor materials, which can efficiently emit light and shape the emission directivity. This can be used to achieve directional nanoscale lasers and enhanced LEDs. The second is based on embedding the nanoantennas inside a tunable liquid crystal medium, which allows to dynamically tune the nanoantenna resonances and achieve dynamic wavefront control by addressing individual nanoantenna pixels.

12:00 Active Dielectric And Plasmonic Optical Antennas (Invited)

Till Leuteritz, Siqi Qiao, Manuel Peter, and Stefan Linden [BUniversität Bonn, Germany]

Optical antennas can be used to modify the radiation properties of nearby quantum emitters. Here, we demonstrate highly directional emission from dielectric optical antennas and report on fluorescence enhancement by a dark plasmon mode.

D1 Antenna and absorber applications

Hall: D **Chairs:** Alex Schuchinsky

10:30 Quasi-isotropic Huygens resonant scatterer in microwaves

Ana C. Escobar , Andrey Sayanskiy, Javier L Araque-Quijano, Stanislav B. Glybovski, and Juan D. Baena [Universidad Nacional de Colombia, Colombia, and ITMO, Russia]

We have designed two Huygens scatterers based on two laterally shifted split ring resonators. The first one acts as a Huygens scatterer under one direction of an incident plane wave, and the other is approximately independent of the relative direction of the incident electromagnetic field. The bistatic radar cross section of both scatterers is close to the one of an ideal Huygens source in a range of frequencies from 8 GHz to 9 GHz where the response of both scatterers is resonant.

10:45 High Gain Resonant Cavity Antenna Integrated with Frequency Selective Surface Radome Absorber

Subekti Ari Santoso, Sofian Hamid, Suramate Chalermwisutkul, and Dirk Heberling [The Sirindhron International Thai-German Graduate School of Engineering, King Mongkut's University of Technology North Bangkok, Thailand, and Institute High Frequency of Technology, RWTH Aachen University, Germany]

A high gain resonance cavity antenna (RCA), integrated with a frequency selective surface (FSS) radome absorber is presented. The RCA has a U-slot microstrip patch antenna (MPA) as the primary source. The cavity resonance is generated by the large ground plane and a single layer of partially reflective structure (PRS) as the superstrate, which is placed at a distance of a half-wavelength from the ground plane. The PRS consists of 12 x 12 square patch arrays. Integration with an FSS radome absorber is performed to create a high gain and low scattering functional antenna. The impact of this integration to the antenna performance is investigated. The input reflection coefficient, realized gain and radiation pattern are compared. They are relatively similar, without and with the FSS radome absorber. A slight increase in the realized gain is expected due to the contribution of the metallic FSS structure since the FSS structure is treated as the second PRS layer for the RCA in the integration.

11:00 Antenna Applications Based on Waveform-Selective Metasurfaces Varying Time-Domain Responses at the Same Frequency

Hiroki Wakatsuchi, Daiju Ushikoshi, and Suhair M. Mahmood [Nagoya Institute of Technology, Japan]

We demonstrate several examples of antenna applications using recently reported waveform-selective metasurfaces, which vary their electromagnetic responses to an incident wave even at the same frequency, depending on the waveform or pulse width.

11:15 Superdirective Antennas of Coupled Helical Elements

Pavel Petrov, Alastair Hibbins, and Roy Sambles [University of Exeter, Department of Physics and Astronomy, UK]

Using magnetically-coupled structures formed of subwavelength metallic helices, we demonstrate superdirective end-fire radiation in the low GHz frequency range. Numerical, experimental and analytical results are presented on superdirective dimers that are almost three times smaller compared to previously demonstrated dimers of split-ring-resonators (0.09λ compared with 0.25λ). Optimisation of such structures in terms of their size, directivity, efficiency and operational passband is demonstrated.

11:30 Using Passive Phase Shifters to Suppress Grating Lobes in Metasurface Antenna Arrays

Michael Boyarsky, Mohammadreza F. Imani, and David Smith [Duke University, USA]

Metasurface antennas are lightweight and low-cost electronically steered antennas. Lorentzian metamaterial elements can lead to strong grating lobes when applying traditional antenna design methods and tuning strategies. We describe how using passive phase shifters to scramble the incident phase of a series of waveguides can suppress grating lobes.

11:45 Topological Design for Antenna Pattern Shaping

Mirko Barbuto, M.-A. Miri, Andrea Alù, Filiberto Bilotti, and Alessandro Toscano [Aalto University, Finland, and Northwestern Polytechnical University, China]

Some recent works have demonstrated that phase singularities of vortex fields can find different applications at microwave frequencies. In particular, it has been shown that topological properties of phase singularity points can be used to design patch antennas with reconfigurable radiation characteristics. The aim of this contribution is to generalize the aforementioned approach and, thus, to present a general design tool for antenna pattern shaping based on topological properties of vortex modes.

12:00 Metamaterial-inspired Solution to Lackluster On-Chip Antenna Performance (Invited)

Richard Ziolkowski [University of Technology Sydney, Australia]

An electric or magnetic dipole antenna located on the interface between a low and high permittivity dielectric faces the problem that the physics tells us that the majority of the power it emits will be radiated into the high dielectric region. This effect is a significant problem for an on-chip antenna associated with systems-on-chip applications such as mobile computing and embedded systems. It is demonstrated that one can use metamaterial-inspired Huygens antennas to overcome this very practical problem.

A2 Plasmonics I

Hall: A **Chairs:** Dorota Anna Pawlak

14:00 Controlling the direction of propagation of surface plasmons via graded index effective dielectric media

Victor Pacheco Pena, and Miguel Beruete [Newcastle University,, UK, and Universidad Publica de Navarra, Spain]

We propose a mechanism to tailor surface plasmon (SP) propagation by using graded index concepts. A block of dielectric with fixed thickness is placed on top of a semi-infinite metal. The steerers are designed by changing the height of the dielectric in the direction perpendicular to the propagation axis. The analytical design is presented and several structures are evaluated with the ability to steer the incoming SP's at any desired output angle.

14:15 Babinet's Principle for Plasmonic Antennas with Electric and Magnetic Response

Vlastimil Křápek, Michal Horák, Martin Hrtoň, Andrea Konečná, Michael Stöger-Pollach, Filip Ligmajer, and Tomáš Šikola [Brno University of Technology, Czech Republic, and Materials Physics Center, Spain]

We present a study of Babinet's principle of complementarity in plasmonics. We discuss the electric and magnetic component of the near field related to solid and hollow antennas and their imaging with electron energy loss spectroscopy. Next, we combine bow-tie and diabolo duality and Babinet's principle to design antennas with electric and magnetic hot spots.

14:30 Metamaterials for All-optical Metrology with Atomic Scale Resolution (Extended)

Nikolay Zheludev, and Guang Hui Yuan [University of Southampton and NTU Singapore, UK, and Nanyang Technological University, Singapore]

We introduce "optical ruler", an electromagnetic analogue of physical ruler. It is a metamaterial structure that simultaneously generates electromagnetic field structured with singularities at the deeply sub-wavelength scale and reveals them for displacement metrology with resolution of ~ $\lambda/1000$.

15:00 Imaging Degenerate States In Plasmonic Nanoparticles With Nanometer Resolution

Viktor Myroshnychenko, Natsuki Nishio, F. Javier García de Abajo, Naoki Yamamoto, and Jens Förstner [Paderborn University, Germany, and Tokyo Institute of Technology, Japan, and ICFO-Institut de Ciencies Fotoniques, Spain]

We demonstrate that the combination of the angle- and polarization-resolved cathodoluminescence provides a powerful technique with ability to detect and image degenerate, weakly radiative, and dark localized plasmon modes in gold nanoprisms with nanometer resolution. Our approach introduces systematics for a comprehensive symmetry characterization of plasmonic states in high-symmetry nanostructures.

15:15 Influence of nonlocality in metallo-dielectric structures with high permittivity dielectrics

Antoine Moreau, Armel Pitelet, Emmanuel Centeno, Nikolai Schmitt, Claire Scheid, Dimitrios Loukresis, Herbert De Gersem, and Cristian Ciraci [Université Clermont Auvergne and INRIA and Université Nice Côte d'Azur, France, and Technische Universität Darmstadt, Germany, and Italian Institute of Technology, Italy]

Spatial dispersion in metals has an impact on many different guided modes in plas\-mo\-nics, like the gap plasmon. Most often, the hydrodynamic model is used to describe this impact. In this framework, we show that when an interface between a noble metal and a high permittivity medium is considered, the surface plasmon is actually sensitive to nonlocality. This means that nanoparticles with any size can be expected to be sensitive too, as well as metallic gratings allowing to excite such modes. We show that nonlocality can be studied and the parameters of the hydrodynamic model retrieved by considering an experiment very close to Wood's seminal experiment of the beginning of the twentieth century.

B2 RF and microwave metamaterials I

Hall: B **Chairs:** Christopher Stevens

14:00 A Meta-Material Position Sensor Based on Magneto-Inductive Waves

Jiaruo Yan, Christopher Stevens, and Ekaterina Shamonina [Oxford University, UK]

In this paper we report our first investigations of a new type of position sensor based on the propagation of metamaterial waves. Using knowledge of magnetoinductive waves in a one dimensional metamaterial we are able to unambiguously localise an object which impinges on the near field of the metamaterial structure. Key performance metrics are investigated and the ultimate range of the sensor is limited only by the metamaterial's quality factor.

14:15 Realization of Achromatic Microwave Metasurface Lenses

Ashif Aminulloh Fathnan, and David Powell [University of New South Wales, Australia]

Achromatic metasurfaces have shown promising features whereby a constant wave-manipulation function can be implemented in a wide bandwidth of operation. Despite ample works on achieving achromatism using metasurfaces, there is a question of how far a metasurface can maintain broadband constant operation. Based on common three metallic layers of a transmission-type metasurface, we previously derived a physical limit, showing that there is a trade-off relation between metasurface aperture size and bandwidth. Here, we verify these findings, using an analytical study of two different metasurface lenses.

14:30 Non-Ideal 'Negation' of Complex Load In Self-Oscillating Non-Foster Structures

Leo Vinceljl, Silvio Hrabar, and Igor Krois [Faculty of electrical engineering and computing, Zagreb, Croatia]

Recent introduction of self-oscillating non-Foster structures prompted the need of 'negation' of a complex load via Negative Impedance Converter (NIC). In the paper, we investigate conversion error of a complex network that mimics an antenna, embedded in a unit cell of a self-oscillating non-Foster metasurface.

14:45 Design of WideBand Transmission Polarization Converters

Filippo Costa, and Michele Borgese [University of Pisa and GreenWaves s.r.l., Italy]

A designing tool for wideband transmission polarization converting surfaces is presented. The optimized wideband polarizer comprises several metasurface layers whose unit cell is gradually rotated. The analysis is based on an analytical transmission line model of the multilayer structure with anisotropic elements.

15:00 Microwave Waveguides Loaded with Dielectric Metasurfaces

Dimitrios Zografopoulos, José Francisco Algorri, Antonio Ferraro , Braulio García-Cámara, José Manuel Sánchez Pena, and Romeo Beccherelli [Istituto per la Microelettronica e Microsistemi, Italy, and Carlos III University of Madrid, Spain]

We theoretically propose the concept of loading microwave waveguides with periodic arrays of dielectric elements that emulate the electromagnetic response of two-dimensional metasurfaces. It is demonstrated that parallel-plate and rectangular waveguides retain almost the same properties at the resonant frequency resonance, while the main attributes are also preserved in standard microstrip lines.

15:15 Toward Sensing and Imaging in Indoor Environments Using Dynamic Metasurface Apertures

Oren Mizrahi, Mohammadreza F. Imani , and David Smith [Duke University, USA]

We propose dynamic metasurface apertures as a novel hardware for sensing objects/events inside a room. The DMA has a single port that feed a planar cavity exciting an array of reconfigurable metamaterial radiators. It can generate a multitude of spatially distinct patterns that realizes desired spatial diversity for sensing applications.

C2 Fabrication and experiment I

Hall: C **Chairs:** Stefan Linden

14:00 Broadband Dielectric Metasurfaces Using Ceramic Stereolithography

Steve Young, Luke Szymanski, and Anthony Grbic [University of Michigan, USA]

A broadband half-wave plate is demonstrated based on cascaded alumina/air subwavelength gratings. Stacked subwavelength gratings can be well-approximated by homogeneous anistropic layers, permitting analysis by plane wave transfer matrix techniques and rapid design optimization. The example waveplate, fabricated using ceramic stereolithography, shows broadband phase performance and low loss over the Ka frequency band (26.5 -- 40 GHz). Analytic calculations show excellent agreement with measured reflection coefficients, validating the design approach.

14:15 Visualization of isofrequency contours of guided modes in all-dielectric hyperbolic-likemetasurface

Dmitry Pidgayko, Ivan Sinev, Dmitry Permyakov$, Stanyslav Sychev, Frank Heyroth, Viktoriia Rutckaia, Joerg Schilling, Andrei Lavrinenko, Andrey Bogdanov, and Anton Samusev [ITMO University, Russia, and Martin Luther University Halle-Wittenberg, Germany,and Technical University of Denmark, Denmark]

It is reported an enhancement of the transverse magneto-optical Kerr effect We designed a SOI-based all-dielectric anisotropic metasurface which supports both hyperbolic-like and elliptic dispersion regimes of guided modes. We employ back focal plane microscope with solid immersion lens for visualization of isofrequency contours in visible and near infrared ranges and reconstruct the full dispersion.

14:30 Imaging of High-Frequency Motion in Artificial Nanostructures

Tongjun Liu, Jun-Yu Ou, Kevin MacDonald, and Nikolay Zheludev [University of Southampton, UK]

The development of nanomechanical photonic metamaterials and devices demands characterisation of fast movements typically picometer amplitude at MHz-GHz frequencies. Here we report on a new approach to the visualization of nanoscale movements based on the detection of secondary electrons and photons emerging from the interaction of focused electron beam with moving components of the nano-object, where the motion is activated thermally, or by external forces.

14:45 Three-Dimensional Structuring of Metasurfaces

Antonio Tricoli [Nanotechnology Research Laboratory, Australian National University, Australia]

Nanostructured materials have the potential to significantly enhance the performance of electronic devices as recently demonstrated for chemical sensors, batteries, and photodetectors. This has resulted in a gold rush toward novel applications ranging from flexible electronics to wearable nanogenerators. Despite these achievements, integration of nanomaterials in devices is challenging, and their assembly in suboptimal structures, lacking of hierarchical design, drastically limit the final performance. Here, we will present the fabrication of highly performing optical gas sensors by the multi-scale engineering of nanoparticle networks on Au metasurfaces (Figure 1). We will showcase the use of scalable and low cost synthesis approaches for the wafer-level fabrication of tailored and well-reproducible 3D morphologies of multi-functional nanoclusters. We will conclude with recent achievements [1] in the nanofabrication of semiconductor-plasmonic nanoparticle structures for localized surface plasmon resonance and chemical sensing.

15:00 3D Antennas and Metamaterials with Additive Manufacturing (Invited)

Yiannis Vardaxoglou [Symeta Research Centre, Loughborough University, UK]

This paper presents several demonstrators that utilize advanced additive manufacturing (AM) to rapidly prototype antennas, RF components for microwave and mm-wave applications. Antenna with integrated tailored permittivity dielectrics, metamaterials and high-performance ceramic materials can be fabricated by using extrusion based AM processes to realize low loss and high gain antenna systems with low material cost and time-saving manufacturing process.ut your abstract here.

D2 Transformational approaches

Hall: D **Chairs:** Muamer Kadic

14:00 Nonlocal and Non-Hermitian Transformation Optics (Invited)

Massimo Moccia, Giuseppe Castaldi, and Vincenzo Galdi [University of Sannio, Italy]

Conventional transformation optics is based on real-valued spatial coordinate transformations which cannot naturally handle nonlocal (spatial dispersion) and gain/loss ef- fects. Here, we review some recent attempts to extend the approach to engineer nonlocal and non-Hermitian effects in metamaterials.

14:30 Linear elastodynamic cloaking : A review of transformational routes (Extended)

Sebastien Guenneau, Andre Nicolet, Frederic Zolla, Andre Diatta, Martin Wegener, and Muamer Kadic [Institut Fresnel, CNRS, Aix-Marseille Université, France, and Karlsruhe Institute of Technology, Germany]

We review miscellaneous transformational proposals for elastodynamic cloaks. The seminal of work of [Milton et al., NJP 8, 248, 2006], on form invariance of the linear elasticity equations has opened new vistas in the control of mechanical vibrations in solids thanks to Willis's equations that retain their form under geometric transform. In their tracks, other proposals have been made, including cloaking via Cosserat media [Brun et al., APL 94, 061903, 2009], wherein the transformed elasticity tensor looses its minor symmetries. It has been also numerically and experimentally demonstrated that a direct lattice approach with an adiabatic transform [Bückmann et al., PNAS 112, 4930, 2015] allows for nearly perfect cloaking in the static case. The latter approach leads to good cloaking efficiency in the dynamic regime. These works pave the way towards control of mechanical vibrations ranging from ultrasonics to geophysics.

15:00 Detecting the Chirp Signals on the Surface of the Transformation Materials GRIN Lens

Jiang-chao Shi, and Jin Hu [Beijing Institute of Technology, China]

Part of the optical axis inside a conventional graded index lens is exposed to the surface with the help of transformation optics, with which the chirpiness detection can be more convenient, efficient and precise based on the optical fractional Fourier transform.

15:15 Waveguide tapering using Conformal transformation optics for ideal transmission

Hossein Eskandari, Amir Reza Attari, Mohammad Saeed Majedi, and Tomas Tyc [Ferdowsi university of Mashhad, Iran, and Masaryk University, Czech Republic]

In this paper, conformal transformation optics (TO) is employed to guide the electromagnetic wave between two waveguides with different cross-sections. Owing to the properties of conformal mapping, an all-dielectric medium is obtained. The conformal transformation is derived by solving the Laplace equation. The tapering equation is obtained by conducting an optimization to achieve maximum less-than-unity refractive index while maintaining the uniformity of the refractive index at the input and output boundaries. The functionality of the proposed idea is confirmed by a simulation in COMSOL.

A3 Special session: Topological band gaps in metamaterials II

Hall: A **Chairs:** Stefano Maci

16:00 Do Truly Unidirectional and Topological Surface Plasmon-Polaritons Exist? (Invited)

Francesco Monticone [Cornell University, USA]

In this talk, we discuss all the available physical mechanisms that may endow a homogenous plasmonic platform with directionality, the impact of nonlocality and dissipation on unidirectional surface plasmon-polaritons, and some apparent paradoxes. Our work sheds new light on the propagation properties of surface waves on nonreciprocal plasmonic materials.

16:30 Experimental Observation Of High-order Topological Corner States In 2D Photonic Kagome Lattice (Extended)

Dmitry Zhirihin, Mengyao Li, Dmitry Filonov, Xiang Ni, Alexey Slobozhanyuk, Andrea Alu, and Alexander Khanikaev [ITMO University, Russia, and The City University of New York, USA]

We designed a sensing defected bandgap microwave structure based In this paper we experimentally realize high-order photonic topological insulator as a two-dimensional triangular distorted Kagome lattice that supports two types of topological states: 1D topological edge states and 0D high-order topological states localized at the corners. Using near-field scanning technique we demonstrate both topological edge states and topological corner state in microwave frequency spectrum.

17:00 Photonic Topological Insulator Edge Modes Using All-Dielectric Kagome Photonic Crystals

Stephan Wong, Matthias Saba, Ortwin Hess, , and Sang Soon Oh [Imperial College London and Cardiff University, UK]

We propose an all-dielectric reciprocal kagome-like photonic topological insulator in which the topological edge modes do not undergo back-reflection for termination along the $Gamma {-} K$ direction. In contrast to the perturbed honeycomb, the edge modes in our kagome-based structure are below the light cone leading to improved vertical mode confinement.

17:15 Symmetry-Protected Edge Modes in Metasurface Junctions (Extended)

Enrica Martini, Mario Silveirinha, Valentina Verri, Fabio Morgia, Claudio Massagrande, Maurizio Mattivi, and Stefano Maci [Huawei Technologies Italia and University of Siena, Italy]

This contribution presents a metasurface-based guiding structure supporting an edge mode which is symmetry-protected against backscattering. It consists of the combination of two couples of semi-infinite planar surfaces with complementary impedances, arranged to form a parallel plate waveguide with mirror reflection symmetry. The particular case of PEC/PMC boundary conditions is analytically characterized and the theory is numerically validated.

17:45 Bounds on Hotspots in Unidirectional Waveguides and Photonic Topological Insulators for Strong, Broadband Light-Matter Interaction

Sander Mann, Ahmed Mekkawy, and Andrea Alù [CUNY ASRC, USA]

We investigate fundamental bounds on the field strength in nonreciprocal hotspots in both magnetically biased plasmonic waveguides and topological photonic insulators. We prove that in topological photonic insulators an output channel is always present, and demonstrate broadband and strongly enhanced second harmonic generation in a magnetically biased plasmonic waveguide.

B3 Acoustical and mechanical metamaterials I

Hall: B **Chairs:** Konstantin Tretiakov

16:00 A gyro-elastic device for cloaking of elastic waves in micro-structured materials

Michael Nieves, Marta Garau, Giorgio Carta, and Michele Brun [Keele University and Liverpool John Moores University, UK, and University of Cagliari, Italy]

The design of a structured gyro-elastic system capable of being used as a cloaking device for a discrete medium is discussed. The efficiency of the gyro-elastic cloak, composed of springs connecting periodically placed masses, attached to gyroscopic spinners, is examined in the transient regime. An important effect encountered shows that the speed of the reconstructed field can be altered by tuning the gyroscopes.

16:15 Tailoring the Size Scaling Of Periodic And Non-periodic Three-dimensional Chiral Microstructures

Patrick Ziemke, Tobias Frenzel, Martin Wegener, and Peter Gumbsch [Karlsruhe Institute of Technology, Germany]

The twist-to-strain coupling of chiral mechanical metamaterials scales asymptotically inversely proportional to the sample side length. Here, we present a threedimensional chiral crystal lattice built from two types of unit cells, which allows tailoring the onset of this asymptotic scaling over an order of magnitude. Furthermore, we present an architecture which does not show any decay of the twist.

16:30 Coherent control of mechanical states in surface-coupled phononic resonators (Invited)

Sarah Benchabane, Laetitia Raguin, Olivier Gaiffe, Roland Salut, Valérie Soumann, Jean-Marc Cote, Vincent Laude, and Abdelkrim Khelif [FEMTO-ST, CNRS, Université de Bourgogne Franche-Comté, France]

We demonstrate that interaction between mechanical resonators and surface acoustic waves (SAW) can be used to manipulate mechanical vibrations in deep sub-wavelength features. By retrieving the frequency dependence and the vectorial nature of the mechanical motion, a variety of coupling schemes are observed, opening prospects for local coherent control of mechanical vibration and SAW propagation.

17:00 Guiding Stress with Discrete Networks (Extended)

Graeme Milton, Guy Bouchitte, Ornella Mattei, and Pierre Seppecher [University of Utah, USA, and Universite de Toulon, France]

Pentamode materials are a class of materials that are useful for guiding stress. In particular, they have been proposed for acoustic cloaking by guiding stress around objects A key feature of pentamode materials is that each vertex in the material is the junction of 4 double cone elements. Thus the tension in one element determines the tension in the other elements, and by extension uniquely determines the stress in the entire metamaterial. Here we show how this key feature can be extended to discrete wire networks, supporting forces at the terminal nodes and which may have internal nodes where no forces are applied. In usual wire or cable networks, such as in a bridge or bicycle wheel, one distributes the forces by adjusting the tension in the wires. Here our discrete networks provide an alternative way of distributing the forces through the geometry of the network. In particular the network can be chosen so it is uniloadable, i.e. supports only one set of forces at the terminal nodes. Such uniloadable networks provide the natural generalization of pentamode materials to discrete networks.

17:30 Towards Vibrational Waves Via High-order Topological Invariants in Mechanical Structures (Invited)

Zeb Rocklin [Georgia Institute of Technology, USA]

The geometry of mechanical elements can induce high-order topological invariants in metamaterials. These invariants, which rely on the number of mechanical constraints, generate and protect modes of deformation localized to corners of the system.

C3 Non-linear, tunable and reconfigurable metamaterials I

Hall: C **Chairs:** Sergei Tretyakov

16:00 Optical bistability theory of film-coupled metasurfaces

Patrick Bowen, Zhiqin Huang, and David Smith [Duke University, USA]

We present an analytic treatment of bistability in metasurfaces of optical nanopatch antenna arrays that are coupled to a metal film using quasinormal modes. Collective surface effects are included through the surface plasmon mediated interaction constant, which predicts bistable surface modes in addition to bistability within the nanopatch resonance.

16:15 Optical Metamaterial Reconfigured with Sound

Dimitrios Papas, Jun-Yu Ou, Eric Plum, and Nikolay I. Zheludev [University of Southampton, UK, and Nanyang Technological University, Singapore]

We demonstrate that ultrasound vibrations cause linear and nonlinear changes of optical properties of nanomechanical metamaterials. We observe up to 73% linear acousto-optical reflectivity modulation in a metamaterial of only 100 nm thickness and substantial nonlinear acousto-optical modulation up to the sixth order.

16:30 Broadband Helicity Switching for Terahertz Waves Using Anisotropically Deformed Checkerboard Metasurface with Vanadium Dioxide

Toshihiro Nakanishi, Yosuke Nakata, Yoshiro Urade, and Kunio Okimura [Kyoto University adn The University of Tokyo and RIKEN and Tokai University, Japan]

We propose an anisotropic metasurface that works as a reconfigurable quarter wave plate for terahertz waves. The helicity of circularly polarized waves can be switched owing to vanadium dioxide introduced at the corners of deformed checkerboard patterns. The fabricated metasurface has realized helicity switching in a broad spectral range.

16:45 Optical Second Harmonic Generation in Amorphous Silicon Metamaterial

Jie Xu, Vassili Savinov, Eric Plum, and Nikolay I. Zheludev [University of Southampton, UK, and Nanyang Technological University, Singapore]

Second harmonic generation in centrosymmetric media is forbidden. However, symmetry breaking by mesoscopic structuring can introduce substantial second-order nonlinear polarizability. We report efficient optical second harmonic generation in 90nm-thick amorphous silicon metamaterial. A chevron nanopattern removes the inversion center, introducing effective second-order polarizability enhanced by a closed-mode resonance.

17:00 Second harmonic generation from resonant dielectric and metal-dielectric nanoantenna (Invited)

Mihail Petrov [ITMO University , Russia]

The generation of second harmonic from nanophotonic structures has been reconsidered recently with the emergence of subwavelength resonant non-plasmonic systems. The wide range of dielectric and semiconductor materials without central symmetry offer new opportunities to achieve high efficiency from subwavelength sources. In this work, we present a basic theoretical description of second harmonic generation from nanoparticles with bulk nonlinearity. We also show how one can enhance efficiency and manipulate the nonlinear emission with hybrid metal-dielectric nanodimers.

17:30 Second harmonic generation driven by magnetic dipole moment in dielectric nanoparticles of different shapes

Kristina Frizyuk, and Mihail Petrov [ITMO University, Russia]

In this work we suggest a technique helping to identify the selection rules in second harmonic generation from dielectric nanoparticles pumped at their magnetic dipole resonance. We present the identified mode content of the second harmonic field for nanostructures of cylindrical, cone, and prism shapes made of a material with Td and C4v symmetries. This method is applicable for finding the selection rules for arbitrary particle shapes and crystalline structures and can be expanded to other nonlinear processes.

17:45 Active Polarized Tuning of Near-field in Hybrid Metal/ Dielectric Nanostructures Upon Femtosecond Laser Reshaping

Yali Sun, and Dmitry Zuev [ITMO University, Russia]

Femtosecond laser reshaping has been proposed to tune the near-field of hybrid oligomers. Strong field enhancement has been observed by scanning near-field optical microscope after modification. A moderate and comparable shift of far-field has been verified by a confocal dark-field measurement of modified oligomers under different polarizations of laser radiation.

D3 RF and microwave metamaterials II

Hall: D **Chairs:** Silvio Hrabar

16:00 Toward Learning Optimal Task-Specific Illumination Patterns: Application to Object Classification with a Dynamic Metasurface Aperture (Extended)

Philipp del Hougne, Aaron V. Diebold, Mohammadreza F. Imani, Roarke Horstmeyer, and David R. Smith [Institut de Physique de Nice, France, and Duke University, USA]

We propose a scheme for object classification that jointly optimizes the illumination of the scene with a dynamic metasurface aperture (DMA) and the weights of the corresponding post-processing artificial neural network. Approximating the DMA's metamaterial elements as magnetic dipoles, we include the physical layer (propagation from each metamaterial element to the scene) in the classification pipeline. Our results demonstrate that tailoring the illumination to the specific classification task at hand highlights important features and considerably reduces the number of required distinct illuminations.

16:30 Left-handed metamaterials matched to free space through mechanical tuning

Juan D. Baena, Ana C. Escobar, Andrey Sayanskiy, and Stanislav B. Glybovski [Universidad Nacional de Colombia, Colombia, and ITMO, Russia]

We have proposed a unit cell with a hybridized electric-magnetic resonant mode. The electric and magnetic polarizabilities approximately match one each other in a certain frequency range around the resonance, so that the effective wave impedance matches the one of the free space. The left-handed behavior was demonstrated between 3.38 GHz and 3.59 GHz where the transmission coefficient approximately reaches 1 with negligible ripples. This fact can be interpreted as a very good impedance matching with the free space.

16:45 Quasi-Optical Excitation of Modulated Metasurface Antennas

Jorge Ruiz García, David González Ovejero, Marco Faenzi, Adham Mahmoud, Mauro Ettorre, Patrick Potier, Philippe Pouliguen, and Ronan Sauleau [Univ. Rennes and Direction Générale de l'Armement, France]

We present a new architecture for modulated metasurface (MTS) antennas with rectangular shape and fed by means of a pillbox-type quasi-optical beamformer. Two design examples are realized, the first one consists of a linearly-polarized antenna with amplitude tapering to increase the aperture efficiency, while the second one provides a circularly-polarized pencil beam. We show that the proposed structure is able to provide high aperture efficiencies similar to those already demonstrated with circular apertures. Moreover, the use of multiple sources in the focal plane allows us to introduce multi-beam capabilities.

17:00 Metamaterials for Wireless Power Transfer

Christopher Stevens [Oxford University, UK]

Wireless power transfer systems using metasurfaces as energy transfer media have been developed. Previous implementations have injected power fro one end of a one dimensional structure and carried it to a load located somewhere over that line. In this work we are looking at power transfer for energy injection at the midpoint of a 1D line as a starting point to begin describing fully two dimensional systems.

17:15 Metasurface for Extension of Wireless Power Transfer Distance

Mingzhao Song, Pavel Belov, Stanislav B. Glybovski, Constantin Simovski, and Polina Kapitanova [ITMO University, Russia, and Aalto University, Finland]

We report on a design of metasurface formed by parallel conducting wires for wireless power transfer system. The metasurface being exited by a dielectric resonator guides the power to the receiving resonator. We both numerically and experimentally demonstrate that a stable power transfer efficiency of 83% can be achieved over the distance up to 100 cm between the transmitting and receiving resonators.

17:30 Metasurface-bounded open cavities supporting virtual absorption: free-space energy accumulation in lossless systems

Angelica Viola Marini, and Davide Ramaccia [Università degli Studi Roma Tre, Italy]

The opportunities offered by energy absorbing, storing, and releasing in lossless systems are here exploited by exciting the zero-scattering condition of a metasurface-bounded open cavity. We investigate on the so-called virtual absorption condition supported by a partially open cavity, bounded by an infinite reflector and a metasurface. Starting from the theoretical analysis, we analytically find that the system exhibits a set of zeros of the scattering eigenvalues in the complex frequency plane, which correspond to the anomalous response of virtual absorption. The feasibility of the structure and its easy physical insights offered by the complex frequency analysis may enable the design of lossless systems with dynamic properties in energy.

17:45 Orbital Angular Momentum Mode Purity Study of 3D-printed Spiral Phase Plates

Dmitry Isakov, Yingwei Wu, Ben Allen, Patrick Grant, Chris Stevens, and Greg Gibbons [University of Warwick and University of Oxford,UK]

Taking advantage of computer-aided design software, additive manufacturing or 3D printing provides great flexibility in the fabrication of new devices. In this work, we benefit from 3D printing in the exploitation of the dielectric Spiral Phase Plate (SPP) generating an electromagnetic wave with helical wavefront. Three types of SPPs, with mode number l = |1| have been 3D-printed using Material Extrusion and Multi-Jetting technologies. The phase mode analysis and mode characteristics of the generated helical radio waves as a function of SPP geometrical features have been investigated through simulation and experimentally in the 12–18 GHz frequency range.

TUESDAY

9:00 **Plenary session II**

10:00 **Coffee**

	Hall A	Hall B	Hall C	Hall D
10:30	**A4**	**B4**	**C4**	**D4**
	Special session: Ttime-varying meta-materials I	*Special session: Meta-materials and electro-magnetic heat transports II*	*Optical meta-materials I*	*Antenna and absorber applications of meta-materials II*

12:30 **Lunch**

14:00	**A5**	**B5**	**C5**
	Optical metrology and imaging	*Chiral and bianisotropic meta-materials*	*Special session: Meta-materials for life-science applications I*

15:30 **Coffee**

16:00	**A6**	**B6**	**C6**	**D6**
	Plasmonics II	*Acoustical and mechanical meta-materials II*	*Special Session: Physical Review Journals Symposium*	*Modelling I*

18:00 **Meet-and-greet the Physical Review Editors**
18:30

Plenary session II

Hall: A **Chair:** Martin Wegener

9:00 Tunable, On-chip Phononic Devices Operating at MHz Frequencies

Chiara Daraio
California Institute of Technology, USA

Nanoelectromechanical systems (NEMS) that operate in the megahertz (MHz) regime allow energy transducibility between different physical domains. For example, they convert optical or electrical signals into mechanical motions and vice versa. This coupling of different physical quantities leads to frequency-tunable NEMS resonators via electromechanical non-linearities. In this talk, I will describe one- and two-dimensional, non-linear, nanoelectromechanical lattices (NEML) with active control of the frequency band dispersion in the radio-frequency domain (10–30 MHz). Our NEMLs consist of a periodic arrangement of mechanically coupled, free-standing nanomembranes with circular clamped boundaries. This design forms a flexural phononic crystal with a wide and well-defined bandgap. The application of a d.c. gate voltage creates voltage-dependent on-site potentials, which can significantly shift the frequency bands of the device. Additionally, I will discuss the experimental realization of topological nanoelectromechanical metamaterials with protected edge states. These on-chip integrated acoustic components could be used in unidirectional waveguides and compact delay lines for high-frequency signal-processing applications.

A4 Special session: Time-varying metamaterials I

Hall:A **Chairs:** Hossein Mosallaei

10:30 Time-Varying Nanoantenna Metamaterials (Invited)

Mohammad Mahdi Salary, and Hossein Mosallaei [Northeastern University, USA]

We review our progress on the area of time-varying metamaterials. We present several methodologies for realization of time-modulated metasurfaces at optical frequencies through integration of electro-optical materials into the constituent nanoantennas. Novel design principles are established for extending the degree of light manipulation in the four-dimensional design space provided by time-varying metamaterials.

11:00 Space-time Modulated Elastic Metamaterials and Their Applications in Floquet Topological Insulators (Extended)

Guoliang Huang, Yangyang Chen, Hui Chen, and Hussein Nassar [University of Missouri, USA]

Breaking reciprocity with spatiotemporal modulation provides an opportunity to design unprecedented optical, acoustic and mechanical waveguides. Here, we design a tunable space-time modulated elastic metamaterial and experimentally demonstrate non-reciprocal flexural wave propagation. A Floquet topological insulator based on the time modulated metamaterial is finally designed and topologically protected one-way edge states are numerically tested.

11:30 Comprehensive Description of Spacetime Crystal Bandgaps

Zoe-Lise Deck-Leger, and Christophe Caloz [Polytechnique Montreal, Canada]

The dispersion diagram is a graphical representation of wave scattering that summarizes the most fundamental properties of crystals: it includes all the information on the frequency dependence of the phase and group velocities and on the attenuation of the medium. Here, we provide exact formulas for the positions of spacetime-crystal bandgaps taking into account the asymmetry of the uncoupled harmonics, and unveil the complex nature of the frequencies in these bandgaps, in addition to the usual complex wavenumbers.

11:45 Wave Propagation In Space-Time Microstructures: The Theory Of Field Patterns

Ornella Mattei, Graeme Milton [University of Utah, USA]

Field patterns are a new type of wave propagating in one-dimensional linear media with moduli that vary both in space and time in a very special manner and which exhibit exotic features.

12:00 Frequency-shifted reflection achieved through time-varying metasurfaces

Davide Ramaccia, Dimitrios Sounas, Andrea Alù, Alessandro Toscano, Filiberto Bilotti ["RomaTre" university, Italy, and Wayne State University and CUNY ASRC, USA]

In this contribution, we present a time-modulated full-reflective metasurface able to realize a frequency shift of a normally impinging electromagnetic plane wave. The frequency conversion is achieved by a dynamic control of the reflection phase, which emulates the phase advance (phase delay) of the field when reflected by a scatterer moving towards (away from) the source. The metasurface consists of three layers: the first two layers are used for realizing an array of mirrored mushrooms, i.e. two metallic patches printed on the two sides of a dielectric substrate and connected by a via; the third layer is a metallic ground plane that enforces the zero transmission. The patches are loaded by a set of varactors controlled by a low-frequency time-varying voltage signal. The metasurface and biasing network are properly designed for ensuring the operation for both polarization of the illuminating plane wave. We report here our results, showing the ability of the metasurface to reflect a frequency-shifted signal according to the modulation imparted by the varactors. The proposed metasurface can be used for realizing electrically thin Doppler cloak, which can restore the source illumination frequency of a moving object, as if it were not in motion.

12:15 Mixer-Antenna Medium

Sajjad Taravati, and George V. Eleftheriades [University of Toronto, Canada]

We introduce a medium that functions simultaneously as a mixer and an antenna. Such a functionality is achieved by leveraging the unique properties of an obliquely illuminated space-time-modulated medium, supporting both propagating and surface waves. We first present the operation principle of surface-wave generation in a space-time-modulated medium and then elaborate on the incoming propagating wave being transformed into a surface wave. The theoretical analysis of the structure is supported by numerical simulation results.

B4 Special session: Metamaterials and electromagnetic heat transport II

Hall: B **Chairs:** Harry Atwater

10:30 Refractory Metasurfaces for Solar Thermophotovoltaics (Invited)

Hou-Tong Chen, Chun-Chieh Chang, Wilton Kort-Kamp, John Nogan, Ting Luk, , Abul Azad, Antoinette Taylor, Milan Sykora, and Diego Dalvit [Los Alamos National Laboratory and Sandia National Laboratories, USA]

We demonstrate tungsten-based refractory metasurfaces for solar thermophotovoltaics (STPV) with tailored absorptance and emittance characterized by in situ high-Temperature measurements, featuring thermal stability up to at least 1200 C. These metasurface structures can be fully integrated as the intermediate structure, opening a path forward for high-performance STPV systems.

11:00 Machine-Learning-Assisted Topology Optimization For Highly Efficient Thermal Emitter (Invited)

Alexandra Boltasseva, Zhaxylyk Kudyshev, Simeon Bogdanov, Alexander Kildishev, and Vladimir Shalaev [Purdue University, USA]

We coupled generative adversarial network with topology optimization for efficient thermal emitter design development. The proposed method can generate highly efficient metasurface designs with a non-trivial topology for efficient spectral control of thermal blackbody. Additionally we have shown that supervised learning algorithms can boost up identification of single-photon emitters through second-order autocorrelation function analysis as well as can be applied to single-shot spin readout process.

11:30 A Metamaterial Approach to Radiative Heat Transfer (Invited)

Juan Carlos Cuevas, Víctor Fernández-Hurtado, Edwin Moncada-Villa, Antonio I. Fernández-Domínguez, Johannes Feist, Juan José García-Esteban, Sanhui Fan, and Francisco J. García-Vidal [Universidad Autonoma de Madrid, Spain, and Universidad Pedagógica y Tecnológica de Colombia, Colombia, and Stanford University, USA]

We demonstrate tunable perfect anomalous reflection with metasurfaces incorporating lumped elements. Properly tuning the capacitance of each element allows for tilting the reflected wavefront. The performance is thoroughly assessed for both TE and TM polarization and for reflection to the first and second diffraction order.

12:00 Mid-IR Emission at High Modulation Rates with Incandescent Metasurfaces (Invited)

Jean-Jacques Greffet, Léo Wojszvzyk, Anne-Lise Coutrot, Mondher Besbes, Jean-Paul Hugonin, and Benjamin Vest [Institut d'Optique, France]

We report a numerical and experimental study of a metasurface patterned with arrays of nanowires, that reaches an emissivity close to 1 at 4.5 microns and can be operated at modulation rates up to 20 MHz.

C4 Optical metamaterials I

Hall: C **Chairs:** Francesco De Angelis

10:30 Helmholtz-like Nanoresonators Applied to Surface Enhanced Infrared Absorption

Alice Fabas, Hasnaa El Ouazzani, Jean Paul Hugonin, Riad Haïdar, Jean Jacques Greffet, and Patrick Bouchon [Université Paris Saclay, France]

Nanostructures exhibiting high electric field enhancement are very appealing for infrared spectroscopic applications. The optical Helmholtz resonator presents very high enhancement factors within hot volumes. Nevertheless, its nanofabrication is rather challenging and has hindered its practical use. Here, we introduce and study, both theoretically and experimentally, a simplified nanostructure that supports an Helmholtz-like resonance with the expected high electric field enhancement. This resonator is then applied to the SEIRA detection of 2,4-dinitrotoluene, leading to reflectivity changes up to 15%.

10:45 Extraordinary transparent metasurfaces composed of transverse scatterers

Hadi Shamkhi, Kseniia Baryshnikova, Andrey Sayanskiy, Polina Kapitanova, Pavel Terekhov, Pavel Belov, Alina Karabchevsky, Andrey Evlyukhin, Yuri Kivshar, Alexander Shalin [ITMO University, Russia, and Ben-Gurion University of the Negev, Isreal, and University of Southern Denmark, Denmark, Australian National University, Australia]

We present a novel optical effect where the scattered light on dielectric particles is suppressed simultaneously in the forward and backward directions. The metasurface constructed from such transverse scatterers is extraordinary transparent for the incident light where neither the phase nor the amplitude is perturbed.

11:00 Dual-Metasurface Superlens: Full Wave Verification of Scatterers Imaging for Practical Applications

Masoud Sharifian Mazraeh Mollaei, and Constantin Simovski [Aalto University, Finland]

A dual-metasurface superlens comprising two planar arrays of silver nanospheres dedicated to the near-field optical imaging of submicron objects is presented. Compared to previous works where we have analyzed this technique, we show the possibility of nano-imaging not for radiating sources but for scattering objects illuminated by a plane wave and refuse of the idea to suppress the horizontal polarization of nanospheres. Using both approximate semi-analytical model and full-wave simulations, we optimize the parameters of the structure and achieve the spatial resolution $\lambda/6$ at the distances slightly larger than $\lambda/2$.

11:15 All-dielectric Metalens Array for Polarimetric Beam Profiling

Zhenyu Yang, Huazhong, Ming Zhao, Huazhong, and Xiuhua Yuan, Huazhong [University of Science and Technology, China]

Here, we show a design and fabrication of all-dielectric metalens array to achieve the state of polarization and the phase gradient detection operating at 1550 nm in transmission mode. Furthermore, we demonstrate an oblique incident radially polarized beam profilling. Each metalens (numerical aperture of 0.32) has an average focusing efficiency of about 45% at 1550 nm.

11:30 How Thin Multilayer Hyperbolic Metamaterial Can Be? (Invited)

Andrei Lavrinenko, Johneph Sukham, Maryam Mahmoodi, Stanislav Sychev, Saint Petersburg Andrey Bogdanov, Seyed Hassan Tavassoli, and Radu Malureanu [Technical University of Denmark, Denmark, and Shahid Beheshti University, Iran, and National Research University of Information Technologies , Russia]

We fabricated a series of stacks with up to 10 periods of 10 nm gold – 10 nm alumina layers of exceptional quality keeping the roughness root mean square well below 1 nm. Characterization supported by modeling shows that starting from four periods, the multilayers properties are reasonably good expressed through effective medium approximation.

12:00 Photoacoustic Spectroscopy for Resonant Phenomena (Invited)

Concita Sibilia [Università di Roma La Sapienza, Italy]

Here we report on the resonant absorption properties in GaAs-based nanowires (NWs), characterized by photo-acoustic spectroscopy (PAS) measurements. NWs were fabricated by self-catalyzed, lithography-free growth on Si substrates and with highly controllable dimensions. Their diameters (~150 nm) and lengths (~5 μm) allow for the excitation of resonant absorption modes in the visible and near-IR parts of the spectrum, which results in the absorption peaks measured by PAS. Both spectral position and peak amplitudes are in great agreement with numerical predictions. Moreover, we use PAS in similar samples partially covered by Au, and we prove circular dichroic behavior at oblique incidence. The results show that this low-cost, stable, and scattering-free technique can be used to characterize, investigate and optimize the design vertical semiconductor NWs for various photonic applications.

D4 Antenna and absorber applications of metamaterials II

Hall: D **Chairs:** Richard Ziolkowski

10:30 Metamaterials for Classical and Quantum Data Processing in All-Optical Fiber Information Networks

Anton Vetlugin, Angelos Xomalis, Salih Yanıkgonul, Ruixiang Guo, Giorgio Adamo, Iosif Demirtzioglou, Yongmin Jung, Eric Plum, Cosimo Lacava, Periklis Petropoulos, David Richardson, Cesare Soci, and Nikolay Zheludev [Nanyang Technological University, Singapore, and University of Southampton, UK]

We report on the use of fiber-integrated plasmonic metamaterial absorbers in signal processing applications in coherent information networks. Quantum states filtering, perfect nonlinear absorption, all-optical gating and encrypted signal distribution are demonstrated.

10:45 Broad Terahertz Radial Perfectly Symmetric Gradient Honeycomb All-Dielectric Planar Luneburg Lens

Jin Chen, Mingji Chen, and Daining Fang [Beijing Institute of Technology, China]

We propose an all-dielectric broad terahertz planar Luneburg lens with radial gradient honeycomb structure. Exquisite microstructure in the form of radial symmetric honeycomb column within subwavelength dimension was put forward to satisfy the requirement of refractive index of Luneburg lens. The results of full-wave simulation demonstrate excellent performance of our designed lens. Far field radiation pattern of the present lens is highly directive, incident waves could be concentrated on the opposite side of the lens with high convergence, and its operating frequency spans from 0.06THz to 0.24THz. Our design has great potential to be applied in terahertz communication and imaging via the growing 3D printing technology.

11:00 Self-Adaptive Invisible Antenna Trough Waveform-Depended Mantle Cloak (Extended)

Stefano Vellucci, Alessio Monti, Mirko Barbuto, Alessandro Toscano, and Filiberto Bilotti [RomaTre University and Niccolò Cusano University, Italy]

The aim of this contribution is to describe an innovative wire antenna able to automatically hide or reveal its presence depending on the waveform of the received/transmitted signal. This unconventional behavior is achieved through the use of a cloaking metasurface (MTS) made of a meander-like unit cell loaded with a lumped-element circuit. Due to the engineered time-domain response of the lumped circuit, the antenna is able switching its behavior when interacts with either a pulsed signal (PW) or a continuous signal (CW). The proposed configuration paves the way to a new generation of self-adaptive cloaking devices for antenna applications.

11:30 High-Performance 50μm Silicon-Based On-Chip Antenna with High Port-To-Port Isolation Implemented by Metamaterial and SIW Concepts for THz Integrated Systems

Mohammad Alibakhshikenari, Bal S. Virdee, Chan H. See, Raed Abd-Alhameed, and Ernesto Limiti [University of Rome "Tor Vergata", Italy, London Metropolitan University and Edinburgh Napier University and University of Bolton ,UK]

A novel 50μm Silicon-based on-chip antenna is presented that combines metamaterial (MTM) and substrate integrated waveguide (SIW) technologies for integration in THz circuits operating from 0.28 to 0.30 THz. The antenna structure comprises a square patch antenna implemented on a Silicon substrate with a ground-plane. Embedded diagonally in the patch are two T-shaped slots and the edges of the patch is short-circuited to the ground-plane with metal vias, which convert the structure into a substrate integrated waveguide. This structure reduces loss resulting from surface waves and Silicon dielectric substrate. The modes in the structure can be excited through two coaxial ports connected to the patch from the underside of the Silicon substrate. The proposed antenna structure is essentially transformed to exhibit metamaterial properties by realizing two T-shaped slots, which enlarges the effective aperture area of the miniature antenna and significantly enhances its impedance bandwidth and radiation characteristics between 0.28 THz to 0.3 THz. It has an average gain and efficiency of 4.5dBi and 65.32%, respectively. In addition, it is a self-isolated structure with high isolation of better than 30dB between the two ports. The on-chip antenna has dimensions of 800×800×60 μm^3.

11:45 50 Reflectionless perfect absorber with low angular and polarization sensitivity

Juan P. del Risco, Andrey Sayanskiy, Julián D. Ortiz, Stanislav B. Glybovski, and Juan D. Baena [Universidad Nacional de Colombia and Universidad San Buenaventura, Colombia, and ITMO, Russia]

We numerically demonstrate a perfect metasurface absorber which reaches the closest to isotropic absorbance that can be theoretically obtained. We got total absorption at 3.18 GHz while negligible reflection for angles of incidence up to 55° or 60°. Theoretical formulas are provided for the absorbance and reflectance as function of the incident angle.

12:00 High Q-factor coupled Fabry-Perot plasmonic nanoresonator

Antoine Moreau, Mamadou Aliou Barry, Vincent Berthier, Marie-Claire Baptiste FIX, Julien Jaeck, Patrick Bouchon, Nathalie Bardou, Sébastien Héron, Benjamin Vest, and Riad Haïdar [ONERA and Center for Nanoscience and Nanotechnology (C2N)-CNRS, France]

Fabry-Perot resonances have been reported in nanoantennas to behave independently. Here, we evidence the interferences between FP nanoantennas, with a strong impact on the optical behavior: increased absorption and Q-factor. We demonstrate analytically the FP-cavity coupling. We experimentally illustrate this high-Q factor resonance in a ribbon-shaped coupled FP-nanostructure.

12:15 Infrared Metamaterial Perfect Absorber Based on Vanadium Dioxide Disk Arrays

Xinrui Lyu, Thomas Taubner, Yunzhen Cao, and Lixin Song Song [RWTH Aachen University, Germany, and Shanghai Institute of Ceramics, China]

Utilizing thermochromic vanadium dioxide (VO2) as metallic arrays in the design of metamaterial absorber, we proposed a dynamic infrared perfect absorber with the structure of VO2 disk arrays/HfO2/Ag multilayers. The absorber exhibits a temperature-dependent absorption property due to the metal-insulator phase transition (MIT) in VO2. The simulation results show the wavelength of the absorption peak linearly redshifts with the increase of diameter of the VO2 disk when VO2 is at its metallic state. The tuning of peak position can be up to 3.7 μm with the change of 1 μm in diameter.

A5 Optical metrology and imaging

Hall: A **Chair:** Andrea Alù

14:00 Metalens Dispersion Engineering and Integrated Imaging Devices (Invited)

Tao Li, , S.M. Wang, R.J. Lin, B.B. Xu, J. Chen, C. Chen, P.C. Wu, V.C. Su, S.N. Zhu, and D.P. Tsai [Nanjing University, Taiwan, China, and National Taiwan University, Taiwan, China]

Recent progresses in metasurface have opened a door of new type of ultra-thin optical elements for versatile applications. In this paper, I would like to firstly introduce several progresses in our group and our collaborators to access achromatic metasurfaces and metalens. Afterwards, we successfully realized a metalens array for light-field image, and an ongoing work using metalens array that integrated directly onto an imaging camera will also be demonstrated. These approaches are expected to advance the current imaging technology to a more compact, integrated, and stable level.

14:30 Subwavelength Polarization Optics Using Helical Travelling-Wave Nanoantennas (Invited)

Mengjia Wang, Roland Salut, Huihui Lu, Miguel Angel Suarez, Nicolas Martin, and Thierry Grosjean [FEMTO-ST Institute, France, and Jinan University, China]

We present and demonstrate the concept of a helical travelling-wave nanoantenna (HTN) consisting of a tiny gold-coated helix end-fired with a rectangular aperture nanoantenna. Taken as individual or coupled nanostructures, HTNs lead to subwavelength polarization optics and provide new degrees of freedom in light polarization control.

15:00 Overcoming the Diffraction Limit with High-index Dielectric Particles

Victor Pacheco-Peña, and Miguel Beruete [Newcastle University, UK, and Universidad Publica de Navarra, Spain]

We propose and demonstrate the ability to produce photonic nanojets using high refractive index dielectric particles. An extremely narrow focus is produced with a spatial resolution of ~0.06 λ_0. The imaging capabilities are studied by introducing metallic spheres within the focal region demonstrating that distances between objects as small as ~0.06 λ_0 can be distinguished.

15:15 The Resonant Behavior of a Single Plasmonic Helix

Katja Hoeflich, Thorsten Feichtner, Enno Hansjuergen, Caspar Haverkamp, Heiko Kollmann, Christoph Lienau, and Martin Silies [Helmholtz-Zentrum Berlin fuer Materialien und Energie and University of Würzburg and Carl von Ossietzky University Oldenburg, Germany]

Single silver helices with strongly resonant features in the visible range are investigated. They show a strong circular dichroism with resonant features in good agreement with full field modeling. The mechanism of excitation is elucidated using a simple geometric model and analytical considerations.

B5 Chiral and bianisotropic metamaterials

Hall: B **Chairs:** Isabelle Staude

14:00 Symmetries and Angular Scattering Properties of Metasurfaces

Karim Achouri [EPFL, Switzerland]

We study the angular scattering behavior of bianisotropic metasurfaces and deduce relationships between the corresponding symmetrical angular scattering properties and the structural symmetries of their scattering particles. This may be of practical interest for the realization of metasurfaces with complex angular scattering characteristics.

14:15 Combining Chirality and PT-symmetry in Metamaterials

Ioannis Katsantonis, Sotiris Droulias, Costas Soukoulis, Eleftherios Economou, and Maria Kafesaki [Forth and University of Crete, Greece, and Forth and Ames Laboratory, USA]

Thanks to their particularly efficient, low frequency Minnaert resonance, air We investigate and present the conditions and the unique physical effects resulting from the combination of Parity-Time (PT-) symmetry with the fascinated properties offered by chiral metamaterials. Novel effects and polarization control possibilities, such as anisotropic transmission resonances for circularly polarized waves, are demonstrated and discussed.

14:30 The interaction of strands in a double DNA-like helix at high-frequency resonance

Ivan Mikhalka, Igor Semchenko, Sergei Khakhomov, and Alexei Balmakou [Francisk Skorina Gomel State University, Belarus]

A double DNA-like helix in which two strands are mutually displaced along a common axis is considered. A high-frequency resonance is investigated, at which the wavelength of the incident radiation is approximately equal to the length of a helix turn. All three components of the electric force and magnetic force acting on an arbitrary element of one strand from the side of the whole other strand are calculated. The dependence of all forces on the pitch angle of the double helix is investigated. The obtained results can be used when considering the equilibrium of a double helix, including as an element of metamaterials.

14:45 Achiral and Helicity Preserving Cavity for Enhanced Infrared Sensing of Chiral Molecules (Extended)

Joshua Feis, Dominik Beutel, Julian Kopfler, Xavier Garcia-Santiago, Carsten Rockstuhl, Martin Wegener, and Ivan Fernandez-Corbaton [Karlsruhe Institute of Technology, Germany]

We present an achiral and helicity preserving cavity that enhances the infrared vibrational circular dichroism signal of chiral molecules by factors of ten to one hundred. In contrast to many previous designs, the enhancement is mostly achieved in relatively large regions that are spatially separated from the meta-surfaces that form the cavity.

15:15 PT-symmetric Multilayer Systems: Homogenization And Beam Propagation

Andrey Novitsky, Denis Novitsky, Alexander Shalin, [National Academy of Sciences of Belarus and Belarusian State University, Belarus, and ITMO University, Russia]

We reveal that the Maxwell Garnett approximation is not capable of predicting a PT symmetry breaking in multilayers and a nonlocal homogenization theory should be employed. Interaction of electromagnetic beams consisting of plane and evanescent partial waves with the PT-symmetric systems is also studied.

C5 Special session: Metamaterials for life-science applications I

Hall: C **Chair:** Miguel Beruete

14:00 Ultrasensitive Exceptional Point Circuit for Enhanced Physiological Sensing

Zhenya Dong, and John S. Ho [National University of Singapore, Singapore]

Exceptional points (EPs) are degeneracies in non-Hermitian systems that have emerged as a new way to tailor the system response. Biasing systems at EPs, in particular, have recently been shown to enhance the sensitivity of certain resonant sensors. Here we demonstrate an EP circuit that enables ultrasensitive readout of wireless physiological health sensors based on LC circuits. We show that this circuit can be automatically operated at an EP and exhibit an amplified response to a small perturbation. In vivo experiments show that enhanced sensitivity can be maintained in dynamic living environments for monitoring of respiratory motion.

14:15 High-sensitivity Labyrinth Metasurface Working at THz for Thin-film Sensing

Irati Jáuregui-López, Pablo Rodriguez-Ulibarri, Aitor Urrutia, Sergei A. Kuznetsov, Miguel Beruete [Public University of Navarra, Spain, and Novosibirsk State University, Russia]

In this work a so-called labyrinth metasurface sensor working at the terahertz (THz) band is presented. The intricate geometry of the design leads to a high electric field confinement in all the structure surface, leading to ultrasensitive performance for thin-film sensing applications. The structure is coated with extremely thin analytes with thicknesses varying from ha = 24 nm to ha = 345 nm of tin dioxide (SnO_2) and its sensing capabilities are numerically and experimentally evaluated. Increasing the analyte thickness leads to a maximum redshift of 8 GHz at the resonance frequency. An average measured sensitivity of 12744.4 GHz/mm·RIU and a measured average FOM of 606.9 (mm·RIU) −1 are obtained, improving previous results found in the literature for designs that have been fabricated with the same manufacturing techniques. The great results obtained can lead to clear advantages for other type of sensing applications, where samples in a thin-film form become essential, such as biological sensing.

14:30 Hyperbolic Dispersion Metamaterials for Life Sciences Applications (Extended)

Giuseppe Strangi [Case Western Reserve University, USA]

In recent years significant efforts have been made to design and fabricate functional nanomaterials for biomedical applications. Optical sensor technology based on plasmonic metamaterials offers significant opportunities in the field of clinical diagnostics, particularly for the detection of lower-molecular-weight (<500 Da) biomolecules in highly diluted solutions. In this context, we have developed miniaturized plasmonic biosensor platforms based on hyperbolic metamaterials supporting highly confined bulk plasmon guided modes that outperform current detection technologies.

15:00 3D plasmonic nanostructures and metasurfaces for hybrid biological interfaces with living tissues (Invited)

Giulia Bruno, Andrea Barbaglia, Giovanni Melle, and Francesco De Angelis [Istituto Italiano di Tecnologia, Italy]

Light scattering by a subwavelength sphere exhibiting a radially inhomogeneous permittivity profile is considered here. A generalization of the polarizability for radially inhomogeneous sphere is given in terms of a so-called inhomogeneity factor. The special case of an inhomogeneous Drude profile unveils a series of scattering peculiarities, motivating further discussion for the implementation of spheres with graded-index plasmonic profiles.

A6 Plasmonics II

Hall: A **Chairs:** Sergey Bozhevolnyi

16:00 Metamaterial-Enhanced Micromechanical Photoswitch for Zero-Power Optical Transceiver

Matteo Rinaldi [Northeastern University, USA]

This paper reports on the first demonstration of a micromechanical photoswitch (MP) with an integrated near-infrared metamaterial electromagnetic absorber for zero-power optical transceivers, suitable for the implementation of on-demand free-space optical (FSO) transceiver nodes. The core element of such FSO transceiver nodes is a novel micromechanical photoswitch with an integrated near infrared (NIR) meatamaterial absorber which remains completely dormant with zero-power until woken up on detection of the incoming optical band of interest (e.g., lambda = 1550 nm). The near-perfect absorption characteristics (near-unity absorptance, spectral selectivity and sub-wavelength thickness form factor) of a metamaterial absorber along with the elimination of standby power consumption are key enablers to establish the next generation on-demand FSO communication link for secure and low-power data transmission.

16:15 Strong Light-Matter Coupling in Plasmonic Systems: a Quantum Hydrodynamic Study (Extended)

Cristian Ciraci [Istituto Italiano di Tecnologia, Italy]

At sub-nanometer length-scale, nonlocal and quantum effects are expected to influence the interaction between emitters and plasmonic systems, which unavoidably requires to go beyond classical models. Here, we apply state-of-the-art quantum hydrodynamic theory to investigate the quantum effects on strong coupling of a point-dipole emitter placed nearby metallic particles. In order to understand the effects of the quantum hydrodynamic model on the plasmon-emitter coupling, we compare our results with the conventional local response approximation and Thomas-Fermi hydrodynamic theory.

16:45 Merging Plasmonics And Quantum Photonics (Invited)

Sergey Bozhevolnyi [University of Southern Denmark, Denmark]

Recent developments in realization of single-photon sources empowered by coupling to localized and propagating surface plasmon modes are presented, paying particular attention to quantum plasmonic circuitry based on dielectric-loaded plasmonic waveguides containing accurately positioned nanodiamonds with colour centres.

17:15 Quantum Emitter Interacting with a WS2 Layer in the Strong Coupling Regime

Vasileios Karanikolas, Nikos Iliopoulos, Dionisis Stefanatos, and Emmanuel Paspalakis [University of Patras, Greece]

We investigate the spontaneous emission (SE) properties of a quantum emitter (QE) near a WS2 layer. The QE is placed above the WS2 layer in a host medium with constant dielectric permittivity and below the WS2 layer is either the same host medium or Au. The surface plasmon mode at the dielectric/Au interface interacts with the excitons of the WS2 increasing the Rabi splitting in the SE spectrum of the QE, compared with the dielectric substrate.

17:30 Magnetic Spin-Locking of Light

Mengjia Wang, Hongyi Zhang, Tatiana Kovalevich, Roland Salut, Myun-Sik Kim, Miguel Angel Suarez, Maria Bernal, Hans-Peter Herzig, Huihui Lu, and Thierry Grosjean [FEMTO-ST Institute, France, and EPFL, Switzerland, and Jinan University, China]

We show the directional excitation of Bloch surface waves controlled by the optical magnetic field. Relying on the helicity of the optical magnetic field, this magnetic effect is non-negligible even with a non-resonant dielectric scatterer (electric dipole) used as a Bloch surface wave coupler. Magnetic spin-locking opens new degrees of freedom in the manipulation and detection of light.

17:45 Plasmonic nanoantennas for excitation of ultrafast magnetization dynamics

Daria Sylgacheva, Mikhail Kozhaev, Denis Krichevsky, Vladimir Belotelov [Russian Quantum Center, Russia, Lomonosov Moscow State University, Russia]

An infinite heterogeneous elastic triangular lattice connected to a non-uniform array of gyroscopic spinners is considered. An algorithm is described for generating interfacial waves that propagate along the boundaries of subdomains containing inhomogeneities in the spinner array. The interfacial waveforms have preferential directions that can be controlled through adjusting the frequency of excitation or the arrangement of the spinners.The RT-CB was recently translated to Fortran 90/95 and the code will be publicly available.

B6 Acoustical and mechanical metamaterials II

Hall: B **Chairs:** Sarah Benchabane

16:00 Design of Thermoelastic Metamaterials for Micro-robotics

Qingxiang Ji, Xueyan Chen, Jun Liang, Jingyuan Qu, Philippe Lutz, Cédric Clévy, Kanty Rabenorosoa, Vincent Laude, and Muamer Kadic [CNRS, University of Besancon, France, Beijing Institute of Technology, China, Karlsruhe Institute of Technology, Germany]

We design thermoelastic metamaterials for use as actuators for soft micro-robots. We start by designing mechanical metamaterial unit-cells and demonstrating the effective translation and rotation mechanism upon heating. Then, we consider their global behavior at a larger scale and analyze the influence of structural parameters on induced motion. We obtain their motional amplitudes as well as the potential torque/force that should be used to position a given object. The system is controlled by a global thermal source that drives the overall system to a given state.

16:15 Graded elastic metasurface for enhanced sensing and energy harvesting

Jacopo Maria De Ponti, Andrea Colombi, Richard Craster, Raffaele Ardito, Francesco Braghin, and Alberto Corigliano [Politecnico di Milano, Italy]

Metamaterials offer extraordinary properties to control the propagation of electromagnetic, acoustic and elastic waves in artificially engineered media. Among other properties, resonant metasurfaces made of rod clusters on elastic substrate, have revealed superior characteristic for broadband wave focusing and mode conversion. In this study, the metasurface broadband control capacities are used to design an innovative metasurface, able to focus waves for enhanced piezoelectric sensing and energy harvesting.

16:30 A New Class Of Body-centered Cubic Shell Lattice Material (Extended)

Xueyan Chen, Qingxiang Ji, Huifeng Tan, Vincent Laude, and Muamer Kadic [Femto-st, CNRS, France, and Harbin Institute of Technology, P.R. China]

Recently, scientist have shown that body-centered cubic (BCC) lattice materials, the best-known bending-dominated metamaterials, can absorb more energy than commercially available aluminum foams. Such metamaterials, however, lack scalability toward extremely low densities – instabilities disappear together with the stiffness and strength. Here, we design a stretching-dominated mechanical metamaterial that can absorb very large energies while retaining a low density. In this study, a few examples of metamaterials are considered and we show that a new class of shell lattice (SL) metamaterials has the best mechanical properties for shock absorption – they are ultrastiff, ultrastrong, and possess high specific energy absorption at low relative density.

17:00 Observation of Mechanical Activity in a 3D Metamaterial (Extended)

Tobias Frenzel, Julian Köpfler, Erik Jung, Muamer Kadic, and Martin Wegener [Karlsruhe Institute of Technology, Germany, and Université de Bourgogne, France]

Using 3D chiral cubic-symmetry microstructured polymer metamaterial beams, we present comprehensive experiments on mechanical activity, the counterpart of optical activity. We study the dependence on frequency in the range 20-180 kHz, on propagation length, and on the beam cross section. Our findings are in good agreement with theory.

17:30 Poisson's ratio of Yukawa systems with nanoinclusions: nanochanel vs nanolayer (Invited)

Konstantin Tretiakov, Jakub Narojczyk, Pawel Piglowski, and Krzysztof Wojciechowski [Institute of Molecular Physics Polish Academy of Sciences, Poland]

The influence of periodically distributed inclusions on elastic properties of crystals in which particles interact through Yukawa potential is discussed briefly. The inclusions in the form of channels oriented along the [001]-direction and layers orthogonal to the [010]-direction are considered. Monte Carlo simulations have shown that, depending on the type of inclusion and the concentration of inclusion particles in Yukawa crystal, qualitative changes in elastic properties occur. In particular, in selected directions, one observes for systems with nanolayers an appearance of auxetic properties and for systems with nanochannels an enhancement of auxeticity.

C6 Special Session: Physical Review Journals Symposium

Hall: C **Chairs:** Andrea Alù

16:00 Exploration of Microwave Edge Modes on a Metasurface with Glide Symmetry (Invited)

Julia D. de Pineda, Alastair P. Hibbins, and J. Roy Sambles [University of Exeter, UK]

In this work we discuss the modes supported by a planar metasurface comprised of two layers of circular metal patches that form two identical hexagonal arrays. The layers are stacked together but displaced with respect to each other and separated by a dielectric slab. In our study, each metasurface is infinitely periodic in one direction (x) but only a few periods wide in the orthogonal direction (y). By modelling and experiment, we find the existence of a localized edge mode that only appears for a certain relative displacement of the layers. This edge mode is later used to guide the propagation of electromagnetic energy around different shapes, including sharp corners.

16:30 Optomechanical Kerker effect (Invited)

Alexander Poddubny, Ivan Avdeev, Alexander Poshakinskiy [Ioffe Institute, Russia]

We consider theoretically an interaction of light with vibrations of nanoparticles and membranes, supporting optical resonances. We predict strong directionality of the inelastic scattering of light on the nanoparticles trembling in space. Tunable directional forward or backward inelastic scattering can be achieved even for a particle lacking magnetic resonances due to the vibration-induced conversion between electric and magnetic dipole modes. We also put forward optomechanical crumpling and tension effects, manifested in a modification of resonant membrane shape by light.

17:00 Negative Stiffness Inclusions as a Platform for Real-Time Tunable Phononic Metamaterials (Invited)

Lorenzo Valdevit [Univ. of California Irvine, USA]

We propose an approach for real-time manipulation of low-frequency phononic band gaps in a metamaterial without affecting the material geometry, microarchitecture, or the crystal structure of the base material. Metamaterials with tunable band gaps are realized by introducing periodically arranged negative stiffness inclusions, the modulus of which can be varied in time in order to modify the metamaterial macroscopic stiffness in certain directions, without bringing the material to the point of elastic instability or inducing extreme geometric change. The evolution of band gaps is investigated numerically, and the proposed concept is verified experimentally in a lattice prototype with magnetic elements functioning as negative stiffness units. Design guidelines for achieving real-time tunable phononic band gap are also presented.

17:30 Chiral Properties of Light in Material Systems (Invited)

J. Enrique Vazquez-Lozano, and Alejandro Martinez [Universitat Politecnica de Valencia, Spain]

Motivated by recent theoretical results concerning dynamical properties of light in dispersive and lossless media, here we address an alternative derivation for the optical chirality, extending it so as to include dissipative effects as well. Looking into the underlying mathematical structure of the continuity equation, we find a new general expression for the optical chirality density in dispersive and lossy media. In spectral regions with high absorption and anomalous dispersion, we observe important deviations in comparison with the lossless case. This fact should be carefully accounted for and examined when analyzing the optical chirality and its interaction with matter, mainly in the context of highly dispersive systems such as plasmonic nanostructures and metamaterials, whose chiral properties are receiving strong attention.

16:00 Nonreciprocal Metagratings

Younes Ra'di, and Andrea Alu [City University of New York, USA]

We introduce the concept of nonreciprocal metagratings. We study surfaces that can enable nonreciprocal energy transfer between multiple Floquet channels. These surfaces are fully periodic arrays of nonreciprocal bianisotropic particles that can enable nonreciprocal wave manipulation with unitary efficiency. Notably, we study metagratings with bianisotropic moving particles as their building blocks. These bianisotropic particles are in fact stationary, however from electromagnetic point of view they emulate the characteristics of a real moving particles. As a possible application, we derive the required electric, magnetic, and electromagnetic polarizabilities of the bianisotropic moving particles for a metagrating capable of nonreciprocal space wave circulation with unitary efficiency.

16:15 The Rayleigh Hypothesis for Metasurface Optimization: Anomalous Grazing Refraction by Corrugated Silicon

Maxim Gorkunov, and Alexander Antonov [FSRC , Russia]

We study dielectric metasurfaces based on periodically corrugated subwavelength-thin silicon layers and explore their ability to control the light propagation direction. We apply the Rayleigh hypothesis that drastically facilitates the evaluation of diffraction efficiencies and perform a multi-parametric numerical optimization of the optical performance. In particular, we adjust the Fourier coefficients of periodic profiles to achieve anomalous refraction of normally incident light into grazing directions with an efficiency of more than 70%.

16:30 Non-Scattering Multi-Mirror Systems for Field Localization (Extended)

Francisco Cuesta, Viktar Asadchy, Mohammad Sajjad Mirmoosa, and Sergei Tretyakov [Aalto University, Finland, and Stanford University, USA]

Resonators composed of two mirrors, such as Fabry-Perot cavities, provide a simple but effective approach to achieve wave transmission with high finesse. Further increase of the quality factor requires reflectors with higher conductivity or multi-mirror solutions. However, the analytical complexity of resonators with more than two mirrors prevents the design of optimal structures without recurring to numerical methods. This work considers an alternative approach to this problem by using cavities which do not produce any electromagnetic scattering. We demonstrate that these invisible cavities can be placed inside one another, resulting in a ``matryoshka-doll''-like resonator. The standing-wave distribution of the inner resonator can be controlled without disturbing that of the outer one, whereas the whole system remains non-scattering.

17:00 Upper Bound for the Light Absorption in a Nanovolume Assisted by a Nanoantenna

Emilie Sakat, Léo Wojszvzyk, Jean-Jacques Greffet, Jean-Paul Hugonin, and Christophe Sauvan [LCF(CNRS), France]

We derive a fully-vectorial upper bound for the absorption cross-section of a nanoparticle in a complex environment. It is valid for any environment and any illumination and allows to decouple the choice of the environment from the one of the absorber. It provides a meaningful figure of merit to compare the ability of different systems to enhance absorption.

17:15 Investigation of surface waves on anisotropic self-complementary metasurfaces

Vladimir Lenets, Andrey Sayanskiy, Stanislav Glybovski, Enrica Martini, Juan Baena, and Stefano Maci [ITMO University, Russia, and Universidad Nacional de Colombia, Colombia, and University of Siena, Italy]

In this work, we numerically study propagation and excitation of surface waves on a resonant and anisotropic self-complementary metasurface in the microwave range. We show that the TE- and TM-polarized fundamental modes have identical dispersion relations in different directions of propagation. Moreover, it is demonstrated that anisotropy of the metasurface results in very different group velocities in two mutually orthogonal propagation directions for both polarizations, which allows unidirectional and localized excitation.

17:30 Analysis of Resonances in Periodic Metasurfaces through the Concept of Self-Coupling Mode

Kevin Müller [École Polytechnique fédérale de Lausanne, Switzerland]

The concept of self-coupling modes, which are eigen-vectors of the roundtrip matrix, is introduced. I investigate its use for the identification and analysis of the resonances taking place in periodic metasurfaces. It also improves the interpolation of the response of a resonant metasurface.

17:45 Multipole analysis of bound states in the continuum supported by a periodic array of spheres

Zarina Sadrieva, and Andrey Bogdanov [ITMO University, Russia]

We study dielectric metasurfaces composed of planar periodic arrays of Mie-resonant nanospheres which support both symmetry protected and accidental bound states in the continuum, and employ the multipole decomposition and symmetry approach to reveal the physical mechanism of the formation of such nonradiating states in terms of multipolar moments.

Wednesday

9:00 Plenary session III

10:00 Coffee

	Hall A	Hall B	Hall C	Hall D
10:30	A7	B7	C7	D7
	Special session: Topological band gaps in meta-materials III	*Non-linear, tunable and reconfigurable meta-materials II*	*Millimeter wave and microwave meta-materials*	*Homogenization*

12:30 Lunch

14:00 Coffee and Poster Session

16:00	A8	C8	D8
	Special session: Topological band gaps in meta-materials IV	*Non-reciprocal meta-materials I*	*Optical meta-materials II*

19:00 Gala Dinner

22:30

Plenary session III

Hall: A **Chair:** Martin Wegener

9:00 Chiral and Topological Surface Waves and Line Waves on Metasurfaces

Daniel Sievenpiper
University of California San Diego, USA

The use of symmetry in electromagnetic structures provides a means for manipulating wave propagation. Line waves can occur at the interface between complementary metallic screens. At optical frequencies, similar structures can be produced with arrangements of holes in a dielectric substrate. Various techniques for designing topological structures will be discussed.

A7 Special session: Topological band gaps in metamaterials III

Hall: A **Chairs:** Simon Horsley

10:30 Non-Hermitian sonic second-order topological insulator (Invited)

Johan Christensen [UC3M, Spain]

Topological phases of matter that have been recently extended to topological phases of sound, can confine acoustic energy at the corners of higher-order topological insulators. We broaden this concept by incorporating parity-time symmetry and show new topologically protected confinement rules that are dictated by the geometrical arrangement of gain and loss units. Particularly, our findings reveal how sound trapping occurs at all corners when parity-time symmetry is intact, beyond the exceptional point within the broken phase however, opposite corners sustain either sink- or source-like states that could lead to novel non-Hermitian guides for sound.

11:00 Edge States and Topological Pumping in Spatially Modulated Elastic Lattices (Invited)

Massimo Ruzzene, and Matheus Rosa [Georgia Institute of Technology, USA]

One-dimensional elastic lattices with spatial modulations of stiffness are shown to exhibit non-trivial topological properties that lead to the existence of edge states. Topological pumping is achieved by modulations of the stiffness phase in a system of coupled elastic beams driving an edge-to-edge transition of the topological modes.

11:30 Solving differential equations with topological acoustic metamaterials (Extended)

Farzad Zangeneh-Nejad, and Romain Fleury [EPFL, Switzerland]

The last few years have seen an ever-growing amount of interest in non-reciprocal photonic systems where the directionality results from driving the system, and not from the use of magnetic or magneto-optic materials. The motivation here ranges from new design principles for photonic devices, to the realization of novel kinds of correlated photonic physics. In this talk, I'll give an overview of recent work in my group exploring how engineered dissipation can be used to make almost any kind of interaction between two subsystems non-reciprocal (i.e. unidirectional). This provides a unified approach for discussing synthetic non-reciprocity in a range of different systems, and also a powerful means to design new kinds of non-reciprocal systems (both classical and quantum). I will touch on connections to quantum-limited amplification, quantum state preparation and measurement-based quantum feed-forward protocols, and also discuss recent implementations of our ideas in quantum optomechanics.

12:00 Guided water waves along a domain wall in a Quantum Valley Hall Effect (QVHE) crystal

Nicolas Laforge, Vincent Laude, Franck Chollet, Abdelkrim Khelif, Muamer Kadic, Yuning Guo, and Romain Fleury [FEMTO-ST, France, and Ecole Polytechnique Fédérale de Lausanne, Switzerland]

Topological phases of matter have been recently extended to classical wave systems such as optics or phononics. Here, we show for the first time an experimental demonstration of topological edge states in a classical water wave system supporting highly non-linear wave dispersion, in the intermediate regime of gravity-capillary waves.

12:15 Self-induced Topological Transition in a Nonlinear Phononic Lattice

Rajesh Chaunsali, and Georgios Theocharis [LAUM, CNRS, Le Mans Université, France]

Topological phases of matter have been recently extended to classical wave systems such as optics or phononics. Here, we show for the first time an experimental demonstration of topological edge states in a classical water wave system supporting highly non-linear wave dispersion, in the intermediate regime of gravity-capillary waves.

B7 Non-linear, tunable and reconfigurable metamaterials II

Hall: B **Chairs:** Mihail Petrov

10:30 Active Metasurfaces as a Platform for Capacitive Wireless Power Transfer Supporting Multiple Receivers

Fu Liu, Prasad Jayathurathnage, and Sergei Tretyakov [Aalto University, Finland]

We show that active metasurfaces can work as transmitters of capacitive wireless power transfer (WPT) systems. It can feed multiple receivers and provide robust operation against load or position variations. We formulate an analytical model for such WPT systems and discuss exact solution of a example with N identical receivers.

10:45 Optimal Analog Data Compression with Reconfigurable Wave-Chaotic Systems

Philipp del Hougne, Fabrice Mortessagne, Olivier Legrand, and Ulrich Kuhl [Institut de Physique de Nice, France]

Propagation of waves through wave-chaotic systems completely scrambles incident wave fronts. Recent computational imaging devices leverage this property to take compressed measurements of multiple input data streams. Here, we demonstrate that carefully configured wave-chaotic systems can optimally compress multiple incoming data streams. Using tunable metasurfaces, we reconfigure the boundary conditions of chaotic microwave cavities and report an experimental in-situ proof of the concept.

11:00 Nonlinear Distortion of Multitone Wave Packets by Lossy Conductors

Alex Schuchinsky, and Michael Steer [University of Liverpool, UK, and NC State University, USA]

The presented new approach enables efficient multiphysics modelling of the products of nonlinear mixing in multi-carrier wave packets and reveals their fundamental properties. The developed methodology is illustrated by an example of distortion of the multi-tone wave packets due to the electro-thermal nonlinearity of a surface with finite conductivity.

11:15 Controlling Surface Acoustic Waves via Magnetically-modulated Contact Resonances

Antonio Palermo, Yifan Wang, Paolo Celli, and Chiara Daraio [University of Bologna, Italy, and California Institute of Technology, USA]

We present a tabletop-scale realization of a tunable metamaterial platform to control surface acoustic waves (SAWs). The platform comprises an array of ferromagnetic beads controlled with permanent magnets, arranged atop an elastic substrate. We demonstrate the possibility of shifting the beads' resonances and, in turn, tuning the SAWs bandgaps.

11:30 Phase-Gradient Metasurfaces Based on a Photosensitive Chalcogenide Glass

Elena Mikheeva, Julien Lumeau, Redha Abdeddaim, Ivan Voznyuk, and Stefan Enoch, [Aix Marseille Univ., France, and Multiwave Innovation SAS, France]

We suggest a realistic design of phase-gradient metasurfaces made of photosensitive chalcogenide (As_2S_3) using the effect of suppressed back-scattering due to modes interference within dielectric particles. We calculate 4 meta-atoms producing phase shifts of $0, \pi/2, \pi, 3\pi/2$ with respect to each other for simulating a micro-lens with a discrete phase profile. Our result confirms the possibility to produce larger diffractive optical elements (DOE) based on photo-sensitivity which has technological advantage of recording the desired phase profile as a post-fabrication step.

11:45 Blueshift in graphene-based hyperbolic metamaterials as a tunable narrowband reflection modulators

Alessandro Pianelli , Rafal Kowerdziej, Marek Olifierczuk, Karol Sielezin, Michal Dudek, and Janusz Parka [Military University of Technology, Poland]

We examine numerically the hyperbolic metamaterials based on graphene in the mid-IR frequencies. Using the capability to tune the hyperbolic dispersion of graphene-based HMM by varying the chemical potential, we report a blueshift and tunability of the reflectance particularly for different incident angles in TM/TE modes. A type I, type II hyperbolic dispersion, as well as an effective metallic dispersion, are shown for three different structures taken into consideration.

12:00 An Ultra-thin Reconfigurable Polarization Converter Based on an Active Metasurface

Long Li, Guangyao Liu, Jiaqi Han, Yajie Mu, and Haixia Liu [Xidian University, China]

In this paper, a novel reconfigurable polarization converter (RPC) based on active metasurface tuned by positive-intrinsic-negative (PIN) diodes is proposed. The metasurface unit cell of the RPC consists of a hexagonal patch and three triangle patches, which are all etched on a substrate backed by a metal ground. In the conversion mode, the linear polarization (LP) along the y-axis can be converted into a left-hand circularly polarized (LHCP) wave and a righthand circularly polarized (RHCP) wave by switching the diodes' states. On the other hand, in the reflection mode, the incident wave is reflected with the original polarization in the corresponding frequency band. The thickness of this metasurface is only 1.5mm and it has great potential applications.

12:15 Non-Linear High Permittivity Artificial Dielectric

Juan P. del Risco, and Juan D. Baena [Universidad Nacional de Colombia, Colombia]

In this work we study the non-linearity effects for a high permittivity artificial dielectric which result from the stacking of many parallel layers each one made of square metallic patches arranged on a square lattice. From the balance between the attractive electric force between induced charges and the restoring force caused by some soft dielectric spacers, we have found strong non-linear effects on the effective permittivity.

C7 Millimeter wave and microwave metamaterials

Hall: C **Chairs:** Samel Arslanagic

10:30 Varactor-Loaded Metagratings For The Dynamic Manipulation Of The Diffracted Waves

Andrea Casolaro, and Alessandro Toscano [Roma Tre University, Italy]

The ability of metagratings to perform extreme wavefront manipulation allowed them to cover a wide range of functionalities in different frequency ranges, from microwave to optics. However, in nowadays applications, reconfigurable devices are often required. In this contribution we present a metagrating enabling the dynamic control of the total diffraction pattern, both in reflection and transmission, using arrays of varactor-loaded strips. First, we analyze the static case of capacitively loaded strips and show how it is possible to control the power carried by each diffraction order by properly tuning the load capacitances. Second, we employ varactor diodes to achieve reconfigurability using a resistive bias network. The developed design procedure is validated through numerical simulations and the effect of losses is also discussed.

10:45 Free-Space Layered Sheet-Isolator

Rodion Kononchuk, Carl Pfeiffer, Nicholaos Limberopoulos, Igor Anisimov, Ilya Vitebskiy, and Andrey Chabanov [University of Texas at San Antonio and Air Force Research Laboratory, USA]

We introduce a multilayer acting as a free-space sheet-isolator with unlimited aperture, strong resonant transmission in the forward direction, and a possibility of broadband omnidirectional rejection of light incident on the opposite (back) side of the multilayer.

11:00 Experiments on the External Coupling Control of a Dirac Cone Metasurface for Extraordinary Transmission

Yuto Kato, and Atsushi Sanada [National Institute of Advanced Industrial Science and Technology and Osaka University, Japan]

We experimentally study an external coupling control of a double-sided Dirac cone metasurface by adjusting the unit cell density to realize the extraordinary transmission with enhanced transmittance. The gain enhancement with an optimized Dirac cone metasurface with the Γ-point frequency of 28 GHz is demonstrated.

11:15 Novel Metasurface Synthesis Algorithm Based On Near-Field Coupling Analysis

Andreas Eduard Olk, and David Anthony Powell [University of New South Wales Sydney, Australia]

Metasurfaces in the microwave and terahertz frequency range are most often composed of several metallic layers with dielectric spacing, which are modeled as cascaded impedance sheets for the synthesis. This widely used model can be significantly inaccurate as it does not account for perturbations caused by near-field coupling between metallic layers. In this work, we use a novel synthesis algorithm that is capable of correcting these perturbations and allows the design of transmissive metasurfaces with high efficiency despite the presence of near-field coupling. Different numerical and experimental examples are presented including beam refraction and a flat lens operating at mm-wave frequencies (W-band).

11:30 Water-Based Microwave Metasurfaces and Electrically Small Antennas (Invited)

Samel Arslanagic, Jonas Ø. Nielsen, Rasmus E. Jacobsen, and Andrei V. Lavrinenko [Technical University of Denmark, Denmark]

Dual scatterers attracted quite a lot of research attention thanks to Recently, it was proposed to use pure water for resonant inclusions in practical all-dielectric metasurfaces with highly tunable dynamic properties. In this work, we review our recent numerical and experimental efforts on simple water-based microwave metasurfaces for switching, waveguiding, and reflect-array applications. We also illustrate how a single resonant water inclusion can form the basis for interesting electrically small antennas.

12:00 Manipulating electromagnetic waves with high-efficiency transmissive metasurfaces (Invited)

Lei Zhou [Fudan University, China]

Near-field directionality of circularly polarized dipoles has opened the way to the design of novel devices such as integrated nano-polarimeters, polarization-based nano-routers, and non-reciprocal optical devices. Here we extend the directionality of dipolar near-fields, uncovering novel directional sources beyond the circularly polarized emitter. These sources exhibit distinct symmetries and behaviors.

D7 Homogenization

Hall: D **Chairs:** Graeme Milton

10:30 Towards Generalized Nonlocal Constitutive Relations For Metamaterials (Extended)

Fatima Z. Goffi, Karim Mnasri, Michael Plum, and Carsten Rockstuhl [Karlsruhe Institute of Technology, Germany]

We consider a nonlocal homogenization to describe the propagation of light within metamaterials. To this end, we use Taylor and Padé-type approximations of the response function of E. We discuss the dispersion relations, the additional interface conditions, study and compare the emerging reflection and transmission coefficients from slabs of metamaterials.

11:00 Quasiperiodic Composites: Two-scale Reiterated Homogenization (Invited)

Elena Cherkaev, Sebastien Guenneau, Harsha Hutridurga, and Niklas Wellander [University of Utah, USA, and Aix-Marseille Universite, France , and Indian Institute of Technology Bombay, India, and Swedish Defence Research Agency, Sweden]

Quasiperiodic materials present a novel class of metamaterials that possess unusual, extraordinary mechanical, thermal and electromagnetic properties. We derive homogenized equations for the effective behavior of multiscale composites with mixtures of periodic and quasiperiodic phases appearing at different scales and discover new effects which could have interesting applications for control of wave and diffusion phenomena.

11:30 Homogenisation and spatial dispersion: Using the constitutive relations in the time domain.

Jonathan Gratus, and Paul Kinsler [Lancaster University and the Cockcroft Institute, UK]

Standard methods of homogenisation and calculating the effective electromagnetic constitutive relations fail in the presence of spatial dispersion. We show using how we can use an time domain kernel approach in order to calculate the spatially dispersive constitutive relations. This is compared to an eigenvalue approach.

11:45 Homogenization of All-Dielectric Metasurfaces: Theory and Applications

Alessio Monti, Andrea Alù, Alessandro Toscano, and Filiberto Bilotti [Niccolò Cusano University and Roma Tre University, Italy, and CUNY Advanced Science Research Center, USA]

In this contribution, we describe a simple and powerful analytical approach to homogenize all-dielectric metasurfaces. The proposed model is based on a combination of the Mie scattering theory of the individual scatterer with a bi-dimensional homogenization approach accounting for the interaction between the electric and magnetic dipoles excited by the external field. Through full-wave simulations, we show that the proposed approach is able to effectively characterize the electromagnetic response of an array of Mie resonators, even for small inter-element separation distances. Several applications of analytically-designed all-dielectric metasurfaces at optical and microwave frequencies are also discussed.

12:00 On static chiral Willis continuum mechanics (Invited)

Muamer Kadic, André Diatta, Tobias Frenzel, Sebastien Guenneau, and Martin Wegener [CNRS, France, and KIT, Germany]

We discuss the Willis equations as a generalization of Cauchy continuum mechanics towards chiral elastic media. We show that this generalization is able to qualitatively describe recent static experiments on 3D chiral cubic-symmetry metamaterials by introducing a single additional parameter with respect to Cauchy elasticity. It is therefore an interesting alternative to Eringen continuum mechanics, in which nine additional parameters appear.

PS: Poster Session

Chairs: Stefano Vellucci and Angelica Viola Marini

14:00

Metamaterials-based antennas

1. New Design of Metamaterial Antenna for 5G Applications
Mondher Labidi, and Fethi Choubani [innovcom, Tunisie]

2. Experimental Validation of Very High Gain Antennas Based on Modulated Metasurfaces
Enrica Martini, Gabriele Minatti, Francesco Caminita, Cristian Della Giovampaola, Stefano Maci [University of Siena and Wave Up Srl, Italy]

3. Silicon-Based 0.450-0.475 THz Series-Fed Double Dielectric Resonator On-Chip Antenna Array Based on Metamaterial Properties for Integrated-Circuits
Mohammad Alibakhshikenari, Bal S. Virdee, Chan H. See, Raed Abd-Alhameed, and Ernesto Limiti [University of Rome "Tor Vergata", Italy, and London Metropolitan University and Edinburgh Napier University and University of Bradford, UK]

4. Frequency Reconfigurable Based Antenna Utilizing Coding Meta-surface for Future 5G Applications
Mahmoud Abdalla, Islam Abdelazeem, and Ahmed Ibrahim [Military Technical College and and Sohag University Minia University, Egypt]

5. Frequency Tunable Monopole Patch Antenna Using Broadside Coupled Split Ring Resonator for Wireless Communication Applications
Joe Kizhakooden, Jovia Jose, Nees Paul, Jolly Andrews, and Joseph V P [University of Calicut, India]

6. Nonstandard FDTD Realization of Radiation Behaviour of Epsilon Negative Metamaterial Corner Reflector Antenna
Jovia Jose, Sikha K. Simon, Joe Kizhakooden, Jolly Andrews, and Joseph V. P. [Christ college , India]

7. Conductivity Effect on Broadband Dipole Antenna with Split Ring Resonators
Kam Eucharist Kedze, Heesu Wang, Ikmo Park [Ajou University, Korea (South)]

8. Antireflective coatings for high impedance jumps
Julian D. Mateus, Herbert Vinck Posada, and Juan D. Baena [Universidad Nacional de Colombia, Colombia]

Metasurfaces

9. Transmission Enhancement by Antireflective Metasurface for Ground Penetrating Radar Applications
Wuan Zheng, and Tong Hao [Tongji University, China]

10. Random Checkerboard Metasurface for wideband RCS reduction
Shraddha Choudhary, and Kirankumar Hiremath [Indian Institute of Technology Jodhpur, India]

11. The Design of the Dual-Frequency Multiplexing Holographic Impedance Metasurfaces
Yunbo Li [Southeast University, China]

12. Changing Profile, Size And Position Simultaneously With Illusion Metasurface
Zijie Jiang, Qingxuan Liang, Zhaohui Li, Peiyao Lv, Tianning Chen, Dichen Li [Xi'an Jiaotong University, China]

13. Software-Defined Metasurfaces: The VISORSURF Project Approach
Odysseas Tsilipakos, Alexandros Pitilakis, Anna Tasolamprou, Christos Liaskos, Ageliki Tsioliaridou, Fu Liu, Mohammad Sajjad Mirmoosa, Xuchen Wang, Kypros Kossifos, Julius Georgiou, Andreas Pitsillides, Nikolaos Kantartzis, Dionysios Manessis, Sotiris Ioannidis, George Kenanakis, George Deligeorgis, Costas Soukoulis, Sergei Tretyakov, and Maria Kafesaki [Foundation for Research and Technology Hellas and Aristotle University of Thessaloniki, Greece, and Aalto University, Finland, and University of Cyprus, Cyprus, and Fraunhofer IZM, Germany, and Ames Laboratory and Iowa State University, USA]

14. Miniaturization of Unit Cell of Self-oscillating Non-Foster Metasurface
Silvio Hrabar, Katarina Cavar, Marko Miksic, Luka Tomic, and Leo Vincelj [University of Zagreb, Croatia]

Metamaterials-based inclusions

15. Simulation and Experimental Studies on Novel Cut-wire and LR based Metamaterial
Subal Kar, Amitesh Kumar, Arijit Majumder, and Shantanu Das [SAMEER, Kolkata Centre and BARC, India]

16. Thin Film Metamaterial Split Ring Resonators at Microwave Frequencies
Nees Paul, Sikha K.Simon, Bindu C., Jolly Andrews, and Joseph V.P. [Christ College Irinjalakuda , India]

17. Metamaterial Split Ring Resonators made of Polyaniline - polytetrafluoroethylene at Microwave Frequencies
Nees Paul, Joe Kizhakooden,Jovia Jose, Jolly Andrews, and Joseph V P, [University of Calicut, India]

18. Specially Designed Metamaterial Split Ring Resonator for High Resolution Imaging at Microwave frequencies
Bindu C., Sreedevi P. Chakyar, Anju Sebastian, Jolly Andrews, and Joseph V. P. [University of Calicut, India]

19. Rotation Sensor based on Near Field Perturbations of Metamaterial Split Ring Resonator
Anju Sebastian, Sreedevi P. Chakyar, Bindu C., Joseph V. P., and Jolly Andrews [Christ College , India]

Absorbers

20. A Wideband Transmission Frequency Selective Surface Rasorber With Low Insertion Loss
Jianfeng Wei, Wei Deng, Yun He, Zhipeng Lei, Yutong Liu, Yulu Zhang, Chengli Li, and Jianjun Jiang [Huazhong University of Science and Technology, China]

21. Wideband skewed grid frequency selective surface absorber for oblique incidenc
Yulu Zhang, and Jianjun Jiang [Huazhong University of Science and Technology, China]

22. Gammadion Resonator Based Metamaterial Absorber Sensor in Application of Chemical Liquids Detection
Yadgar.I Abdulkarim, Lianwen Deng, Muharrem Karaaslan, and Emin Unal [Central South University, China, and Iskenderun Technical University, Turkey]

23. Wide Band Microwave Absorber using Flexible Broadside Coupled Split Ring Resonator Metamaterial Structure
Umadevi K.S., Sikha K. Simon, Sreedevi P.Chakyar, Jolly Andrews, and Joseph V.P., [Prajyothi Nikethan Pudukkad and Christ College Irinjalakuda, India]

24. Ideal Absorption In Individual Dielectric Subwavelength Sized Scatterers
Claire Guidet, Redha Abdeddaim, Brian Stout, and Nicolas Bond [Institut Fresnel, France]

Metamaterial applications at microwaves

25. A High-Power Wireless Charging System Based on Fano Resonance
Yu Liu, Yewen Zhang, Jun Jiang, Kai Fang, Kejia Zhu, Keqiang Lv, and Yunhui Li [Tongji University, China]

26. High Dielectric Ring Resonators
Bahareh Moradi, Joan Gaecia [Polytechnic University of Catalunia, Autonoma university of Barcelona, Spain]

27. Diplexer Based on Surface Plasmon Polariton-like Propagation Induced by Structural Dispersion of Substrate Integrated Waveguide
Mihailo Drljaca, Zarko Sakotic, Norbert Cselyuszka, Vesna Crnojevic Bengin, Nikolina Jankovic [Institute BioSense, Serbia]

28. Investigations of a Wideband Metamaterial-based Microstrip Meander Line with Slotted Screen
Andrey Yelizarov (Elizarov), Alexander Kukharenko, and Andrey Skuridin [Moscow Institute of Electronics and Mathematics and Science-Research University of Technical Physics and Automatisation, Russia]

29. Direct Amplitude Modulation Technique using Metamaterial Broadside Coupled Split Ring Resonator (BCSRR) Structure
Sikha K. Simon, Sreedevi P. Chakyar, Anju Sebastian, Jolly Andrews, and Joseph V.P. [Christ College Irinjalakuda, India]

30. Topological Robustness of Phase Singularities at Microwave Frequencies
Andrea Bassotti, Mirko Barbuto, Andrea Alù, Filiberto Bilotti, and Alessandro Toscano [Niccolò Cusano University and Roma Tre University, Italy, and City University of New York, USA]

31. High-efficiency Generation Of Bessel Beams With Transmissive Metasurfaces
Zhuo Wang [Fudan University, China]

32. Generation of Bessel Bottle Beam Using Metasurfaces
Long Li, Yongjie Liu, Hao Xue, Haixia Liu, and Yan Shi [Xidian University, China]

Plasmonics and Optics

33. All-Dielectric Metasurfaces with Toroidal Mode Resonances at sub-THz
Jose Francisco Algorri, Dimitris Zografopoulos, Antonio Ferraro, Pedro Martin-Mateos, Braulio Garcia-Camara, Aldo Moreno-Oyervides, Viktor Krozer, Pablo Acedo, Romeo Beccherelli, Jose Manuel Sanchez-Pena, Ricardo Vergaz [Carlos III University of Madrid, Spain, and Istituto per la Microelettronica e Microsistemi (CNR-IMM), Italy, and Goethe University, Germany]

34. Self-Complementary Metasurfaces As Efficient Tools For Polarization Sensitive Control Of THz Beams
Andrey Sayanskiy, ITMO University, Russia
Vladimir Lenets, ITMO University, Russia
Sergei Kuznetsov, Rzhanov Institute of Semiconductor Physics SB RAS, Russia
Stanislav Glybovski,
and Juan Domingo Baena [ITMO University and Rzhanov Institute of Semiconductor Physics SB RAS, Russia, and Universidad Nacional de Colombia, Colombia]

35. Making Second-Order Optical Nonlinearity in Metallic Film
Teruya Ishihara, Yusuf B. Habibullah, Max Lein [Tohoku University, Japan]

36. Optical Metasurface as a Wave Retarder and Tunable Partial Polarizer
Somendu Maurya, Markus Nyman, Andriy Shevchenko, Matti Kaivola [Aalto University, Finland]

Plasmonics

37. Acousto-optical Light Modulation At 10.6 μm Using Multilayered Structures
Ivan Sopko, Grigory Knyazev, Daria Ignatyeva, Daria Sylgacheva, Vladimir Belotelov [Lomonosov Moscow State University, Russia]

38. Metamaterials on Helix Structures with Abnormal Dispersion
Andrey Yelizarov (Elizarov), Alexander Kukharenko, Andrey Skuridin, and Valentina Karavashkina [Moscow Institute of Electronics and Mathematics and Science-Research University of Technical Physics and Automatisation and Moscow Technical University of Communications and Informatics, Russia]

39. Numerical Investigation of the Fano Resonance Based Complementary All-dielectric Metasurface
Keshav Samrat Modi, Umesh Tiwari, Ravindra Kumar Sinha [CSIR-CSIO, India]

40. Electromagnetic waves through metamaterial superlattices
Pedro Pereyra, and Fatna Assaoui [Universidad Autonoma Metropolitana , Mexico, and University Mohamed V, Morocco]

41. Transverse Magneto-Optical Intensity Effect in Non-symmetric Plasmonic Nanostructures
Olga Borovkova, Andrey Kalish, Daria Ignatyeva, A.A. Voronov, Mikhail Kozhaev, Hisham Hashim, Sarkis Dagesyan, Alexander Shaposhnikov, Vladimir Berzhansky, Venu Gopal Anatoly Zvezdin, Larissa Panina, and Vladimir Belotelov [Russian Quantum center and National University of Science and Technology and M.V. Lomonosov Moscow State University and V.I. Vernadsky Crimean Federal University and Tata Institute of Fundamental Research, Russia]

42. Surface Plasmon-Polaritons On The Boundary Vacuum-Metamaterial
Olga Ivannikova, Alexey Tishchenko, and Michael Strikhanov [National Research Nuclear University MEPhI, Russia]

43. Inversion of the Dark and Bright Modes of a Nanoparticle Dimer
Thomas Sturges, Charles Downing [University of Warsaw, Poland, and Universidad de Zaragoza, Spain]

44. The Accurate Mathematic Model Based on 2x2-Matrix For Anisotropic Photonic Crystals with Metamaterial Layers
Konstantin Vytovtov, Elizaveta Barabanova, and Vladimir Vishnevskiy [Astrakhan State Technical University and V.A.Trapeznikov Institute of Control Sciences of RAN, Russia]

45. Blue-shift in hyperbolic metamaterials structure based on Al/HfO2
Karol Sielezin, Alessandro Pianelli , Michal Dudek, Rafal Kowerdziej, Marek Olifierczuk, and Janusz Parka [Military University of Technology, Poland]

46.Wide Band Polarization Converter Graphene Metasurface for Mid-Infrared Band
Mahmoud Abdalla, Ahmed Abdel Aziz , and Ahmed Ibrahim, Minia University, Egypt]

47. Ellipsometric Study of Ferritin Clusters Adsorbed on Metasurface and Influenced by UV Irradiation
Maya Tanovska, Mohsen Rahmani, Nikolay Zografov, Lilia Vladimirova-Mihaleva , and Dragomir Neshev [Sofia University "St. Kliment Ohridski" Faculty of Physics , Bulgaria, and The Australian National University, Australia]

48. Enhancement Of Magnetooptical Effects In Nanostructured Iron-Garnet Meta-Surface
Andrey Voronov, Daria Ignatyeva, Dolendra Karki, Mikhail Kozhaev, Miguel Levy, and Vladimir Belotelov [M.V.Lomonosov Moscow State University and Prokhorov General Physics Institute of the Russian Academy of Sciences, Russia, and Michigan Technological University, USA]

49. Highly sensitive magnetometry method based on the magnetoplasmonic crystal
Grigory Knyazev, Daria Sylgacheva, Pavel Kapralov, Nikolay Gusev, Andrey Kalish, Petr Vetoshko, Sarkis Dagesyan, Alexander Shaposhnikov, Vladimir Berzhansky, Anatoly Zvezdin, and Vladimir Belotelov [Lomonosov Moscow State University, Russian, Russia]

50. Cavity Enhanced Transverse Magneto-optical Kerr Effect of Al\AAO Based Nanostructure Arrays
Weiwei Zhang, Daria Sylgacheva, Pavel Kapralov, and Vladimir Belotelov [University of Science and Technology, China, and Lomonosov Moscow State University, Russia]

Theory and Methods

51. Theoretical study of a high-permittivity dielectric ring resonator for Magnetic Resonance Microscopy applications
Marine A.C. Moussu, Stanislav Glybovski, Luisa Ciobanu, Ivan Voznyuk, Redha Abdeddaim, and Stefan Enoch [Aix Marseille University and CEA Neurospin and Multiwave Innovation, France, and ITMO University, Russia]

52. Controlling emission close to surfaces
Dean Patient, Simon Horsley [University of Exeter, UK]

53. Topological Tuning of a Dispersion Curve by Controlling Locations of Impurities with Equivalent Circuit Model
Akira Hasegawa, Takashi Hisakado, AKMMahfuzul Islam, and Osami Wada [Kyoto University, Japan]

54. Numerical Method to Study Three-Dimensional Metamaterial Composites
Takamichi Terao [Gifu university, Japan]

55. Enhancement of Weak Nonlocality in Aperiodically Ordered Multilayered Dielectric Metamaterials
Marino Coppolaro, Giuseppe Castaldi, and Vincenzo Galdi [University of Sannio, Italy]

56. Some Ideas for Non-Hermitian Doping of Epsilon-Near-Zero Media
Marino Coppolaro, Massimo Moccia, Nader Engheta, and Vincenzo Galdi [University of Sannio, Italy, and University of Pennsylvania, USA]

57. Parametric resonances in time-varying ("photonic Floquet") media
Peter Halevi, and Juan Sabino Martínez Romero [INAOE, México]

58. Surface Waves Propagation on the Interface Between the High-Permittivity Dissipative Dielectric Layer and the Double-Negative Metamaterial with Gain
Viktor Galaydych, Mykola Azarenkov, Volodymyr Olefir, and Oleksandr Sporov [V. N. Karazin Kharkiv National University, Ukraine]

59. Plane Wave Diffraction by PEC – DNG Metamaterial Junctions in Non-Planar Arrangements
Giovanni Riccio, and Gianluca Gennarelli [University of Salerno and I.R.E.A. - C.N.R., Italy]

60. Controlling Energy Spectra and Whispering Gallery Modes of Electrons in a Few Electrons Lateral Quantum Dot
Shahab Ramezanpour, Alexander Mintairov, and Andrey Bogdanov [Saint Petersburg State University of Information Technologies, Mechanics and Optics, Russia and University of Notre Dame, USA]

61. Tensile and Compressive Properties of 3D Printed Schlegel Perspective Uniform-4-polytope Based Mechanical Metamaterials
Gabrielis Cerniauskas, Parvez Alam [The University of Edinburgh, UK]

62. Study about Shape Conversion for Resonant Tunneling Method for Subwavelength Imaging
Md Anzan-uz-Zaman, Kyungjun Song, and Shin Hur [University of Science and Technology and Korea Institute of Machinery and Materials, Korea (South)]

63. Numerical Study of Acoustic Metamaterial Composites in Higher Dimension
Takamichi Terao [Gifu university, Japan]

64. A semi-analytical method for acoustic phononic crystals by weak formulation
Dongwoo Lee, Minkyung Kim, and Junsuk Rho [Pohang University of Science and Technology, Korea (South)]

65. A Study On Beam Splitting In An Underwater Phononic Crystal With Dirac-like Point
Wonjae Choi, and Jaeyub Hyun [Korea Research Institute of Standards and Science (KRISS), Korea (South)]

66. An Acoustic Frequency Selective Curtain Composed of Thicker and Thinner Membranes and Periodically Connected Elastic Pillars
Yasushi Horii, Wenjia Hong, Airi Tamaki, and Toshiaki Kitamura [Kansai University, Japan]

67. Gravitationally-Small Gravitational Antennas, the Chu Limit, and Exploration of Veselago-Inspired Notions of Gravitational Metamaterials
Thomas Weldon, and Kathryn Smith [University of North Carolina at Charlotte, USA]

68. Energy Gaps And Conservation Of Transmittance Plus Slippage In Poynting Flow And Its Orbital And Spin Parts In The Presence Of Metal-Like Losses
Hyoung In Lee [Seoul National University, Korea (South)]

69. Adjoint-based Topology Optimization Applied to Inverse Design of Nanophotonic Materials
Yannick Augenstein, and Carsten Rockstuhl [Karlsruhe Institute of Technology, Germany]

70. Enhanced Magneto-Optic Response of the Ultrathin Iron-Garnet Films
Olga Borovkova, Miguel Levy, A.A. Voronov, Mikhail Kozhaev, Ashim Chakravarty, Hisham Hashim, Brandon Blasiola, Dolendra Karki, Colin Sheidler, François Jomard, S.A. Dagesyan, Elena Popova, Niels Keller, and Vladimir Belotelov [Russian Quantum Center and National University of Science and Technology (MISIS) and Moscow State University, Russia, and Michigan Technological University, USA, Radboud University, Netherlands, Université Paris-Saclay, France]

A8 Special session: Topological band gaps in metamaterials IV

Hall: A **Chair:** Massimo Ruzzene

16:00 Bound States, Reflection and Topology (Invited)

Simon Horsley [University of Exeter, UK]

I shall discuss new applications of topology to the design of electromagnetic materials, showing that the Atiyah–Singer index theorem determines the existence of modes in inhomogeneous media via material properties at the edge of the device.

16:30 Enhanced Transmission in Non-Hermitian One-Dimensional Photonic Crystals Under Topological Phase Transition

Vladimir Novikov, and Tatiana Murzina [M. V. Lomonosov Moscow State University, Russia]

We study the light transmission through absorbing one-dimensional photonic crystals at the Laue diffraction scheme. The considered structure is designed to demonstrate topological phase transition associated with the changing of the symmetry of the eigenstates of electromagnetic modes. We showed that photonic crystal demonstrates enhanced transmission and pronounced features of frequency-angle transmission spectrum associated with topological phase transition.

16:45 Experimental Realization of Topologically Protected Photonic Modes in Composite Quantum Hall/Quantum Spin Hall Waveguides

Shukai Ma, and Steven Anlage [University of Maryland, USA]

Experimental demonstration of bianisotropic meta-waveguides consisting of quantum spin Hall and quantum Hall interfaces supporting backscatter-free and uni-directional electromagnetic modes.

17:00 Constructing symmetry-protected valley-Hall networks in photonic and phononic systems

Mehul Makwana, Richard Craster, Sebastien Guenneau, Kun Tang, Patrick Sebbah, and Gregory Chaplain [Imperial College London, UK, and CNRS, France, and Bar-Ilan University, Israel]

Predictive theory to geometrically engineer materials in continuum systems to have desired symmetry-induced effects is developed here by bridging the gap between quantum and continuum descriptions. We emphasise a predictive approach, the strength of which is demonstrated by the ability to design well-defined broadband edge states and valley-Hall networks. The design of these valley-Hall networks are contingent upon properties specific to the underlying geometries chosen. To achieve complete control over the flow of light, power division and redirection devices are required, of which beam-splitters are those most commonly utilised. We hope that the additional degrees of freedom afforded by our designs, in addition to the topological robustness of the modes, will result in its assimilation into practical devices.

17:15 Violation of The Bulk-Surface Correspondence Principle in Topological Photonics

Vasily Klimov [Lebedev Physical Institute, Russia]

We have derived exact analytical description of waveguide made of chiral hyperbolic metamaterial. It allows us to investigate topologically protected surface states in details and to demonstrate violation of bulk-surface correspondence principle in topological photonics.

C8 Non-reciprocal metamaterials I

Hall: C **Chairs:** Kosmas Tsakmakidisr

16:00 Breaking Time-Reversal Symmetry Within Infinitesimal Dimensions Through Staggered Switched Networks

Negar Reiskarimian, Mykhailo Tymchenko, Andrea Alu, and Harish Krishnaswamy [Columbia University and Massachusetts Institute of Technology, and University of Texas at Austin and City University of New York, USA]

Here we report on our recent results on breaking time-reversal symmetry in infinitesimal dimensions by exploiting spatio-temporal modulation in staggered switched networks. We demonstrate nonreciprocal components such as isolators that can be built exclusively based on switched capacitor networks which exhibit a quasi-electrostatic wave propagation mode with extremely slow wave velocity when operated in a previously unexplored regime between the traditional ”sampling” and ”filtering” regimes. An extremely compact ”inductor-less” isolator with an overall size of λ/3600xλ/1600 has been built in a 65nm CMOS IC fabrication process and provides <2 dB loss and up to 30 dB isolation.

16:15 Non-reciprocal Metasurfaces Using Magnetochiral Effects At Optical Frequencies

Satoshi Tomita, Nobutaka Ohnishi, Hiroyuki Kurosawa, and Hisao Yanagi, [Tohoku University and NAIST and NICT, Japan]

We numerically study non-reciprocal light transmission through magnetochiral metasurfaces. The metasurfaces consisting of planar plasmonic gammadion nanostructures on a magnetic garnet film gives rise to the directional birefringence, referred to as the magnetochiral effect. The present study opens a door to a non-reciprocal polarization-independent one-way mirror in visible and near-infrared regions.

16:30 Plasmonic Thouless Pump

Zlata Cherpakova, and Stefan Linden [Universität Bonn, Germany]

We report on the observation of quantized transport of SPPs in a Thouless pump consisting of periodically modulated plasmonic waveguides. The samples are fabricated by negative-tone gray-scale electron beam lithography. The SPP intensity evolution in real and Fourier space is recorded by leakage radiation microscopy.

16:45 Angle-Independent Nongyrotropic Metasurfaces

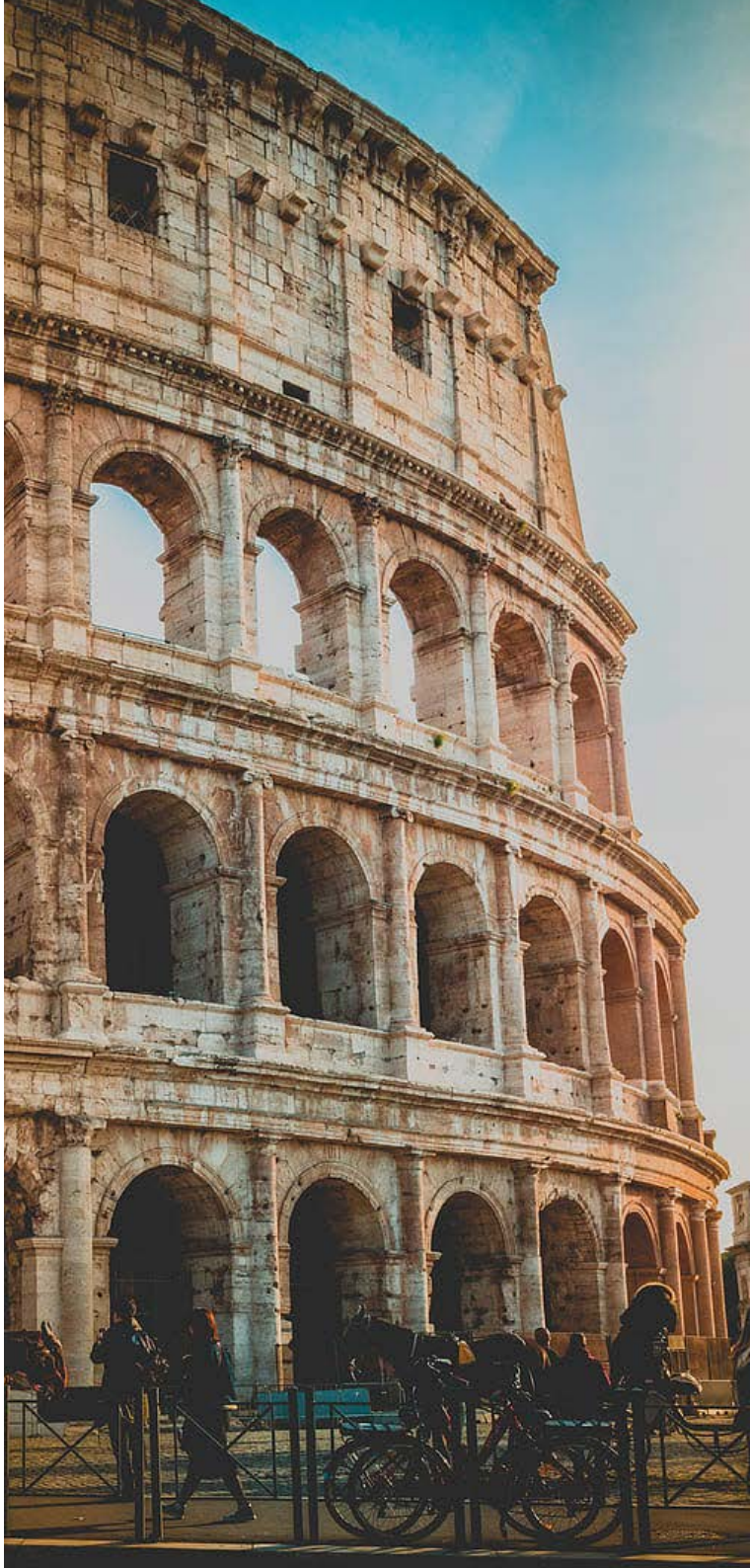
Guillaume Lavigne, and Christophe Caloz [Polytechnique Montreal, Canada]

We derive a general condition for angle-independent bianisotropic nongyrotropic metasurfaces and present two applications corresponding to particular cases: an angle-independent absorber/amplifier and an angle-independent spatial gyrator.

17:00 Hidden Time-Reversal Symmetry in Optical Systems (Invited)

Mario Silveirinha [University of Lisbon, Portugal]

The reciprocity of dissipative systems is typically justified by the microscopic reversibility of physical processes. Here, I show that it is unnecessary to invoke microscopic arguments to establish a direct relation between “macroscopic” reciprocity and time-reversal invariance. Furthermore, I will discuss novel mechanisms that lead to a hidden time-reversal symmetry in optical systems.



D8 Optical metamaterials II

Hall: D **Chairs:** Andrei Lavrinenko

16:00 Novel Avenues for Optical Antennas

Hongyue Wang, Abdelhanin Aassime, Xavier Le Roux, Nick J. Schilder, Jean-Jacques Greffet, and Aloyse Degiron [Univ. Paris-Sud and CNRS and Univ. Paris-Saclay and Univ. Paris-Diderot, France]

Optical antennas have become ubiquitous tools to enhance the spontaneous emission of atoms, molecules and quantum dots. The designs rules that have been established over the years are based on the understanding that optical antennas operate through the Purcell effect. We show that this paradigm fails for ensembles of interacting emitters and that a statistical framework is required to understand their interactions with optical antennas. We illustrate these findings with assemblies of PbS nanocrystals in direct contact with arrays of metal nanoparticles and show that these structures have an interesting potential as optoelectronic metamaterials.

16:15 Resonant Transmittance of Asymmetric Array of Optical Cavities

Rodion Kononchuk, Ilya Vitebskiy, Andrey Chabanov [University of Texas at San Antonio and Air Force Research Laboratory, USA]

We thoroughly investigate the electromagnetic response of intelligent Resonant transmittance of an asymmetric pair of optical cavities with accidental spectral degeneracy can be strongly suppressed, within broad frequency range, by a small nonlinearity or a small change in the direction of incidence.

16:30 Ballistic Metamaterials (Extended)

Evgeniy Narimanov [Purdue University, USA]

Ballistic metamaterials, metal-dielectric composites with the unit cell size smaller than electron mean free path, represent a new class of composite media with many unique properties, such as hyperbolic response above the plasma frequency.

17:00 Optical Second Harmonic Generation in Cobalt Nanolayers Influenced by Nonmagnetic Heavy Metals

Tatiana Murzina [Moscow State University, Russia]

Optical second harmonic generation (SHG) is used to study magnetic properties of planar nanostructures based on ferromagnetic and heavy metals. Based on the SHG magnetic field dependencies, we show clear differences in the magnetic behavior of the interfaces and of bulky materials attributed in part to interfacial chiral magnetization.

17:15 Polarizing Beamsplitter Grating based on Asymmetric Slot Waveguide Scatterers

Ashutosh Patri, Stephane Kena-Cohen, and Christophe Caloz [Polytechnique Montreal, Canada]

We demonstrate a novel design for grating-based polarizing beamsplitters. The structure has a subwavelength thickness and is engineered to suppress all diffraction orders except for those of the desired orthogonal polarizations. This is achieved by using an asymmetric slot waveguide scatterer unit cell to ensure polarization-selective directional scattering.

THURSDAY

9:00 Plenary session IV

10:00 Coffee

	Hall A	Hall B	Hall C	Hall D
10:30	**A9**	**B9**	**C9**	**D9**
	Special session: Time-varying meta-materials IIs	*Acoustical and mechanical meta-materials III*	*Cloaking*	*Special session: Meta-materials for life-science applications II*
12:30	**Lunch**			
14:00	**A10**	**B10**	**C10**	**D10**
	Fabrication and experiment II	*Non-reciprocal meta-materials IIs*	*Extreme parameters*	*Modelling II*
15:30	**Coffee**			
16:00	**A11**	**B11**	**C11**	**D11**
	Plasmonics III	*Special session: Time-varying meta-materials III*	*Acoustical and mechanical meta-materials IV*	*Optical meta-materials III*

18:00 Closing Ceremony

18:30

Plenary session IV

Hall: A **Chair:** Martin Wegener

9:00 Nonlinear, Tunable and Light-Emitting All-Dielectric Metasurfaces

Isabelle Staude
Friedrich Schiller University Jena, Germany

All-dielectric metasurfaces have been established as a versatile platform for manipulating light fields at the nanoscale. While initial research efforts were concentrated on purely passive structures, all-dielectric metasurfaces also hold a huge potential for dynamic control of light fields, as well as for tailoring light emission processes, such as spontaneous emission and nonlinear frequency generation. This talk will review our recent advances in nonlinear, tunable and light-emitting all-dielectric metasurfaces..

A9 Special session: Time-varying metamaterials II

Hall: A **Chairs:** Harish Krishnaswamy

10:30 4D Metastructures: Merging Spatial and Temporal Metamaterials (Invited)

Nader Engheta, Victor Pacheco-Pena, Yasaman Kiasat, Mario Junior Mencagli, Ehsan Nahvi, and Brian Edwards [University of Pennsylvania, USA, and Newcastle University, UK]

We are exploring new phenomena and unique features of various mixtures of spatial and temporal metamaterials, providing novel 4-dimensional platforms for light-matter interaction. Several research thrusts are being studied in our group, including the anti-reflection temporal coatings, the effective-medium concepts for temporal metastructures, time-varying metastructures, the static-to-radiative and radiative-to-static field conversions, and freezing and amplifying waves using non-Foster concepts, just to name a few. In this talk, we present the results of some of our ongoing efforts in these areas.

11:00 Metamaterials in Time and Metamaterials With Gain (Invited)

John Pendry, Emanuele Galiffi, and Paloma Huidobro [Imperial College London, UK, and I.T. University of Lisbon, Portugal]

Much of our understanding of material properties is based on energy conservation, or the assumption than energy is not created within the material. Casting aside this assumption opens new possibilities for the response of such materials: input signals can be amplified on transmission, 'superluminal' bands can appear in which the group velocity exceeds the velocity of light in free space. Curiously in many instances input signals neither gain nor lose energy giving little hint that a source of energy is available. Metamaterials with gain and those with time dependence will be discussed with some simple insights.

11:30 Towards Experimental Verification of Zero-reflection from Time-varying Capacitor (Extended)

Silvio Hrabar, Borna Jelacic, Luka Mandic, and Jurica Papak [University of Zagreb, Croatia]

A feasibility of experimental investigation of recently predicated zero-reflection from a time-varying reactive element is analyzed. It is shown that a capacitive bank with commercial CMOS switches is a promising candidate for a hardware demonstrator and preliminary experimental results will be presented at the conference.

12:00 Instantaneous Control of Scattering From a Time-Modulated Meta-Atom

Grigorii Ptitcyn, Mohammad Mirmoosa, and Sergei Tretyakov [Aalto University, Finland]

Time-modulation of material parameters is a powerful tool that enables ultimate control over scattered light. Proper description of scattering from time-modulated materials should be written rigorously in the time domain. This becomes possible if the properties of a single time-varying meta-atom are also considered in the time domain. In this talk we will present a theoretical model which describes a time-variant meta-atom and its interaction with an incident electromagnetic wave. Based on the developed theory, we will present several peculiar applications of time-varying meta-atoms, such as cancellation of scattering and shifting the frequency of the scattered wave.

12:15 Theory of Periodically Time-Varying Induced Exceptional Points of Degeneracy

Hamidreza Kazemi, Mohamad Y. Nada, Robert Marosi, Tarek Mealy, Ahmed F. Abdelshafy, and Filippo Capolino [University of California Irvine, USA]

We present the novel concept of exceptional points of degeneracy (EPDs), which denote a coalescence of multiple eigenmodes, that directly emerge in systems when a linear time-periodic (LTP) variation is applied. Though the presented theory is general, as an example we establish the general conditions that yield an EPD in a single LTP LC resonator with a capacitance that varies periodically in time. We show a potential application of the proposed LTP system in making sensors to exploit the ultra-sensitivity associated with operating at an EPD.

10:30 Effect of hydrostatic pressure on a bubble anechoic metascreen

Margaux Thieury, Arnaud Tourin, Jean Dasse, and Valentin Leroy [Institut Langevin and Thales Underwater Systems and Laboratoire Matière et Systèmes Complexes, France]

Bubble metascreens consist of a single layer of gas inclusions in an elastomer. They can be used as ultra-thin coatings for turning acoustic reflectors into perfect absorbers. The effectiveness of such a coating at a chosen frequency is mainly determined by three parameters: the size of the bubbles, the distance between them, and the rheology of the elastomer. If any of these parameters vary during the use of the coating, the performance is affected. We used numerical simulations to investigate the effect of the static pressure on the acoustic properties of bubble metascreens with spherical or cylindrical inclusions.

10:45 3D bandgaps in hybrid elastic metamaterials

Federico Bosia, Anastasiia Krushynska, Pavel Galich, Nicola Pugno, and Stephan Rudykh [University of Torino, Italy, and University of Groningen, The Netherlands, and Technion–Israel Institute of Technology, Israel, and University of Wisconsin–Madison, USA]

We propose a design strategy for hybrid metamaterials with alternating phononic plates and pentamode units that produce complete bandgaps at low-frequencies for elastic waves, thanks to two different scattering mechanisms. The design strategy can be applied to various configurations of phononic plates with cavities, inclusions or slender elements.

11:00 Experimental Investigation on Density Near Zero Plate-type Acoustic Metamaterial

Matthieu Malléjac, Aurélien Merkel, José Sánchez-Dehesa, Johan Christensen, Vincent Tournat, Vicent Romero-García, Jean-Philippe Groby [Le Mans Université, France, and Universidad Carlos III de Madrid and Universitat Politècnica de València, Spain]

The aim of this work is to experimentally, numerically and theoretically report and characterize the anomalous propagation of sound waves in a one-dimensional periodic system of thin elastic clamped plates emphasizing a hiding zone due to the near zero density regime.

11:15 Scalable Piezoelectric Effect in Silicon Doped Hafnium Oxide for Acoustic Wave Applications

Sven Kirbach [Fraunhofer IPMS - CNT, Germany]

This paper presents the scalability of piezoelectricity in silicon doped hafnium oxide(Si:HfO2). From different thicknesses of 10 nm to 50 nm we obtained piezoelectric coefficients d33,f between 20 pm/V and 10 pm/V. During the cycling procedure a decreasing piezoelectric coefficient d33,f can be observed depending on the total number of cycles. Thus a specific piezoelectric condition can be set appropriating for the desired application.

11:30 Experimental demonstration of a Willis metamaterial for elastic waves (Invited)

Jensen Li [Hong Kong University of Science and Technology, Hong Kong]

Here, we report the realization of Willis coupling on a structured beam with resonating cantilever structures and its resultant asymmetric propagation of flexural waves on such a beam. Willis coupling is the analogy of electromagnetic bianisotropy in elastic waves, which allows cross-coupling between stress and velocity or equivalently between momentum and strain. We will also discuss its extension to active media.

12:00 Characterization of Phase Rigidity in Non-Hermitian Acoustic Systems (Invited)

Guancong Ma [Hong Kong Baptist University, Hong Kong]

By tuning of system parameters, a non-Hermitian system can be driven across a specific point in the parameter space, known as the exceptional point. At the exceptional point, the relevant eigenfrequencies of the system become degenerate, and the eigenvectors become parallel. Such behavior can be captured using a concept called phase rigidity. In this work, we present a theoretical analysis and experimental measurement of phase rigidities of a 2×2 and a 3×3 tight-binding non-Hermitian acoustic system. The 2×2 system is a well-known and well-characterized system that serves as a reference to show the effectiveness of our approach. The 3×3 system can produce an order-3 exceptional point at which three eigenmodes coalesce. Interestingly, we found that among the three eigenmodes, two approach the exceptional point with the same critical exponent and the same slope, whereas the third one has a different slope.

C9 Cloaking

Hall: C **Chairs:** Tommaso Isernia

10:30 Design of Invisibility Devices Through Artificial Materials: Further Possible Tools from the Inverse Scattering Perspective (Invited)

Roberta Palmeri, Martina Teresa Bevacqua, and Tommaso Isernia [DIIES - Università Mediterranea of Reggio Calabria, Italy]

The design of invisibility devices shows several common traits with inverse problems. In this contribution, some inverse scattering basic concepts are reconsidered to give additional point of views and possible new paths to follow for the design of invisibility devices.

11:00 A Novel 3D Printing Technique for Complex–Structured Metasurface Carpet Cloak

Qingxuan Liang [Xi'an Jiaotong University, China]

A novel fabrication method based on 3D printing and injection molding of liquid metal is proposed to realize a cylindrical metasurface carpet cloak in microwave frequencies. The cloak exhibits good cloaking performance under both Ex and Ey polarization. The technique is flexible and especially suitable to fabricate metasurfaces with arbitrary shape. Moreover, it can be easily scaled to terahertz domain.

11:15 Design of a Compact and Multifunctional Radiating Structure Exploiting the Mantle Cloaking Technique

Fabrizio Andreaus, and Mirko Barbuto [Roma Tre University and Niccolo Cusano University, Italy]

A linear passive plasmonic meta-surface platform is introduced to In this contribution, we investigate the possibility to apply the mantle cloaking technique to radiation platforms consisting of a combination of different antenna types. More specifically, we consider the challenging case of a half-wavelength dipole working in close electrical proximity to an Archimedean spiral slot antenna. We show that by covering the dipole with a suitable cloaking metasurface, it is possible to significantly reduce its blockage on the Archimedean antenna and make it work as if it were isolated. We also show that the same system can be engineered to exploit the aperture antenna as a reflector for the dipole that, thus, can operate as a standard sector antenna. This cloaking application is confirmed by realistic full-wave numerical simulations.

11:30 Active Exterior Cloaking in Three-Dimensional Acoustics

Cheuk-Him Yeung, William Parnell, and Tom Shearer [University of Manchester, UK]

The Kirchhoff integral theorem is exploited to construct an acoustic cloak in three dimensions using a number of active sources. We apply the addition theorem for Bessel functions to replace the continuous source distribution by multipolar point sources. Expressions for the multipole amplitudes are derived for certain uniform source arrangements.

11:45 Novel wave phenomena to be identified on artificial soils made of deep piles

Stephane Brule, Stefan Enoch, and Sébastien Guenneau [Institut Fresnel, France]

In very particular cases of soil conditions, some authors evoke the phenomenon of "double resonance" during an earthquake. The seismic signal induces the resonance of the sediments filling the basin, causing the selective resonance of the buildings at the ground free surface. However, buried and slender structures in very soft soil, such as deep piles, can also be solicited on their first fundamental modes. This local resonance effect is essential in the feasibility of seismic metamaterials.

12:00 Controlling Seismic Elastic Surface Waves via Interacting Structures (Extended)

Bogdan Ungureanu, Sébastien Guenneau, Stéphane Brûlé, and Richard Craster [Imperial College London, UK, and Aix Marseille Univ., France]

We present some recent research advances on controlling elastic surface waves in thin and thick plates, this is aimed at understanding the seismic wave trajectories in soils structured with buildings. We show the influence of building interactions on surface and body waves when a significant proportion of soil is replaced by inclusions with different densities and Lamé coefficients acting as building foundation, raising the question of the effective dynamic properties of these smart soils. One of our objectives is to improve the control of seismic waves by taking into consideration the in-plane twisting motion of local helical resonators.

D9 Special session: Metamaterials for life-science applications II

Hall: D **Chairs:** Giuseppe Strangi

10:30 Design of Frequency Selective Devices for the THz Domain with Applications on Structural Health Monitoring

João Pedro Pavia, Marco Alexandre Ribeiro, and Nuno Souto [Instituto de Telecomunicações/ISCTE-IUL, Portugal]

In this paper, a study on the transmittance as a function of applied force for a new THz sensor is proposed. The sensor consists of two frequency selective surfaces (FSSs) based on metamaterial wire resonators and works as a re-configurable selective THz filter in which only radiation of certain desired frequencies is allowed to pass. Numerical modelling of both the mechanical and electromagnetics behavior of the sensor is reported for a device assembled with a High-Density PolyEthylene (HDPE) thermoplastic polymer host at a target frequency of 408 GHz.

10:45 Meta-optics inspired configurations for magnetic resonance imaging applications

Carlo Rizza, Marco Fantasia, Elia Palange, Marcello Alecci, and Angelo Galante [CNR-SPIN and University of L'Aquila, Italy]

We deal with the topics of the metamaterial-based systems in the field of magnetic resonance imaging (MRI). We show our recent results where we consider a novel and alternative use of a magnetic metamaterial to increase the performances of an RF surface coil in an MRI experiment. We prove that our proposed configuration holds great potential to enhance the MRI signal to noise ratio with respect to the standard setup.

11:00 Metasurfaces For Biosensing and BioImaging (Invited)

Hatice Altug [Swiss Federal Institute in Lausanne, Switzerland]

Nanophotonics has been unveiling a plethora of new optical phenomena, yet a critical issue ahead is the development of novel devices and applications taking advantage of nano-scale effects. Here, I will cover our work on dielectric and plasmonic metasurfaces for biosensing and bioimaging applications and their use in real-world settings.

11:30 Ablation of Deep-Seated Brain Tumors Using Metasurfaces

Mohamad-Javad Haji-Ahmadi, Reza Faraji-Dana, and Christophe Caloz [University of Tehran, Iran, and Polytechnique Montreal, Canada]

We leverage the wavefront shaping capability of metasurfaces to generate optimally focused fields for the ablation of deep-seated brain tumors. We obtain the optimal wavefront profile via the concept of time-reversal focusing and design the corresponding metasurface using the generalized sheet transition condition (GSTC) method. Preliminary simulation for a flat metasurface placed at the back of the head already demonstrate promising focusing resolution compared with conventional hyperthermia techniques.

11:45 Sensing Biological Fluids using Resonating Surface Plasmon Polaritons in the THz Range

Gian Paolo Papari, Can Koral, and Antonello Andreone [Università di Napoli Federico II and INFN Naples Unit,, Italy

We study the sensitivity of two different metagrids to the presence of biological fluids on the surface. When a THz beam impinges on each metagrid capped with a dielectric substrate, peaks in transmission related to the onset of high order surface plasmon polaritons appear and allow to estimate the properties of a guest fluid filling the partition volume with a very high sensitivity, comparable with record literature values.'

12:00 Rapid spectroscopic cytopathology using plasmonic metasurfaces: from drug screens to characterization of flowing cells mixtures (Invited)

Gennady Shvets [Cornell U., USA]

Optical spectroscopy is a powerful technique that allows for label-free, noninvasive, and real time characterization of biomolecules. Compared with other optical techniques that relies on the shift of a single resonance, such as surface plasmon resonance (SPR) sensors and optical-grating-based cell assays, spectroscopic techniques can discriminate between different chemical species and are suited for analyzing complex biological samples. Here, we demonstrate the use of metasurface-enhanced infrared reflection spectroscopy (MEIRS) to observe and characterize live cells cultured on top of the plasmonic metasurface. MEIRS has a penetration depth on the order of tens of nanometers, making it uniquely suited for probing the surface of a cell, and for observing features such as protein expression in the cell membrane and cellular adhesion. This has important implications in the detection of cancer cells through spectroscopic cytology, as cancer cells significantly differ from the normal ones in the expression of membrane proteins and adhesion molecules. In this work, we demonstrate the observation of cancer cell adhesion through IR spectroscopic mapping. Furthermore, we show that MEIRS can be used to observe the effect of different anticancer cocktails. Finally, we demonstrate how metasurfaces can be used as radio-frequency electrodes for differentiated attraction of the cells that act as core-shell nanoparticles with frequency-dependent polarizability. Once attracted from the flow to the metasurface, the cells can be spectroscopically characterized using MEIRS.

A10 Fabrication and experiment II

Hall: A **Chairs:** Anthony Grbic

14:00 Fabrication of freestanding metasurfaces for optical frequencies

Mike Prämassing, Till Leuteritz, Alexander Fassbender, Stephan Irsen, and Stefan Linden [Universität Bonn and Center of advanced european studies and research (caesar), Germany]

We report on the fabrication of freestanding metasurfaces operating at optical frequencies consisting of a 40 nm thick nanostructured gold film. As a first example, we present a metasurface lens composed of V-shaped nanovoids. In the second example, we discuss a metasurface phase plate for the generation of Laguerre-Gaussian beams.

14:15 Advanced in Novel Photonic Materials and Novel Phenomena Enabled by Crystal Growth

Dorota Pawlak, P. Paszke, R. Nowaczyński, K. Szlachetko, P. Piotrowski, M. Tomczyk, K. Sadecka, A. Materna, B. Surma, A. Belardini, J. Toudert, and C. Sibilia [University of Warsaw and Institute of Electronic Materials Technology, Poland, and Sapienza Università di Roma, Italy and Instituto de Óptica, Spain]

Recent advances in development of novel materials enabled by the crystal growth will be presented. This will include such materials as volumetric nanoplasmonic materials in visible and infrared, passive and active nanomaterials. It will also include various unusual phenomena such as metastable photoluminescent defects in nanoplasmonic materials.

14:30 Engineering Structural and Optical Properties of 3D Chiral Dielectric Nanostructures (Extended)

Mariachiara Manoccio, Marco Esposito, Vittorianna Tasco, Massimo Cuscunà, and Adriana Passaseo [University of Salento and CNR-Nanotec, Italy]

In this work we analyzed 3D chiral dielectric nano-helix arrays for nanophotonic devices made with focus electron beam induced deposition. This technique allows to vary the geometrical parameters of the periodic structures providing their action the visible range with high values of circular dichroism. The possibility to modify the structural parameter allow the realization of different geometrical arrangement ranging from chiral photonic crystal-like , to a metamaterial-like structures across intermediate regions between them, opening the way to new nanophotonic applications.

14:45 Using Optical Tweezers to Assemble Micro-spheres within Metamaterials that Achieve Engineered Wave Propagation Properties

Lucas Shaw, Samira Chizari, Miles Lim, Michael Porter, Sydney Austin, and Jonathan Hopkins [University of California, USA]

This work introduces a method to fabricate metamaterials that consist of carefully organized micro-spheres using optical tweezers. Due to the nonlinear stiffness that results at the junction between such micro-spheres, these metamaterials give rise to nonlinear stress-wave propagation properties that enable various applications (e.g., acoustic lenses, sound scramblers, and armor).

15:15 Quantitative Phase Imaging of Plasmonic Metasurfaces

Vlastimil Křápek, Petr Dvořák, Alexander Faßbender, Petr Bouchal, Martin Hrtoň, Jiří Babocký, Filip Ligmajer, Radim Chmelík, Stefan Linden, and Tomáš Šikola [Brno University of Technology, Czech Republic, and Universität Bonn, Germany]

We present two novel real-time, wide-field, and quantitative light-microscopy techniques enabling phase imaging of electromagnetic fields. Coherence-controlled holographic microscopy enables three-dimensional phase imaging of metasurfaces. Quantitative 4th generation optical microscopy is the first diffraction-limited non-scanning phase imaging technique capable to detect a single building block of a metasurface. The performance of the techniques is demonstrated for several metasurfaces.

B10 Non-reciprocal metamaterials II

Hall: B **Chair:** Mario Silveirinha

14:00 Breaking Lorentz Reciprocity to Overcome the Time-Bandwidth Limit (Invited)

Kosmas Tsakmakidis [National and Kapodistrian University of Athens, Greece]

All resonant systems in physics and engineering, independent of their physical implementation, have a bandwidth that is inversely proportional to the decay time. A similar limitation exists for standard slow-light (waveguiding) systems, where the group index (and thus the delay, for a given footprint) is inversely related to the bandwidth. Therefore, resonant or slow-light systems can either store a broad signal for a short time, or a narrow signal for a long time, but cannot achieve large delay for broad bandwidth signals. Here, we discuss our recent work on non-reciprocal optical systems that are not constrained by the delay-bandwidth limit. We show that large and, simultaneously, broadband optical delay is achievable with current optical technology. We discuss the underlying physics of delay and bandwidth in non-reciprocal optical systems and present an experimental implementation, based on a figure-9 cavity. We demonstrate a delay-bandwidth product 30 times above the "fundamental" limit of traditional (reciprocal) systems. Furthermore, we show that the optical pulse can be released after an arbitrary number of round trips, providing the control and tunability lacking from conventional spiral waveguide or fiber loop delay lines.

14:30 N-Way, Ultra-Broadband, Magnetic-Free Non-Reciprocity Based on Angular Momentum Biasing in Commutated Multipath Networks With Infinitesimal Form-Factor (Extended)

Aravind Nagulu, Mykhailo Tymchenko, Andrea Alu, Harish Krishnaswamy [Columbia University and The University of Texas at Austin and City University of New York, USA]

Recent research has revealed the possibility to achieve magnetic-free non-reciprocity using spatio-temporal modulation. Some approaches use traveling-wave-like permittivity modulation along a transmission line or in a resonant ring structure to achieve non-reciprocity. However, small permittivity modulation contrasts result in large device form-factors or narrow bandwidths of operation, along with high insertion loss at high frequencies. More recent approaches leverage much larger contrasts of conductivity modulation available in standard semiconductors processes to achieve drastically smaller form-factors and low-loss non-reciprocity, albeit over narrow operation bandwidths. In this work, we present a novel approach to realize an ultra-broadband, highly reconfigurable, non-reciprocal delay element based on staggered commutation in multipath networks. This topology overcomes the delay-bandwidth product limitations incurred in linear time-invariant systems. We also combine this concept with the angular momentum biasing approach to realize an highly-reconfigurable, ultra-broadband N-port circulator. We corroborate our findings by simulating a 8-path delay element and an 8-port circulator comprised of commutated network with 8 branches.

15:00 Nonreciprocal Phase Gradient Metasurface: Principle And Transistor Implementation

Guillaume Lavigne, and Christophe Caloz [Polytechnique Montreal, Canada]

We introduce the concept of nonreciprocal nongyrotropic phase gradient metasurfaces. Such metasurfaces are based on bianisotropic phase shifting unit cells, with the required nonreciprocal and nongyrotropic characteristics. Moreover, we present a transistor-based implementation of a nonreciprocal phase shifting subwavelength unit cell. Finally, we demonstrate the concept with a simulation of a 6-port spatial circulator application.

15:15 Low-Loss Hexaferrite Self-Biased Microstrip and CPW Circulators

Sumin Joseph, Richard Lebourgeois, Yi Huang, Laurent Roussel, and Alex Schuchinsky [University of Liverpool, UK, and Thales Research & Technology and Thales LAS OME, France]

Newly developed La-Co substituted hexaferrite compounds are explored and used for self-biased microstrip and CPW circulators. The novel materials enable the insertion loss of the Ku band circulators to be reduced for more than a half, while maintaining the high isolation and return loss across 5% frequency band.

C10 Extreme parameters

Hall: C **Chairs:** John Pendry

14:00 Implementation Aspects of Multiresonant Metasurfaces for Broadband Group Delay

Odysseas Tsilipakos, Thomas Koschny, Maria Kafesaki, and Costas Soukoulis [Foundation for Research and Technology Hellas & Ames Laboratory and Iowa State University, Greece, and Ames Laboratory and Iowa State University, USA]

We design multiresonant metasurfaces offering broadband group delay in reflection, based on the spectral interleaving of electric and magnetic Lorentzian resonances. We demonstrate a metasurface at 10 GHz comprising five meta-atoms in a subwavelength unit cell that can delay broadband 700-MHz-wide pulses without distorting the pulse shape.

14:15 Faraday cage of interlaced wire metamaterial becomes transparent

Dmitry Dobrykh, Ildar Yusupov, Dmitry Filonov, Ivan Iorsh, and Pavel Belov [ITMO Universty, Russia]

We study wire metamaterial consisting of two displaced subsets of three-dimensional connected wire media. This very unusual metamaterial supports no-cutoff isotropic longitudinal modes at low frequencies. These modes are bulk plasmons of the medium with extremely high spatial dispersion. We do demonstrate unexpectedly high propagation through a Faraday cage formed by interlaced wire metamaterial due to these modes.

14:30 PT-Symmetric Cladding Layers for high-Q Brewster Modes and Embedded Eigenstates

Zarko Sakotic, Alex Krasnok, Norbert Cselyuszka, Nikolina Jankovic, Andrea Alù [Advanced Science Research Center, City University of New York, United States of America]

In this work we address embedded eigenstates using epsilon near-zero materials and present a strategy to tackle the losses of ENZ materials in order to produce unbounded high-Q resonances with the use of PT-symmetry and the concept of suppressed leakage.

14:45 Propagation of Dirac-cone Modes in Photonic Crystal Slabs

Kazuaki Sakoda, Yuanzhao Yao, Naoki Ikeda, Takashi Kuroda, Takaaki Mano, Hiromi Koyama, and Yoshimasa Sugimoto [National Institute for Materials Science, Japan]

We report the theoretical study on the propagation of Dirac-cone modes in photonic crystal slabs. We focus on the absence of light scattering due to the vanishing refractive index, the beam shape emitted from the slab surface, and the reflection spectra of non-Hermitian systems.

15:00 Phonon-Polaritonic Metasurfaces Based on 2D Materials (Invited)

Rainer Hillenbrand [CIC nanoGUNE, Spain]

Phonon polaritons in 2D materials exhibit ultra-short wavelengths, long lifetimes and strong field confinement, which allows for nanoscale control of infrared light. Here, we discuss real-space nanoimaging of infrared phonon polaritons in boron nitride and molybdenum trioxide metasurfaces, revealing intriguing aspects such as polariton propagation with anomalous wavefronts.

14:00 Menger Fractal Acoustic Metamaterials With Double-Negative Property

Yu Liu, Wenshuai Xu, Meng Chen, Heng Jiang, and Yuren Wang [Chinese Academy of Sciences, China]

We construct new three-dimensional fractal acoustic metamaterials by adopting Menger structure and calculate the effective parameters of them, the results show the structures have excellent double-negative property with a single structure.

14:15 Advanced Control of Invisible Cavity Resonators with Bianisotropic Metasurfaces

Francisco Cuesta, Jingbo Li, Ana Diaz-Rubio, Viktar Asadchy, Steven Cummer, and Sergei Tretyakov [Aalto University, Finland, and Duke University, USA]

Recently, invisible cavities formed by two parallel metasurfaces have demonstrated the ability to support so-called "driven" bound states in the continuum. The existence of these modes allows excitation of non-scattering resonant cavities with strongly enhanced fields inside the resonator volume. These invisible cavity resonators have been proposed for several applications such as sensor enhancement and cloaking. In this work, we propose and analyse invisible cavity resonators formed by two bianisotropic metasurfaces. Our results show that resonant cavities made of bianisotropic metasurfaces allow rather general control of the distribution of field inside the resonant volume between the metasurfaces and offer a possibility to design invisible resonant cavities of arbitrary thickness.

14:30 A Metasurface Based Mode Converter (Extended)

Faris Alsolamy, and Anthony Grbic [University of Michigan, USA]

We report a mode converter using reflectionless metasurfaces. The mode converter consists of five inhomogeneous electric sheets cascaded within a cylindrical waveguide. The sheet profiles are calculated analytically using a modal wave matrix formulation. The modal wave matrices are derived using the Discrete Hankel Transform. The design example is simulated using a commercial electromagnetic solver to verify the proposed design approach.

15:00 Higher Order Huygens' Metasurfaces for Holograms and Perfect Absorbers

Carsten Rockstuhl, Aso Rahimzadegan, Rasoul Alaee, David Dams, Achim Groner, Denis Arslan, Thomas Pertsch, Isabelle Staude, and Ivan Fernandez-Corbaton [Karlsruhe Institute of Technology and Friedrich Schiller University Jena, Germany, and University of Ottawa, Canada]

We consider dipolar-quadrupolar metasurfaces operated in the Huygens' regime. When compared to previously considered dipolar Hyugens' metasurfaces, they offer a much more profound control on the amplitude and phase of the transmitted field. We demonstrate two applications. First, we signify the necessity of quadrupolar moments in the constituents to enable a full 2π phase-shift coverage in the transmitted wave at a fixed frequency. Second, perfect absorbers with quadrupolar constituents are explored.

15:15 Wave Propagation In Poro-elastic Materials Using A Shifted Cell Method For Theory Of Biot

Sepide Ahsani, Claus Claeys, Elke Deckers, and Wim Desmet [KU Leuven, Belgium]

In this paper, we propose a weak formulation for the Biot theory of poro-elastic materials to calculate the dispersion properties of non-trivial realization of porous material. This formulation considers the periodicity within the field variables which are solid displacements and pressure in pores, resulting in a quadratic eigenvalue problem in terms of wavenumber.

A11 Plasmonics III

Hall: A **Chairs:** Stefan Linden

16:00 Plasmon-Exciton Coupling: Light-forbidden Transitions and Quasichiral Interactions (Invited)

Antonio I. Fernández-Domínguez [Universidad Autónoma de Madrid, Spain]

In this talk, we will investigate the impact that light-forbidden exciton We present two plasmon-exciton coupling phenomena emerging due to the deeply sub-wavelength nature of surface plasmon (SP) resonances. On the one hand, the modification of the Purcel and Rabi phenomenology due to light-forbidden exciton transtions in the emitter level structure. On the other hand, the ocurrence of quasichiral, non-reciprocal interactions among circularly polarized emitters on top of a flat metal surface.

16:30 Bi2O3-Ag plasmonic eutectic composite as an example of surface enhanced Raman scattering from volumetric material

Kamil Szlachetko, Piotr Piotrowski, Katarzyna Sadecka, Pawel Osewski, Dobroslawa Kasprowicz, Dorota Anna Pawlak [University of Warsaw and Institute of Electronic Materials Technology and Poznan University of Technology, Poland]

Surface Enhanced Raman Scattering (SERS) is a powerful tool in chemical analysis and characterization of extremely low concentrated materials. Despite many advantages, due to surface nature of SERS, it is limited to locally modified surfaces. At this work we demonstrate enhanced Raman scattering effect from real volumetric plasmonic material Bi2O3-Ag.

16:45 Nonlocality and singular metasurfaces

Fan Yang, Yao-Ting Wang, Paloma Huidobro, John Pendry [Imperial College London, UK]

The far field spectrum of plasmonic metasurface with sharp features is very sensitive to nonlocality in the metal such that the continuous nature of spectrum now becomes discrete and the microscopic nonlocal effects can be unveiled from far field measurements.

17:00 Conformal Transformation in Bowtie Nanoantennas and Nanocavities: Unveiling Hidden Symmetries

Victor Pacheco Peña, Rúben Alves, and Miguel Navarro-Cía [Newcastle University and University of Birmingham, UK]

Bowtie nanoantennas and nanocavities are analyzed using conformal transformation. Their performance is studied in terms of the non-radiative Purcell enhancement and self-induced optical forces experienced by quantum emitters. It is demonstrated how these two geometrically different plasmonic nanoparticles can share the same non-radiative Purcell spectra. This hidden symmetric response is unveiled by properly applying the conformal transformation technique, demonstrating that both nanoparticles share the same transformed geometry.

17:15 Cooperative Energy Transfer Controls the Spontaneous Emission Rate Beyond Field Enhancement Limits

Giuseppe Strangi, Mohamed ElKabbash, Tigran V. Shahbazyan, Jesse Berezovski, and Francesco De Angelis [Case Western Reserve University and Jackson State University, USA, and Istituto Italiano di Tecnologia, Italy]

Here, we demonstrate significant acceleration of quantum emitter spontaneous emission (SE) rate in a plasmonic nano-cavity due to cooperative energy transfer (CET) from plasmon-correlated emitters. The accelerated SE rate exceeds the rate acceleration experienced by individual emitters due to local field enhancement. Plasmon-assisted CET offers unprecedented control over the SE rate and allows to dynamically modulate the spontaneous emission rate at room temperature enabling an SE rate based optical modulator.

17:30 A multiplasmonic sensor of very high sensitivity using hyperbolic chiral sculptured thin film in the prism-coupled configuration

Muhammad Faryad, and Farhat Abbas [The University of Texas at Dallas, USA]

Plasmonic film-coupled nanocubes are used to demonstrate large-area perfect In this presentation, we present a highly sensitive plasmonic sensor using chiral sculptured thin films (STFs) made of a hyperbolic medium in the prism coupled configuration. This sensor can have a sensitivity as high as 6000 degrees per refractive index units of the fluid infiltrating the hyperbolic chiral STF. Furthermore, more than one surface plasmon-polariton (SPP) waves of different sensitivities are available for sensing the same fluid because chiral STFs can support multiple SPP waves.

17:45 Single- and Multi-Channel Nonlinear Phenomena in Resonant Structures Comprising Graphene

Odysseas Tsilipakos, Thomas Christopoulos, Georgios Sinatkas, and Emmanouil Kriezis [Foundation for Research and Technology Hellas and Aristotle University of Thessaloniki, Greece]

We consider single- and multi-channel nonlinear phenomena in resonators comprising graphene to exploit its high third-order nonlinearity. We study optical bistability and four-wave mixing employing a recently developed perturbation/coupled mode theory framework. We find low power requirements and high conversion efficiencies, respectively, highlighting graphene's potential for nonlinear applications.

B11 Special session: Time-varying metamaterials III

Hall: B **Chairs:** Guoliang Huang

16:00 Ultra-Compact, Passive, Reconfigurable, CMOS Circulator-Coupler Based on Commutated Multipath Networks

Aravind Nagulu, Mykhailo Tymchenko, Andrea Alu, and Harish Krishnaswamy [Columbia University and The University of Texas at Austin and City University of New York, USA]

Integrated passives such as couplers typically occupy a substantial area. Various miniaturization techniques based on lumped components, coupled microstrips and active approaches were proposed in the past but have seen limited use due to technological constraints and/or issues of bandwidth, linearity and noise performance. Recent works on reconfigurable quasi-electrostatic wave propagation in commutated multi-path networks have revealed new possibilities to miniaturize reciprocal and non-reciprocal electronic components through temporal modulation without the use of magnetic materials, making them fully compatible with CMOS fabrication. In this work, we propose a single reconfigurable Swiss-Army-Knife electronic device which can be configured to act as a rat-race coupler, a branch-line coupler, or a 3-port circulator. The device is realized using four arrays of commutated shunt capacitors connected in a loop, with four ports attached in between. We corroborate our findings by designing and simulating a prototype device to be implemented in a standard 65nm CMOS process.

16:15 Tailoring non-reciprocity in discretely modulated plates

Emanuele Riva, Gabriele Cazzulani, Matteo Di Ronco, and Francesco Braghin [Politecnico di Milano, Italy]

We investigate nonreciprocal wave propagation in discretely modulated plates using a generalization of the Plane Wave Expansion Method. This new analysis tool allows to compute the band diagram for a wider class of spatiotemporal materials, which are able to break reciprocity principle along different wave propagation directions.

16:30 Space-Time-Coding Digital Metasurfaces

Lei Zhang, Xiao Qing Chen, Shuo Liu, Qian Zhang, Jie Zhao, Jun Yan Dai, Guo Dong Bai, Xiang Wan, Qiang Cheng, Giuseppe Castaldi, Vincenzo Galdi, and Tie Jun Cui [Southeast University, China

We study, theoretically and experimentally, space-time modulated digital coding metasurfaces that enable simultaneous manipulations of electromagnetic waves in both space and frequency domains, including harmonic beam steering/shaping and scattering-signature control. Our results may find interesting applications to a variety of fields, including wireless communications, cognitive radars, adaptive beamforming, and holographic imaging.

16:45 Spacetime-Modulated Metasurface for Spatial Multiplexing Communication

Xiaoyi Wang, and Christophe Caloz [Polytechnique Montréal, Canada]

We present a metasurface that is spacetime-modulated to perform spatial multiplexing. This metasurface is made of a 2D array of patches on a grounded substrate that operates as a mirror with two phase reflection states provided by connecting or disconnecting the patches to the ground with integrated diodes controlled by an external processing unit. Each column of the metasurface is temporally-modulated by a different code from a set of orthogonal codes, which are here Hadamard-Walsh sequences. Compared to conventional spatial multiplexing, this metasurface-based multiplexing technology provides the advantage of requiring only one transmitting antenna rather than an array of antennas with complex, bulky and costly feeding network. The spacetime multiplexing metasurface is demonstrated by successfully routing two data streams to two different users located at different positions. This concept may even more immediately be applied to dynamically deflect incoming waves to different direction of space via the spacetime coding, hence providing an unprecedented technique for tunable generalized reflection-refraction.

17:00 Time-Modulated Metamaterials (Invited)

Andrea Alù [CUNY Advanced Science Research Center, USA]

Spatial and temporal modulations have introduced in recent years exciting new knobs in the context of exotic wave interactions with metamaterials. In this talk, I review some of our recent progress in pushing the boundaries of metamaterial technology through the use of suitable temporal and spatio-temporal modulation schemes. I will focus on opportunities offered by temporal modulation to break reciprocity, enhance bandwidths of operation of devices, and mold the topology of the band diagram in periodic systems. Physical insights into the observed phenomena and opportunities for applications will be discussed during the talk.

17:30 Diffraction Theory of Spatiotemporally Periodic Gratings

Sajjad Taravati, and George V. Eleftheriades [University of Toronto, Canada]

We present the theory of the diffraction of electromagnetic waves by generalized space-time periodic diffraction gratings. It is shown that such gratings produce spatial and temporal diffraction orders, yielding a quite unique diffraction pattern, not seen in conventional spatially periodic diffraction gratings. We show that in contrast with conventional static gratings, space-time periodic diffraction gratings generate both spatial and temporal diffraction orders, where each spatial diffraction order is formed by an infinite set of temporal diffraction orders. Such dynamic gratings offer enhanced functionalities and unique characteristics, e.g., an asymmetric diffraction pattern, nonreciprocal transmissive and reflective diffraction, and enhanced diffraction efficiency. In addition, the theoretical analysis of the structure is supported by time and frequency domain FDTD numerical simulation results.

17:45 Floquet Analysis of a Time-Modulated Metasurface

Francis Salas, Zhanni Wu, Cody Scarborough, and Anthony Grbic [University of Michigan, USA]

A Floquet scattering matrix method is presented for the characterization and design of a time-modulated metasurface. The analysis is applied to a metasurface composed of two tunable, shunt resonators separated by an impedance inverter. The tunable shunt resonators are composed of an inductor and an anti-series varactor pair biased with a time-modulated waveform. The technique is shown to accurately predict the magnitude and phase of the reflected and transmitted voltage and current harmonics.

16:00 Tsunami Lens

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

A removable tsunami lens made of expandable rubber pillars or balloons of acoustic Eaton lenses is proposed theoretically. The lens array creates a stop-band by rotating the incoming tsunami wave and reduces the pressure by canceling each other. The diameter of a lens is order of the wavelength of the tsunami at the coast, that is, a kilometer. Before appearing a tsunami, the Eaton balloons are buried underground near the coast in folded or rounded form. Upon sounding of the tsunami alarm, water and air are pumped into the pillars, which expand and erect the wall above the sea level. After the tsunami, the water and air are released from the pillars, which are then buried underground for reuse. Electricity is used to power the entire process. Numerical simulations with some tsunami models are carried out.

16:15 Acoustic Subwavelength Networks for Waveguiding

Olivier Richoux [Le Mans University, France]

In this work, we demonstrate (both theoretically and numerically) that an acoustic resonant subwavelength three-port can be used to obtain at the same time a symmetric splitter and a symmetric combiner with a perfect transmission despite the presence of losses in the system. The device is composed of waveguides side-loaded by resonant scatterers. The control of the wave is made possible using the interaction of the resonances of each scatterers through the waveguide. Tuning these resonances, this system can provide multi-functionalities with a very small amount of losses during the propagation offering a large panel of applications in the field of acoustic waves routing or manipulation. Two examples of 4-ports system made by the combination of 3-ports systems with prescribed wave guiding properties are shown demonstrating the abilities of this type of systems to route the waves playing with the symmetries of the whole structure.

16:30 Experimental validation of maximal Willis coupling in an acoustic meta-atom

Anton Melnikov, Yan Kei Chiang, Li Quan, Sebastian Oberst, Andrea Alù, Steffen Marburg, and David Powell [Fraunhofer Institute for Photonic Microsystems (IPMS) and Technical University of Munich, Germany, and University of New South Wales, Canberra, Australia, and The University of Texas at Austin and City University of New York, USA]

Willis coupling is the acoustic analog of bianisotropy, representing coupling between the monopolar and dipolar degrees of freedom. It has recently been theoretically demonstrated that there is an upper bound on the strength of this coupling, imposed by the conservation of energy. Here we present a scalable meta-atom design, and experimentally demonstrate that it approaches the theoretical limit for Willis coupling.

16:45 Binary Gas Concentration Sensing Using Acoustic Mach-Zehnder Interferometer Based On Acoustic Spoof Surface Waves

Norbert Cselyuszka, Andrea Alu, Nikolina Jankovic [BioSense Institute, Serbia]

Acoustic spoof surface waves are supported at the interface between a fluid and a corrugated rigid plate, and their dispersion is very sensitive to minute changes in the fluid parameters. Relying on this distinct feature, we design and numerically analyze the acoustic analogue of a Mach-Zehnder interferometer based on acoustic spoof surface waves, and demonstrate its potential for sensing of binary gas mixtures. The design procedure of the Mach-Zehnder gas sensor is presented, together with the structure response for different concentration of carbon monoxide in CO/air mixture, confirming the high sensitivity of the proposed structure.

17:00 All-electric Imaging of Inductance-loaded Tunable Piezoelectric Phononic Plates

Feriel-Hiba Chikh-Bled, Rebecca Sainidou, Pascal Rembert, and Bruno Morvan [University of Le Havre, France]

We study experimentally the frequency response of a one-dimensional piezoelectric phononic crystal plate, structured on both surfaces with thin millimeter-scaled metallic strips, on which electric-inductance loads are applied. All-electric measurements, in good agreement with finite-element calculations, reveal strong coupling of the electric-resonant modes with Lamb-like guided waves propagating in the plate, leading to opening of large avoided-crossing gaps that become tunable through the external choice of the electric circuit characteristics.

17:15 A Numerical Method for Computing the Scattering Matrix by the Boundary Element Method with Applications to Phononic Band Analysis

Kei Matsushima, Hiroshi Isakari, Toru Takahashi, and Toshiro Matsumoto [Nagoya University, Japan]

This paper presents a numerical method for computing scattering matrices of periodic elastic structures using the boundary element method with periodic Green's function. We demonstrate a numerical example of a phononic band calculation as an application of the S-matrix and confirm the effectiveness of our proposed method.

17:30 Deep Sub-wavelength Metamaterials for Sound Absorption for the Reflection and Ventilation Problems (Invited)

Vicente Romero García, Noé Jiménez, Jean Philippe Groby, and Vincent Pagneux [LAUM - UMR 6613 CNRS, France, and Universitat Politècnica de València, Spain]

Acoustic absorbers developed up to now are efficient in the high frequency range with sizes comparable to the wavelength of the frequency to be absorbed. In this talk we discuss acoustic metamaterials based on slow sound and critical coupling conditions showing efficient absorption at low frequencies with deep subwavelength dimensions.

16:00 Generating high performance, topologically-complex metasurfaces with neural networks (Invited)

Jiaqi Jiang, David Sell, Stephan Hoyer, Jason Hickey, Jianji Yang, and Jonathan Fan [Stanford University and Google AI Applied Science, USA]

We show that generative neural networks, combined with topology optimization, are a computationally efficient route to producing high efficiency, topologically-complex metasurfaces across a broad operating parameter space.

16:30 Interaction of quantum states of light with metasurfaces (Invited)

Andrey Sukhorukov [Australian National University, Australia]

We present theoretical and experimental results demonstrating that non-classical multi-photon interferences can be achieved at the subwavelength scale in all-dielectric metasurfaces, and outline new opportunities for ultra-thin quantum imaging metadevices compatible with single-photon sensitive cameras for the manipulation and measurement of multi-photon quantum states for free-space quantum imaging and communication applications.

17:00 Optical Knot Metasurfaces

Xiangdong Zhang, Lei Wang, Weixuan Zhang, and Hongxing Yin [Beijing Institute of Technology, China]

We propose and demonstrate experimentally for the first time that the optical vortex knot can be effectively generated by our designed metasurface device. The size of created optical vortex knot using such a device can be six orders of magnitude smaller than those produced by spatial light modulators.

17:15 A Single-Layer Dielectric Metasurface Enabling Wave Incidence Direction Control

Muhammad Afnan Ansari, Muhammad Qasim Mehmood, Inki Kim, Muhammad Hamza Waseem, Tauseef Tauqeer, Selcuk Yerci, and Junsuk Rho [University of the Punjab and University of Engineering and Technology, Pakistan, and Middle East Technical University, Turkey, and Pohang University of Science and Technology, Republic of Korea]

Multi-layer three-dimensional (3D) metamaterials have emerged as a platform to realize multifunctional chiral devices such as for asymmetric transmission. However, the alignment and fabrication methods of 3D chiral metamaterials are quite complex and time consuming, which deteriorate the pragmatic use of such devices. Here, a unique type of direction-controlled single-layer metasurface hologram consisting of low-loss hydrogenated amorphous silicon meta-atoms is proposed. The hologram behaves like a chiral metasurface and generates two unique holographic images in the forward and backward directions. The observed direction-sensitivity is explained by the spin dependent multiplexing of two independent single layer metasurfaces. Our proposed metasurface has an obvious advantage over multi-layer chiral structures in terms of ease of fabrication, robustness, scalability, and cost-effectiveness. Finite difference time-domain simulations proved the feasibility of direction-controlled all-dielectric holograms with high transmission efficiency in the visible domain. Due to the relatively easy manufacturing method utilized and novel functionality, this work can empower practical applications using direction-dependent integrated functional devices.

17:30 Highly Efficient All-dielectric Metasurfaces for Airy Beam Generation

Hammad Ahmed, Arbab Abdur Rahim, Nasir Mahmood, Muhammad Mahmood Ali, Husnul Maab, and Muhammad Qasim Mahmood [Ghulam Ishaq Khan Institute of Engineering Sciences and The University of Lahore and Technology and Information Technology University of the Punjab, Pakistan and University of Limerick, Ireland]

A highly efficient all-dielectric metasurface based Airy beam generation via simultaneous amplitude and phase modulation of the transmitted wave by controlling the rotation angle of silicon nanorods.

17:45 Metamaterials for Generating Space-Time Coupled Few-Cycle Pulses

Apostolos Zdagkas, Huifang Zhang, Tanchao Pu, Vassili Savinov, Nikitas Papasimakis, and Nikolay Zheludev [University of Southampton, UK]

Flying Doughnuts are exact propagating solutions of Maxwell equations in the form of single-cycle, space-time non-separable pulses with complex topology of spectrally broadband vortices. We present the experimental generation of Flying Doughnut pulses and discuss their topological and spatiotemporal structure.

Student Paper Competition

Following the tradition of past editions, particular attention will be paid to the student achievements. This comprises Bachelor, Master, or PhD students. A total of 24 students participated in the competition, and after a careful evaluation process, 5 students were selected as finalists. The selected finalists are:

Zoe-Lise Deck-Leger
Polytechnique Montreal, Canada
"Comprehensive Description of Spacetime Crystal Bandgaps"

Tongjun Liu
University of Southampton, UK
"Imaging of High-Frequency Motion in Artificial Nanostructures"

Elena Mikheeva
Aix Marseille Univ., France
"Phase-Gradient Metasurfaces Based on a Photosensitive Chalcogenide Glass"

Zarko Sakotic
BioSense Institute, Serbia
"PT-Symmetric Cladding Layers for high-Q Brewster Modes and Embedded Eigenstates"

Farzad Zangeneh-Nejad
EPFL, Switzerland
"Solving differential equations with topological acoustic metamaterials"

The Student Best Paper Awards will be announced during the Closing Ceremony on Thursday, September 19.

European School on Metamaterials

20 September - 21 September, 2019

Spatial, temporal and phase control in Metamaterials and Metasurfaces: New frontiers in wave tailoring

The course will be focused on emerging engineered artificial materials whose electromagnetic, optical and acoustic properties are dynamically controlled in space, time and phase. The recent interest in this topic is motivated by the possibility to engineer both the spatial and temporal characteristics of the wave interacting with these materials almost at will, opening up possibilities to envision new wave phenomena and create new devices.

Lecturers:

Andrea Alù (CUNY Advanced Science Research Center, USA)

Mirko Barbuto (Niccolò Cusano University, Italy)

Isabelle Staude (Friedrich Schiller University Jena, Germany)

Nader Engheta (University of Pennsylvania, USA)

Davide Ramaccia ("RomaTre" University , Italy)

Vicent Romero-García (Le Mans Université, France)

Sergei Tretyakov (Aalto University, Finland)

SOCIAL EVENTS

Monday, September 16, at 18:00–19:30

Prof. Victor Veselago Memories. *Some memories in honor of Prof. Victor Veselago will be shared by Konstantin Simovski, Sergey Bozhevolnyi and Alexandra Boltasseva at Hall A.*

Welcome Reception *at the Congress venue, right after the end of the sessions and Prof. Victor Veselago Memories. 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 appetizers will be served..*

Wednesday, September 18, at 19:00–22:30

Gala Dinner. *The conference dinner will take place at at the magnificent Villa Quintili starting at 19:00 and departure by busses will start at 18:00 from the Congress venue. Villa Quintili is a magnificent historical residence with 200 years of history. Located in the heart of Appia Antica and close to the nymphaeum of what was once the residence of the consuls Sesto Quintilio Valerio and Condiano, Villa Quintili is a jewel set among the superb and majestic beauty of Imperial Rome.*

Workshop

Application of EM and acoustic metamaterials for sensing and actuating technologies

Thursday, September 19 from 10.15 to 13.15 in Room E

The workshop will bring together distinguished speakers to present the major results of the NOCTURNO project, but it will be also a unique opportunity to get acquainted with the latest achievements in the fields of electromagnetic and acoustic metamaterials and their application in sensing technologies. Some of the topics that will be addressed are bounded state in continuum, parity-time symmetry, and acoustic surface spoof plasmons, as well as how they can be applied for advanced sensing devices.

NOCTURNO project - Non-Conventional Wave Propagation for Future Sensing and Actuating Technologies is funded through H2020-MSCA-RISE programme, and it focuses on development of sensors and actuators based on non-conventional propagation of acoustic waves in artificial media, electromagnetic/optical sensors based on metasurfaces, and advanced manufacturing technologies with the aim to provide practical solutions for the fabrication of novel acoustic and metasurface-based sensors and actuators. The project consortium comprises renowned research groups from BioSense Institute, Serbia, École Polytechnique Fédérale de Lausanne, Switzerland, University of Birmingham, UK, City University of New York and University of Texas at Austin, USA, Australian National University, Australia, University of Sofia, Bulgaria, and one SME - Plasmore, Italy.

nocturno

List of speaker and lectures:

Prof. Hatice Altug, EPFL, Swiss Federal Institute in Lausanne, Switzerland	Optical Metasurfaces for Biosensing and Biolmaging
Prof. Andrea Alù, The City University of New York, USA	Metamaterial technology for sensing
Dr Oubo You, University of Birmingham, United Kingdom	Topological metamaterials
Prof. Andrey Sukhorukov, Australian National University, Australia	Enhanced Polarization Sensing with Non-Hermitian Metasurfaces
Dr. Bakhtiyar Oraybayev, EPFL, Swiss Federal Institute in Lausanne, Switzerland	Time modulated sensors based on PT symmetry physics
Dr Nikolina Jankovic , BioSense Institute, Serbia	Dispersion control of spoof-fluid-spoof acoustic waveguides by external pressure, and their application in wave manipulation and gas sensing
Prof. Franco Marabelli, University of Pavia, Italy	Looking for signal enhancement and tunability on sensor oriented plasmonic gratings
Prof. Nikolay Zografov, Sofia University "St. Kliment Ohridski" Faculty of Physics, Bulgaria	Biosensing on Metasurfaces - Ellipsometric Assay

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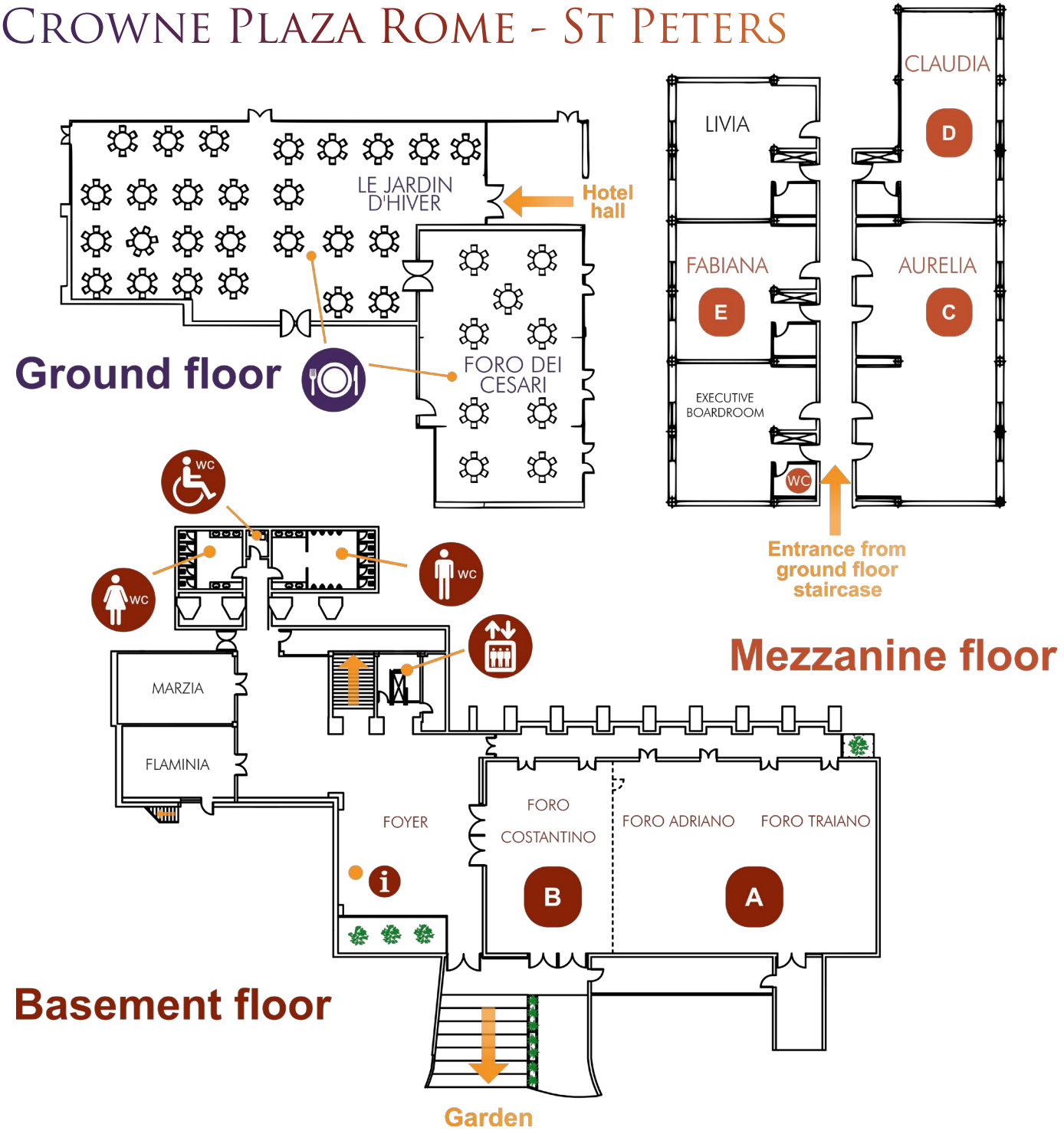

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Metro station line A Battistini - Anagnina (to the centre and Termini railstation)

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