Queen Mary
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meta morphose

The Third International Congress on Advanced Electromagnetic Materials in Microwaves and Optics

METAMATERIALS 2009
London 30th Aug – 4th Sept


SOPHOCLES

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Foreword

Sergei Tretyakov
General Chair

Alexander Schuchinsky
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Filiberto Bilotti
Chair of the Steering Committee

It is our great pleasure to welcome you to the Third International Congress on Advanced Electromagnetic Materials in Microwaves and Optics (Metamaterials 2009), initiated by the European Network of Excellence Metamorphose and organized by the Virtual Institute for Artificial Electromagnetic Materials and Metamaterials (Metamorphose VI).

This series of events brings together and continues the traditions of the highly successful series of International Conferences on Complex Media and Metamaterials (Bianisotropics) and Rome International Workshops on Metamaterials and Special Materials for Electromagnetic Applications and Telecommunications. International Conferences on Complex Media and Metamaterials had eleven editions, with the names "Chiral", "Bi-isotropics", or "Bianisotropics", reflecting the developments in the field of artificial electromagnetic materials. The first two editions of the Congress, held in Rome in October 2007 and in Pamplona in September 2008, have established good traditions which we are happy to follow and develop.

The Congress programme covers a wide area of research, related to artificial electromagnetic materials and surfaces for microwave, terahertz, and optical ranges, and encompasses various aspects of their general theory, modelling, design, applications, fabrication and measurements. It is formed as a balanced set of plenary talks, keynote talks, invited and contributed presentations, all subjected to rigorous peer review. Special sessions address key topical problems.

We would like to thank all colleagues who have helped with the organization of this event and offered their scientific and technical contributions, as well as our sponsoring agencies. The papers in the Congress programme are of the highest standard and address the most challenging problems in this exciting area of Advanced Electromagnetic Materials.

Sergei Tretyakov, *General Chair*
Alexander Schuchinsky, *General Co-Chair*
Filiberto Bilotti, *Chair of the Steering Committee*

Preface

Ari Sihvola
Chair of the Technical Programme Committee

The interaction of electromagnetic waves with metamaterials is a fascinating subject. It extends broadly over the whole electromagnetic spectrum, and even more extended is the range of disciplines that are touched by this new paradigm of metamaterials. Researchers from solid state physics, microwave and antenna engineering, materials science, semiconductor engineering, optoelectronics, classical optics, and nanoscience can have a common focus of interest in metamaterials.

The broadband character of the field of metamaterials is a source of new ideas and nearly unlimited opportunities in tackling scientific problems and their engineering applications. But at the same time it is one of the reasons that made the work of the Technical Programme Committee (TPC) of Metamaterials'2009 Congress extremely challenging. In contrast with more straightforward conference preparation in technically more narrow-scoped areas, in our work we were faced with fuzzy questions on general level. What are fair-enough criteria to evaluate and judge the submitted 314 contributions that come from different traditions? Can we find a common opinion based on diametrically opposite judgments on a given submitted paper? How to create cohesion and order within and between the numerous sessions in the congress, given this volume and variety of input?

Hard work it was indeed. And it could not have been finished without the help of many people. I am grateful to all the members of the TPC for their assistance, work, and support during the past year. The Steering Committee and also the Local Organizing Committee of the Metamaterials'2009 Congress have kept strong interest and participated actively in forming the scientific programme, and deserve thanks for their positive involvement. Our Paper Review Board consisted of 47 experts in various fields of metamaterials. This number sounds large but yet I feel that each expert was loaded with a painfully high number of evaluation requests. In average we received 14 evaluation reports from each reviewer. This I acknowledge with gratitude. To finish, I use this opportunity to thank our technical assistant Valentyna Kanevska for her large efforts in building up and maintaining the Internet platform of the congress, and for help in keeping the contact with the authors, reviewers, organizers, and all committees of the Metamaterials'2009 Congress.

Ari Sihvola, *Chair of the Technical Programme Committee*

A Welcome Message from the Local Organizing Committee

Yang Hao
Chair of the Local Organizing Committee

Ian Youngs
Co-Chair of the Local Organizing Committee

Stefan Maier
Co-Chair of the Local Organizing Committee

Dear Friends and Colleagues
A very warm welcome to Queen Mary, University of London!

The International Congress on Advanced Electromagnetic Materials in Microwaves and Optics is one of the major conferences in the community of Metamaterials. We are very honoured that London is chosen to be the venue to host the conference this year.

Queen Mary, University of London is one of London's and UK's leading research-focused higher education institutions. Amongst the largest of the colleges of the University of London, Queen Mary's 3,000 staff deliver world class degree programmes and research across a wide range of subjects in Humanities, Social Sciences and Laws, in Medicine and Dentistry and in Science and Engineering.

Queen Mary's locations span London's diverse districts. Two of our four campuses are in east London, in the Borough of Tower Hamlets between The City and Canary Wharf, a multicultural and socially diverse area that is one of the most rapidly developing parts of London. We have the advantage of being the London research-focused university closest to the site of the 2012 Olympic Games, only two miles from the Mile End site, our main residential campus.

We wish you enjoy the technical programme as well as your stay at Queen Mary, and do not forget to visit the beautiful city of London during the conference.

Many people have helped in making this conference a success. We would like to take this opportunity to thank our industrial sponsors for their generous support. We also wish to warmly thank the local committee members: Prof. Clive Parini, Themos Kallos, Christos Argyropoulos, Anestis Katsounaros, Di Bao, Wenxuan Tang and Khalid Rajab among others for their assistance in preparing for this conference.

Yang Hao, Queen Mary University of London, *Local Committee Chair*
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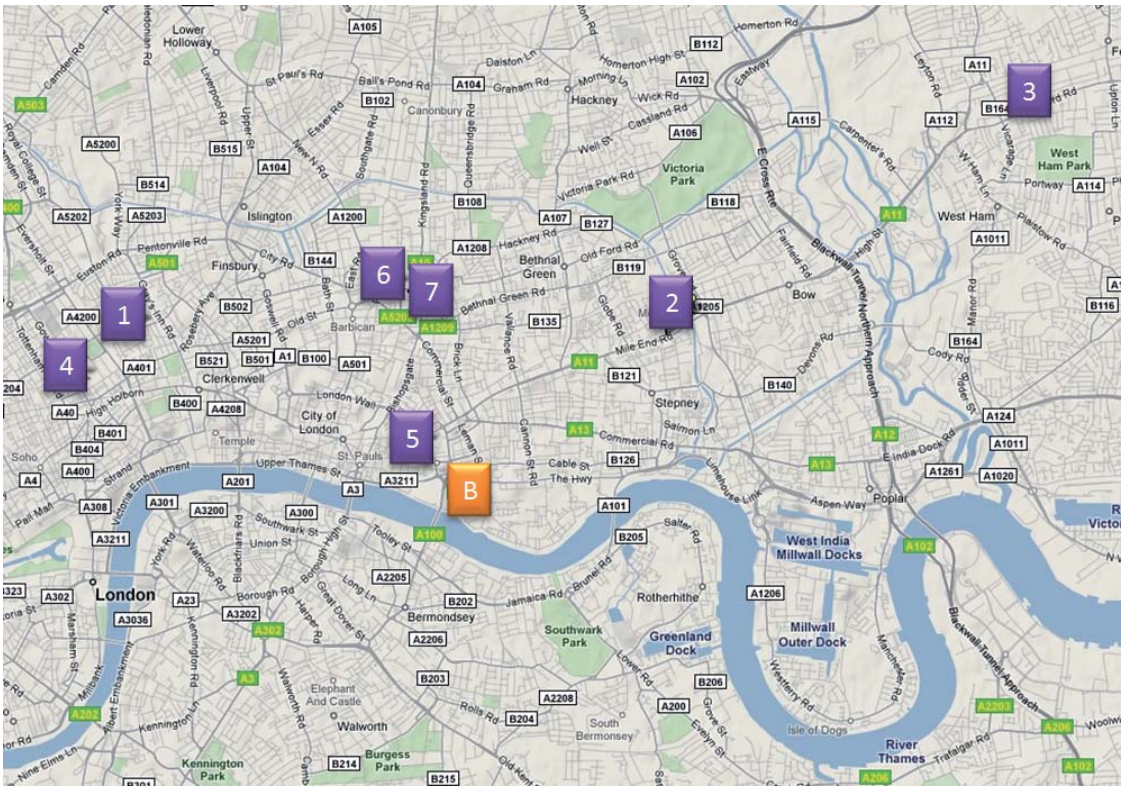
The City of London

London needs little introduction. A world in a city, a sprawling metropolis of over 12 million people, the English capital has always been one of the most dynamical hubs on earth. It is the cultural and financial center of Europe, with enough sights and activities that even locals could never manage to absorb in years.

London is also the first city in history that will host the Olympic Games for the third time, in 2012. Heavy construction is currently underway in the Olympic facilities, which are located around Stratford, just one tube (subway) stop away from the conference location at the Queen Mary campus.

The conference venue is located in London's East End. The East End served as Jack the Ripper's former stomping ground, and while it suffered by poverty in the Victorian era, it is now a predominantly working class area where waves of immigrants have provided the neighborhood with a unique multicultural feel.

We encourage you to take advantage of one of the best public transportation systems in the world and hope that the experiences in the city will be as exciting as the scientific experiences at the Congress.



1: University of London – International Hall
Lansdowne Terrace WC1N 1AS
Russell Square (5 min)

2: Queen Mary Campus – Accommodation
Westfield Way, Mile End E1 4PD
Mile End (5 min)

3: Viking Hotel
162 Romford Rd
E15 4LD
Stratford (20 min)

4: St. Giles Hotel
Bedford Avenue
WC1B 3AS
Tottenham Court Road (5 min)

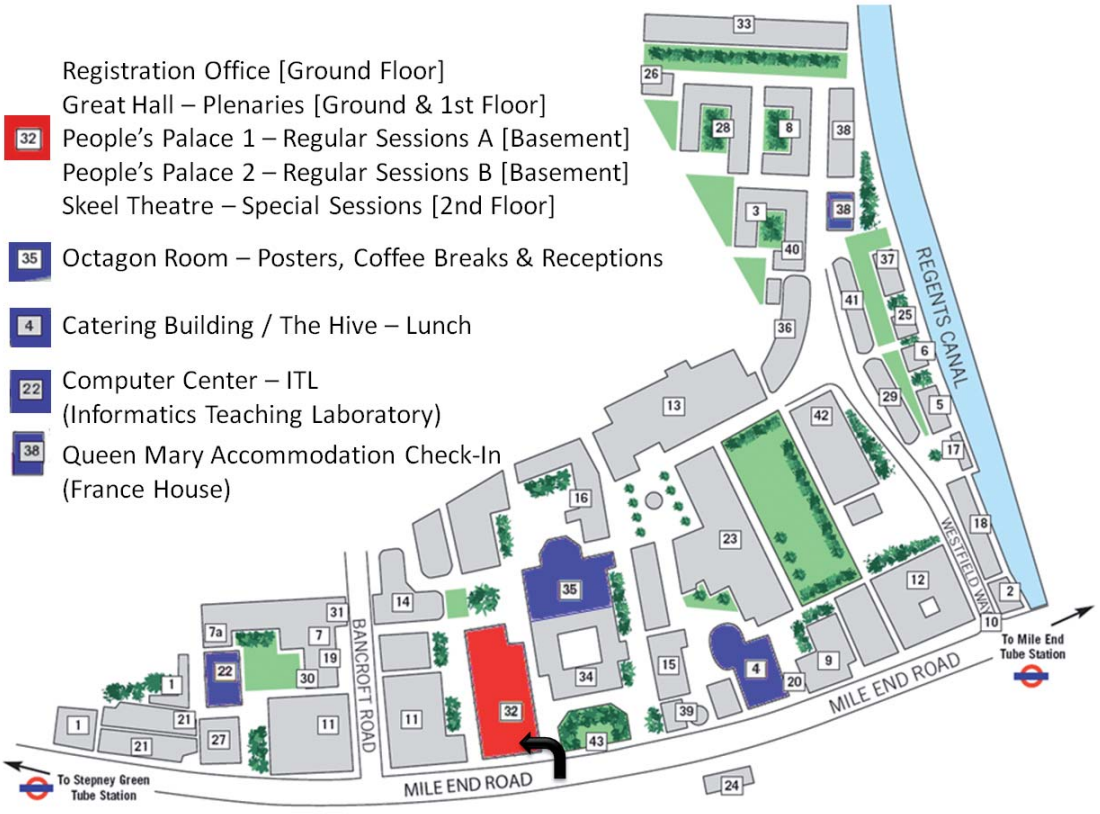
5: Tower Cuoman
St Katherines Row
EC3 M5
Tower Hill (5 min)

6: Holiday Inn Express
275 Old Street
EC1V 9LN
Old Street (10 min)

7: Crown Plaza
100 Shoreditch High Street
E1 6JQ
Old Street (10 min)

B: Medieval Conference Banquet
St. Katherine's Dock
E1W 1BP
Tower Hill (5 min)

Venue – Campus Map



The conference will take place in the historic campus of Queen Mary University of London, located in the east side of London near the Mile End Subway Station (or, as Londoners call their subway, "Tube" Station). The university was founded in the 19th century mid-Victorian era, while the origins of its medical school date as far back as 1123. It provides all the necessary modern facilities to accommodate the Congress, a variety of dining and social options within walking distance, and easy access to the city centre through public transport.

Registration and the scientific meetings will take place at the People's Palace, where four lecture halls are spread among four floors. The building was erected in 1936 and was opened by King George the VI, as his first public engagement. The original People's Palace, built in 1887, provided facilities for recreation, culture, amusement, sport, training and education for the people of East London.

Historic image of the Peoples Palace

The Octagon

Monday
Pre-Registration, drinks, reception & exhibition, 17:00
Where: Octagon Room, Queen Mary Campus

Tuesday
Welcome Cocktail Reception & exhibition, 17:40
Where: Octagon Room, Queen Mary Campus

Wednesday
Sponsored Reception & Exhibition, 17:40
Where: Octagon Room, Queen Mary Campus

Thursday
Tower Bridge & Tower of London Bus Tour, 17:40
(Departing from Bancroft Road on campus)
Conference Medieval Banquet Dinner, St. Katherine's Dock, 19:00

Conference Banquet

The regal banquet takes place by flickering torchlight in the vaulted cellars of Ivory House, just a stone's throw from the Tower of London and Tower Bridge. Accompanying King Henry VIII are fighting knights, strolling players and dancing wenches which provide a magical medieval pageant for your delight. After the show, there is music and dancing, or you could take a two minute walk to Tower Bridge and enjoy a panoramic view of London by night. www.medievelbanquet.com

Awards Announcement

Best poster award in the field of metamaterial antennas
The IET Antennas & Propagation Network Prize will be awarded for the best poster in the field of metamaterial applications in antennas. The award winner will be announced at the closing ceremony of the conference.

Best student paper award
The Conference organizers have run a competition for the best student paper. After a careful evaluation of the applications, the Steering Committee has selected the following finalists of the student paper competition:

Angela Demetriadu, Anthony Murphy, Wei Hsiung Wee, Claudiu Biris, Rotislav Mikhaylovskiy, Irina Khromova, Charles Croenne

The finalists will present their papers according to the technical program of the conference. In addition, they will give an interactive presentations at the dedicated poster session (Friday 4 Sept., 10:40-11:40). The members of the Steering Committee will select the winner. The award, which is sponsored by the Journal Metamaterials published by Elsevier, will be announced at the closing ceremony of the conference. Further sponsorship is provided by IET, Artech House and Cambridge University Press.

Registration
9:00 (Registration Office)

Opening Ceremony
10:20 (Great Hall)
Session chairperson(s): Yang Hao

Plenary session I
10:40 (Great Hall)
Session chairperson(s): Yang Hao

10:40 - **Transformation optics at optical frequencies**[Plenary]
Author(s): John Pendry, *Imperial College London, United Kingdom*

Abstract: Transformation optics tells us how a distortion of space, and the objects it contains, maps into changes of the effective electric and magnetic responses of the distorted materials. This can be exploited to generate new devices from familiar ones. For example it is well known that a slab of negatively refracting material has lens like properties and can focus light. However the images are always of exactly the same size as the objects. This restriction can be lifted by applying transformation optics to create a negatively refracting magnifying lens that also has the property of sub wavelength resolution (see JB Pendry and SA Ramakrishna, J. Phys. [Condensed Matter] 15 6345-64 (2003)). In the exact formulation both electrical and magnetic properties are equally affected by the transformation, but in the near field approximation at optical frequencies we can neglect the magnetic component. This leads to some novel devices that will be described in this talk.

Bio: John Pendry has worked at the Blackett Laboratory, Imperial College London, since 1981. He began his career in the Cavendish Laboratory, Cambridge, followed by six years at the Daresbury Laboratory where he headed the theory group. He has worked extensively on electronic and structural properties of surfaces, developing the theory of low energy diffraction and of electronic surface states. In 1992 he turned his attention to photonic materials and developed some of the first computer codes capable of handling these novel materials. This interest led to his present research concerning the remarkable electromagnetic properties of materials where the normal response to electromagnetic fields is reversed, leading to negative values for the refractive index. In collaboration with the Marconi Company he designed a series of 'metamaterials' whose properties owed more to their micro-structure than to the constituent materials. These made accessible completely novel materials with properties not found in nature. Successively metamaterials with negative electrical permittivity, then with negative magnetic permeability were designed and constructed. These designs were subsequently the basis for the first material with a negative refractive index. John Pendry went on to explore the surface excitations of the new negative materials and showed that these were part of the surface plasmon excitations familiar in metals. This project culminated in the proposal for a 'perfect lens' whose resolution is unlimited by wavelength. These concepts have stimulated further theoretical investigations and many experiments which have confirmed the predicted properties. The simplicity of the new concepts together with their radical consequences have caught the imagination of the world's media generating much positive publicity for science in general.

Poster Session I - Theory

11:40 – 12:40 (Octagon Room)

Session chairperson(s): Henrik Kettunen

1 - **Effect of applied magnetic field on the negative refraction in antiferromagnet-semiconductor periodic nanostructures**[Poster]

Author(s): Roland Tarkhanyan, *Institute of Radiophysics and Electronics, Armenia*,
Dimitris Niarchos, *Institute of materials science, Demokritos, Greece*

Abstract: The peculiarities of the negative refraction in periodic multilayered antiferromagnet-semiconductor nanostructures are investigated in the presence of an external magnetic field parallel to the plane of the layers. Effective material tensors are obtained using method of anisotropic homogeneous medium. Dispersion and energetic relations for the mixed magnon-plasmon polaritons are investigated in the case of the Voigt geometry and frequency regions are found where the structure behaves as a left-handed negative-index metamaterial. Analytical expressions for the frequency- dependent phase and group refractive indices are obtained.

2 - **The artificial microwave complex networks designed with dispersive metamaterials: the theoretical case**[Poster]

Author(s): Taner Sengor, *Yildiz Technical University, Turkey*

Abstract: The time and frequency dependence in complex materials are obtained in state space formalism. The convenient transformations for waves in dispersive, anisotropic, and plasma materials are used. The cold plasma is modelled according to the introduced approach. The complex materials are modelled by applying an approach used to define circuit and system elements; i.e., state space method in this paper. The definition of a suitable circuit and/or system element, which we call complex microwave circuit and/or system element, is given by this approach in where the materials having complicated characteristics are involved. Several cases like anisotropic, chiralic, dispersive, complex, and metamaterials, etc. are discussed for suitable designing of complex microwave networks. Both frequency and spatial dependences are considered. Design possibilities to use in commercial systems are studied.

3 - **A one-dimensional magnetic photonic crystal in crossed magnetic and electric fields as a chiral bianisotropic composite**[Poster]

Author(s): Dmitriy Kulagin, *DÓnetsk Institute for Physics & Engineering of the National Academy of Sciences of Ukraine, Ukraine;*
Andrey Savchenko, *DÓnetsk Institute for Physics & Engineering of the National Academy of Sciences of Ukraine, Ukraine;*
Sergey Tarasenko, *DÓnetsk Institute for Physics & Engineering of the National Academy of Sciences of Ukraine, Ukraine*

Abstract: By an example of a semibounded one-dimensional magnetic photonic crystal of easy-axis antiferromagnet–nonmagnetic dielectric type placed in mutually orthogonal dc magnetic and electric fields, conditions are found under which the quadratic magneto-optical interaction leads to a number of anomalies in the reflection and propagation conditions for TM or TE waves.

4 - **Investigation of plane-wave reflection and transmission through the multilayered quasiperiodic semiconductor waveguide**[Poster]

Author(s): Oksana Shramkova, *Institute of Radiophysics and Electronics of the NAS of Ukraine , Ukraine;*
Yevgeniy Olkhovskiy, *Kharkiv National Pedagogical University, Ukraine*

Abstract: The problem of plane-wave reflection and transmission through the periodic and quasiperiodic structures placed into rectangular metal waveguide is studied. The electromagnetic wave is incident at oblique angle from the uniform medium onto the multilayered structure.

5 - **Multipole moments of radiating split ring resonators**[Poster]

Author(s): Vasundara Varadan, *University of Arkansas, USA; Liming Ji, University of Arkansas, USA*

Abstract: In this paper, we study the multipole radiation characteristics of split ring resonators. We demonstrate that multipole moments are induced only at the plasmonic resonance and the strength of the electric and magnetic multipoles is very much influenced by the polarization.

6 - **On the radiation characteristics of the dipole**[Poster]

Author(s): Ketevan Kotetishvili, *Georgian Technical University, Tbilisi, Georgia*
G. Chikhladze, *Georgian Technical University, Tbilisi, Georgia*

Abstract: In presented article a new theory of the short dipole antenna disposed within the material absorbing environment is proposed. The given theory is based on the solution of Hallen's integral equation for the short vibrator – dipole antenna. The solution of this equation presenting the distribution of the axial current through the dipole antenna is found as well, as the radiation characteristic of the short dipole antenna.

7 - **Magnetic multilayered structure as 1D magnetic metamaterial. Spin-wave spectrum and dispersion characteristics**[Poster]
Author(s): Natalya Grigoryeva, *State Electotechnical University, Russia*; Boris Kalinikos, *State Electotechnical University, Russia*

Abstract: We present a dipole-exchange theory of spin waves propagating in a periodic magnetic multilayered structure. The considered magnetic/nonmagnetic multilayered structure exhibits the specific properties of magnetic metamaterial although the spin wave propagation arises only in the plane of magnetic layers. An approximate dispersion relation obtained in analytical form appears to be very useful for investigation of the linear and nonlinear properties of propagating spin waves (SW) in such structures. An analytical theory of the dipole-exchange SW spectrum in such periodic structures is presented and a relation of the main dispersion characteristics with the parameters of the magnetic structure is given.

8 - **Modelling of resonant metamaterial-based transmission lines using circuit theory**[Poster]
Author(s): Seongnam Jang, *Kyunghee University, Korea (South)*; Bomson Lee, *Kyunghee University, Korea (South)*

Abstract: Some closed-form expressions for circuit parameters are derived based on the equivalent circuits for the resonant MTM-TL (open and short). The lumped series resistance and shunt conductance, which explain radiation effects of a unit cell may be found by |S11| (simulated or measured) with open and short terminations, respectively. The EM-simulated results and circuit-simulated results (obtained using extracted circuit parameters) are shown to be in good agreement.

9 - **Scattering and penetrating of microwaves by metallic powders**[Poster]
Author(s): Anton P. Anzulevich, *Chelyabinsk State University, Physics Faculty, Condensed Matter Physics Department, Russia;*
Igor V. Bychkov, *Chelyabinsk State University, Physics Faculty, Condensed Matter Physics Department, Russia;*
Vasiliy D. Buchelnikov, *Chelyabinsk State University, Physics Faculty, Condensed Matter Physics Department, Russia;*
Dmitri V. Louzguine-Luzgin, *WPI Advanced Institute for Materials Research, Tohoku University, Japan*

Abstract: Owing to so-called skin-effect bulk metals can undergo only surface heating due to limited penetration of the microwave radiation. Whereas metallic powders can be penetrated into itself and absorb such radiation and efficiently heat. In this presentation we will tell about mechanisms of scattering and absorbing of microwaves by metallic powders.

10 - **Unusual entanglement transformation properties of the quantum radiation through one-dimensional random system containing left-handed-materials**[Poster]
Author(s): Kaige Wang, *Dept. of Physics, Beijing Normal University, Beijing 100875, China;*
Xiangdong Zhang, *Dept. of Physics, Beijing Normal University, Beijing 100875, China;*
Yunxia Dong, *Dept. of Physics, Beijing Normal University, Beijing 100875, China*

Abstract: In this presentation we report the investigations on the quantum radiation through the multilayer structures containing the left-handed materials based on the Green-function approach to the quantization of the phenomenological Maxwell theory. Emphasis is placed on the effect of randomness on the generation and transmission of entangled-states. It is shown that some unusual properties appear for the present systems in comparison with those of the conventional dielectric structures. The quantum relative entropy is always enhanced with the increase of random degree due to the existence of nonlocalized mode in the present systems, while the maximal entanglement can be observed only at some certain randomness for the conventional dielectric structures. In contrast to exponential decrease in the conventional systems, the entanglement degrades slowly with the increase of disorder and thickness of the sample near the nonlocalized mode after transmission through the present systems. This will benefit the quantum communication for long distances.

11 - **External field radiation of plane source from instantly generated plasma**[Poster]
Author(s): Anna Vozianova, *OSA Student Member, Ukraine;*
Alexander Nerukh, *OSA/IEEE Member, Ukraine*

Abstract: Creation of surface quasi-plasmon-polaritons at a plane boundary of newly created plasma is considered. The initial field generated by a plane source at an angle to the plasma boundary and parallel to the plasma boundary was considered.

12 - **No-reflection conditions for chiral media**[Poster]
Author(s): Yasuhiro Tamayama, *Department of Electronic Science and Engineering, Kyoto University, Japan*;
Toshihiro Nakanishi, *Department of Electronic Science and Engineering*, Kyoto *University, Japan;*
Kazuhiko Sugiyama, *Department of Electronic Science and Engineering, Kyoto University, Japan;*
Masao Kitano, *Department of Electronic Science and Engineering, Kyoto University, Japan*

Abstract: We study no reflection conditions for a boundary between vacuum and a chiral medium. When the wave impedance and wavenumber of the chiral medium are equal to the corresponding parameters of vacuum, one of the circularly polarized waves is transmitted to the medium without reflection for all angles of incidence.

13 - **UAPO-based diffracted field from non-planar junctions of DNG metamaterial slabs**[Poster]
Author(s): Giovanni Riccio, *University of Salerno, Italy; Gianluca Gennarelli, University of Salerno, Italy*

Abstract: The scattering by a junction of two lossless and isotropic DNG metamaterial slabs joining at arbitrary angle is here considered when illuminated at normal incidence by a plane wave. A Uniform Asymptotic Physical Optics solution for the diffracted field is here proposed.

14 - **Subwavelength electromagnetic imaging of dipole field with metamaterial nanoslab**[Poster]
Author(s): Timo Hakkarainen, *Department of Applied Physics, Helsinki University of Technology, Finland*;
Ari T. Friberg, *Department of Applied Physics, Helsinki University of Technology, Finland*

Abstract: We carry out a detailed analysis of near-field imaging of a point dipole by a lossy, nano-scale metamaterial slab. We derive an analytical expression for the dipole electric field transmitted through the slab, and study numerically the imaging properties, e. g., resolution and brightness, of this system.

15 - **Weakly nonlinear waves in layered bi-anisotropic metamaterials**[Poster]
Author(s): A. D. Boardman, *Joule Physics Laboratory, Institute for Materials Research, University of Salford, Salford, Greater, United Kingdom;*
R. C. Mitchell-Thomas, *Joule Physics Laboratory, Institute for Materials Research, University of Salford, Salford, Greater, United Kingdom*;
Yu. G. Rapoport, *Kiev National University, Physics Faculty, Ukraine*

Abstract: A very general method for deriving nonlinear evolution equations in layered bi-anisotropic metamaterials is presented. Both volume and surface nonlinearities are included and weakly nonlinear waves in a metamaterial are investigated. In particular, frequency bandwidth and nonlinear resonant behaviour are shown to have a strong influence.

16 - **Double-negative (DNG) metamaterials achieved by identical hard spheres randomly dispersed in a matrix**[Poster]
Author(s): Jin Liu, *Department of Materials Science and Engineering, Iowa State University, USA;*
Nicola Bowler, *Department of Materials Science and Engineering, Iowa State University, USA*

Abstract: Conditions for double-negative (DNG) behaviour achieved by randomly dispersed identical hard spheres embedded in a matrix are theoretically investigated. DNG behavior in a random system is possible because the Mie resonances on which the DNG effect relies are a property of the particles themselves rather than of periodicity in their arrangement.

17 - **A uni-directional pulse propagation equation for materials with both electric and magnetic responses**[Poster]
Author(s): Paul Kinsler, *Imperial College London, United Kingdom*

Abstract: I show how only a single assumption is necessary when deriving a completely general uni-directional first-order pulse propagation equation suitable for use in nonlinear metamaterials. In contrast, competing approaches usually rely on several assumptions, some of which require poorly controlled approximations.

18 - **The unit effective refractive index and the reflectance of composite medium with Ag spheroids**[Poster]
Author(s): Sergey Moiseev, *Ulyanovsk Branch of the Institute of Radio Engineering and Electronics, Russian Academy of Sciences, Russia*

Abstract: Optical properties of composite medium consisting of a transparent dielectric matrix with inclusion of silver nanoparticles of various sizes and shapes are investigated theoretically. It is shown that for a certain geometric parameters of constituents, intensity reflection coefficient may be considerably decreased in specified spectral regions of visible or near IR radiation.

19 - **Theoretical investigation of optical properties of metal-dielectric composite media with active component on the basis of exact electrodynamical calculation and Maxwell-Garnett approach**[Poster]
Author(s): Sergey Moiseev, *Ulyanovsk Branch of the Institute of Radio Engineering and Electronics, Russian Academy of Sciences, Russia;*
Sergey Sukhov, *Ulyanovsk Branch of the Institute of Radio Engineering and Electronics, Russian Academy of Sciences, Russia*

Abstract: Theoretical investigation of optical properties of three-dimensional metal-dielectric composite media composed of dielectric matrix and nano-dimensional inclusions is performed. The optical properties of composites are explored including the case when the absorption of propagating wave by dissipative component is completely compensated by amplification in active (lasing) medium. Composite media with inclusions of spherical and nonspherical shapes are considered. The use of exact electrodynamic calculations with the help of computer modeling allows us to perform investigation for the wide range of material and geometrical parameters of composite media. Based on obtained results, the verification of applicability of quasi-electrostatic Maxwell-Garnett model for the calculation of effective optical properties of composite media is performed.

20 - **Transformation optics for a directive antenna**[Poster]

Author(s): Paul-Henri Tichit, *Institut d'Electronique Fondamentale, France;*
Shah Nawaz Burokur, *Institut d'Electronique Fondamentale, France;*
André de Lustrac, *Institut d'Electronique Fondamentale, France*

Abstract: *Spatial coordinate transformation is used as a reliable tool to control electromagnetic fields. In this paper, permeability and permittivity tensors of a metamaterial able to transform an isotropically radiating source to a compact ultra-directive antenna in the microwave domain are calculated. The directivity of this antenna is competitive with regard to conventional directive antennas (horn, reflector antennas) even with its smaller dimensions. Numerical simulations using Finite Element Method (FEM) are performed to illustrate these properties. A reduction of the electromagnetic material parameters is also proposed for an easy fabrication of this antenna from existing materials. Following that, the design of the proposed antenna using a layered metamaterial is presented with simple metal-dielectric structures.*

21 - **Cloaking moving electron beam and relativistic energy loss spectra**[Poster]

Author(s): Xiangdong Zhang, *Beijing Normal University, China*

Abstract: In this presentation we report the investigations on the interaction of ideal and nonideal metamaterial cloaks with an electron beam. The exact solution for the energy loss suffered by a fast electron moving inside or outside the spherical and cylindrical cloaks has been established within a fully relativistic approach. The effect of various imperfect parameters on the efficiency of the cloak has been discussed. It is shown that the radiation can be shielded very well by such cloaks when an electron moves inside or outside the cloaks. The efficiency of nonideal cloaks and the effect of various nonideal parameters on the cloak invisibility can exhibit in spectra of the electron energy loss and radiation emission. This means that the property of the cloaks can be explored by scanning transmission electron microscopy.

22 - **Electrostatic waves in conducting double-wall carbon nanotubes**[Poster]

Author(s): Mikhail Shuba, *Institute for Nuclear Problems, Belarus State University, Belarus;*
Sergey Maksimenko, *Institute for Nuclear Problems, Belarus State University, Belarus;*
Gregory Slepyan, *Institute for Nuclear Problems, Belarus State University, Belarus;*
Akhlesh Lakhtakia, *Nanoengineered Metamaterials Group, Pennsylvania State University, USA;*
Christian Thomsen, *Institut fur Festkorperphysik, Technische Universitat Berlin,* Germany

Abstract: A double-wall carbon nanotube (DWCNT) was modeled as comprising two conducting, concentric, cylindrical shells. After examining the influence of intershell electron tunneling on theoptical properties of a DWCNT, electrodynamic boundary conditions for the DWCNT were formulated. The solution of a boundary-value problem showed that longitudinal electrostatic waves can exist in a DWCNT due to intershell tunneling.

23 - **The effect of spontaneously generated coherence on the group velocity of reflected light and transmitted light from one-dimensional photonic crystals with a dispersive defect** [Poster]

Author(s): Mostafa Sahrai Barenji, *University of Tabriz, Iran*

Abstract: The transmission and reflection of a light pulse through one-dimensional photonic crystals that contain dispersive defect layer doped with three levels-type atom is theoretically investigated. The effect of spontaneously generated coherency (SGC) on the group velocity of the reflected and transmitted pulse is then discussed. It is shown that with applying this coherence, the group velocity of the reflected and transmitted pulse changes from subluminal to superluminal or vice versa.

24 - **Modified single side paired S-ring resonators**[Poster]

Author(s): Muhammad Faisal Khan, *Ghulam Ishaq Khan Institute of Engineering Sciences & Technology, Pakistan;*
Muhammad Junaid Mughal, *Ghulam Ishaq Khan Institute of Engineering Sciences & Technology, Pakistan*

Abstract: Single side paired S-ring resonator (SSP-SRR) exhibits negative permittivity and negative permeability within same frequency band for left handed materials. In this paper, two modified cases of SSP-SRR are presented. Tunability of the resonant frequencies of original and modified SSP-SRR is also discussed using varactors.

25 - **Bulk isotropic negative-index material design for infrared**[Poster]

Author(s): Andrei Andryieuski, *Technical University of Denmark, Denmark;*
Radu Malureanu, *Technical University of Denmark, Denmark;*
Andrei V. Lavrinenko, *Technical University of Denmark, Denmark*

Abstract: We propose a "Split-Cube-in-Carcass" MTM design with negative refractive index -1.5, FOM 2 and transmittivity 30% at the telecom wavelength 1.6 µm. Effective parameters converge fast with slab thickness. The effective parameters retrieval method based on the wave propagation simulation is proposed and compared with standard procedure. It is shown that standard method used for time-domain S-parameters calculations can contain an error connected to transient processes.

26 - **Metamaterials of plasmonic nano-cavity array**[Poster]
Author(s): Masanobu Iwanaga, *National Institute for Materials Science, Japan*

Abstract: Metamaterials of plasmonic nano-cavity array are numerically explored. It is show that the plasmonic metamaterials are effectively high refractive-index and low-loss media of n_eff~4 at propagating resonance in the visible range, and double high refractive index can be obtained by designing the magnetic field distribution in the cavity.

27 - **Diffraction radiation of electromagnetic waves produced by electron current, moving above periodic boundary of metamaterial**[Poster]
Author(s): Nataliya Yashina, *Institute of Radiophysics and Electronics of National Academy of Sciences of Ukraine, Ukraine;*
Petr Melezhik, *Institute of Radiophysics and Electronics of National Academy of Sciences of Ukraine, Ukraine;*
Anatoliy Poyedinchuk, *Institute of Radiophysics and Electronics of National Academy of Sciences of Ukraine, Ukraine;*
Gérard Granet, *Universite Blaise Pascal, France*

Abstract: The subject of the presentation is the study of diffraction radiation from a periodic surface of metamaterial produced by electron stream moving above. Effective parameters of metamaterials are supposed to be frequency dispersive and already defined. On the base of rigorous method and relevant efficient numerical algorithm several interesting effects and regularities emerging in the process of electron beam interaction with a periodic surface of metamaterial have been studied. Examples, interesting for applications have been found out.

28 - **Slow light propagation in slab waveguide with anisotropic meta-material cladding: the loss and gain effects**[Poster]
Author(s): Yijun Feng, *Nanjing University, China;*
Tian Jiang, *Nanjing University, China;*
Qi Zhang, *Nanjing University, China*

Abstract: In this presentation we will discuss a dielectric slab waveguide with anisotropic metamaterial cladding that support slow and even stopped light propagation. The proposed slab waveguide could be realized through multi-layered alternating metal and dielectric film structure. We will show that although the loss in the realistic metamaterial will destroy the zero energy velocity condition, the loss effect can be fully compensated by incorporating gain in the core material and recover the stopping and storing of light propagation in the waveguide. We will demonstrate FDTD simulations on the realistic waveguide that validate our theoretical analysis.

29 - **Characterisation of electromagnetic cylindrical cloaks**[Poster]
Author(s): Christos Argyropoulos, *Queen Mary, University of London, United Kingdom;*
Efthymios Kallos, *Queen Mary, University of London, United Kingdom;*
Yang Hao, *Queen Mary, University of London, United Kingdom*

Abstract: Different electromagnetic cylindrical cloaking designs are modeled with a radially-dependent dispersive Finite-Difference Time-Domain (FDTD) method. The behavior of the different cloaks is compared in terms of scattering performance. Their transient responses are investigated for the first time in the literature, leading to interesting results and a better understanding of the cloaking phenomenon towards its experimental verification.

30 - **Exact analytical treatment of the graded interfaces between RHM and LHM media**[Poster]
Author(s): Nils Dalarsson, *Royal Institute of Technology, Sweden;*
Mariana Dalarsson, *Royal Institute of Technology, Sweden;*
Philippe Tassin, *Vrije Universiteit Brussel, Belgium*

Abstract: We investigated electrodynamics of structures incorporating composites with negative dielectric permittivity and magnetic permeability, the popular ''left-handed metamaterials". We obtained the exact analytical solutions to the Helmholtz equation for normal incidence on the gradient-index interfaces between the positive and negative index part in the special case of matched impedances of the two materials. We derived the general expressions for the field intensity and compared the analytical results with the corresponding results obtained by the numerical simulations using the Finite Element Method (FEM) in the special case of the normal incidence. The model allows for arbitrary spectral dispersion and lossy media.

31 - **Tunability of symmetric and antisymmetric resonances in metal-dielectric nanoshell pairs**[Poster]
Author(s): Andrea Vallecchi, *University of Siena, Italy; Filippo Capolino, University of California, USA*

Abstract: Resonances relative to symmetric and antisymmetric polarization states in pairs of nanoshell particles made of either a dielectric core and a metallic shell or, viceversa, a metallic core and dielectric shell are analyzed at optical frequencies. The investigation is carried out using the single dipole approximation (SDA) by including all the dynamical retarded field terms. It is observed that the resonance frequencies can be tuned over a wide range of wavelength-frequencies. These nanoparticles can serve as constituents of metamaterials with operating frequency ranging from the visible to the infrared spectral regions.

32 - **Dispersive characteristics and magnetic field polarization of surface waves formed by a bianisotropic layer in free space**[Poster]

Author(s): Valery Butylkin, *Institute of Radioengineering & Electronics RAS, Russia;*
Galina Kraftmakher, *Institute of Radioengineering & Electronics RAS, Russia;*
Valery Mal'tsev, *Institute of Radioengineering & Electronics RAS, Russia*

Abstract: Dispersive characteristics, power flow distribution, and polarization of magnetic field of surface waves that formed in free space by a bianisotropic layer with resonant anisotropic chirality, permittivity, and permeability are investigated theoretically.

33 - **Vacuum form reduction for moving bi-isotropic media**[Poster]

Author(s): Sérgio Matos, *Instituto de Telecomunicações and Department of Electrical and Computer Engineering, Portugal;*
Carlos Paiva, *Instituto de Telecomunicações and Department of Electrical and Computer Engineering, Portugal;*
Afonso Barbosa, *Instituto de Telecomunicações and Department of Electrical and Computer Engineering, Portugal*

Abstract: We generalize the vacuum form reduction – a technique made possible due to the dimensional grading of Clifford (geometric) algebra – for the study of moving bi-isotropic media. The advantage of this technique is that a moving medium is studied in a similar way as vacuum – although in a fictitious spacetime. It is shown that the Bohren decomposition is applicable to moving chiral media: we can apply the vacuum form reduction, separately to each one of the two equivalent isotropic media of the Bohren decomposition, to obtain the two isonormal waves of a moving chiral medium in the lab frame.

34 - **A geometric algebra approach to the reflection and transmission of electromagnetic waves at interfaces between isotropic and general anisotropic media**[Poster]

Author(s): João Canto, *Instituto de Telecomunicações and Department of Electrical and Computer Engineering, Portugal;*
Carlos Paiva, *Instituto de Telecomunicações and Department of Electrical and Computer Engineering, Portugal;*
Afonso Barbosa, *Instituto de Telecomunicações and Department of Electrical and Computer Engineering, Portugal*

Abstract: Using a mathematical framework, based on Clifford (geometric) algebra, we develop a coordinate-free approach to interfaces between isotropic and general anisotropic media. The anisotropy is characterized by two linear operators: the dielectric permittivity ε and the magnetic permeability μ. Two different approaches are adopted and compared: (i) using a simple geometric approach that is applicable only when the two operators commute, i.e., if $\varepsilon\mu = \mu\varepsilon$; (ii) using a general approach, applicable even when $\varepsilon\mu \neq \mu\varepsilon$, which leads to the more analytical formulation based on the solutions of the Booker quartic equation.

35 - **Vacuum form reduction: revisiting relativistic optics in moving media with Clifford (geometric) algebra**[Poster]

Author(s): Marco Ribeiro, *Instituto de Telecomunicações, Portugal;*
Carlos Paiva, *Instituto de Telecomunicações, Portugal*

Abstract: A new approach to relativistic optics is proposed. Using the «vacuum form reduction», a technique already developed by the authors in previous publications, several results for complex media and metamaterials are derived, thereby shedding light on the everlasting research topic of moving media in classical electrodynamics, in particular, and on relativistic optics, in general. This new approach to relativistic optics in isotropic moving media stems from the application of Clifford (geometric) algebra to Minkowski spacetime, solving problems in a fictitious spacetime with a constitutive relation with the same form as in vacuum – although characterizing a general class of nonreciprocal bianisotropic media.

36 - **A coordinate-free criterion for negative phase velocity propagation**[Poster]

Author(s): Martin McCall, *Imperial College, United Kingdom;*
Shah Nawaz Burokur, *IEF, Univ. Paris-Sud, CNRS, UMR 8622, France;*
Alberto Favaro, *Imperial College, United Kingdom;*
André de Lustrac, *IEF, Univ. Paris-Sud, CNRS, UMR 8622, France*

Abstract: We present a coordinate-free criterion for negative refractive index, fully generalizing previous criteria, and setting the results in the context of exterior calculus. Importantly, our mathematical formalism is compatible with the use of a generally covariant dispersion relation. Furthermore, non-rigid media are also considered.

12:40 – Lunch (The Hive – Catering Building)

Special Session 1 - Theoretical modelling of metasurfaces

(Skeel Theatre)

Organizer(s): Mario Silveirinha
Session chairperson(s): Mario Silveirinha

14:00 - **Recent advancements in modeling of artificial impedance surfaces**[Keynote]
Author(s): Sergei Tretyakov, *Helsinki University of Technology, Finland;*
Olli Luukkonen, *Helsinki University of Technology, Finland*

Abstract: In this review presentation the state-of-the-art understanding of the physics of artificial impedance surfaces is discussed. The presentation will cover general types of artificial impedance surfaces and discuss the recent advancements in the modeling of these surfaces. All the discussed surfaces carry one common feature: the surfaces are comprised partially or completely from wire medium and therefore their distinctive properties are largely based on the properties of the wire medium. Attention is paid especially to the spatial dispersion of wire media and its influence on the surface impedance. The recent advancements in the understanding of the physics of the artificial impedance surfaces allow us to combine features with different nature to one superior artificial impedance surface.

14:40 - **Electromagnetic boundaries defined by normal components of EM fields**[Invited]
Author(s): Ismo Lindell, *Helsinki University of Technology, Finland;*
Ari Sihvola, *Helsinki University of Technology, Finland*

Abstract: Introducing a set of four scalar conditions involving normal components of the fields D and B and their normal derivatives, four condition pairs turn out to yield meaningful electromagnetic boundaries. Two of them correspond to PEC and PMC boundaries while the other two are less known and labeled as DB and D'B' boundaries. Properties of such boundaries to electromagnetic fields are studied.

15:00 - **Can optical metamaterials be described by effective material parameters?** [Invited]
Author(s): Falk Lederer, *University of Jena, Germany;*
Christoph Menzel, *University of Jena, Germany;*
Carsten Rockstuhl, *University of Jena, Germany;*
Thomas Pertsch, *University of Jena, Germany*

Abstract: We show that contemporary optical metamaterials operated in the resonance domain must not be described in terms of effective material parameters. This is due to the strong spatial dispersion in mesoscopic systems.

15:20 - **Design and implementation of near-field plates**[Invited]
Author(s): Anthony Grbic, *University of Michigan, USA;*
Mohammadreza F. Imani, *University of Michigan, USA*

Abstract: In this presentation, we will describe the theory behind the operation of near-field plates, as well as methods used in their design and implementation. Near-field plates are non-periodic, grating-like surfaces that can focus electromagnetic waves to subwavelength resolutions.

15:40 – Coffee break (Octagon Room)

Regular Session 1A - Tunable and active metamaterials

(People's Palace 1)

Session chairperson(s): John (Yiannis) Volakis, Peter S. Hall

14:00 - **Active self-adaptive metamaterials based on two-port impedance loaded dipole arrays**[Invited]
Author(s): Luk Arnaut, *NPL & Imperial College, United Kingdom*

Abstract: We present a realizable design and theoretical model for a periodic active controllable meta-surface, together with full-wave numerical simulation results. The implementation is based on a two-port active tunable circuit interconnecting two sensor and actuator electric dipole antennas with feedback coupling. Judicious choice of the attenuation network in the active circuit allows for control of the frequency response of the equivalent effective permittivity, reflectivity and transmittivity of the surface.

14:20 - **Microstrip transmission lines loaded by SRRs tunabled by ferro-electrics**[Regular oral]
Author(s): Didier Lippens, *IEMN/USTL, France;*
Gregory Houzet, *IEMN/USTL, France;*
Xavier Mélique, *IEMN/USTL, France;*
Gabriel Velu, *LEMCEL, France;*
Ludovic Burgnies, *LEMCEL, France;*
Jean Claude Carru, *LEMCEL, France*

Abstract: The tunability of a microstrip transmission line loaded by Split Ring Resonators (SRRs) is numerically and experimentally investigated. Ferroelectric thin films were inserted in the vicinity of the SRR gaps and are used for dc-voltage controlling the SRR equivalent capacitance and hence the resonant frequency

14:40 - **Electric metamaterials with a nonlinear response**[Regular oral]
Author(s): David A. Powell, *The Australian National University, Australia;*
Ilya Shadrivov, *The Australian National University, Australia;*
Yuri Kivshar, *The Australian National University, Australia*

Abstract: We design and study nonlinear electric metamaterials operating at microwave frequencies. By introducing a varactor diode as a nonlinear element in each electric oscillator, we are able to shift the location of the negative permittivity stop-band by changing the incident power. These elements could be combined with the previously developed nonlinear magnetic metamaterials in order to create negative index media with both electric and magnetic nonlinearities.

15:00 - **Ferromagnetic materials to obtain left-handed transmission**[Regular oral]
Author(s): Jorge Carbonell, *ITEAM - Universidad Politécnica de Valencia, Spain;*
Hector Garcia-Miquel, *GFO - Universidad Politécnica de Valencia, Spain;*
Vicente Boria, *ITEAM - Universidad Politécnica de Valencia, Spain;*
José Sánchez-Dehesa, *GFO - Universidad Politécnica de Valencia, Spain*

Abstract: Experimental evidence of left-handed transmission is demonstrated through ferromagnetic microwires. We have used amorphous magnetic microwires to take advantage of both electric and magnetic responses locally generating a double negative effective medium at microwave frequencies, where the ferromagnetic resonance effects occur. The great advantage offered by ferromagnetic materials is that having a single element or inclusion in a microstructure permits one to generate a double-negative medium, instead of double 'traditional' arrays of metallic wires and split ring resonators.

15:20 - **Dynamic metamaterials composed of helical conductors and microplasmas**[Regular oral]
Author(s): Takuya Shimomura, *Kyoto University, Japan;*
Osamu Sakai, *Kyoto University, Japan;*
Kunihide Tachibana, *Kyoto University, Japan*

Abstract: Microplasmas have a potential to control electromagnetic waves. Permittivity of plasmas can be easily controlled by the external parameters to be less than unity or even negative value. For realization of metamaterials with a negative refractive index, we demonstrated microwave modulation with composites of the microplasmas and the novel microresonators.

15:40 – Coffee break (Octagon Room)

Regular Session 1B - Periodical structures

(People's Palace 2)

Session chairperson(s): David Jackson, Keith Whites

14:00 - **Extremely slow waves in periodic arrays of metallic carbon nanotubes**[Invited]
Author(s): Igor Nefedov, *Helsinki University of Technology, Finland*

Abstract: In this talk we present results of we discuss electromagnetic waves propagating in two- and three-dimensional periodic arrays of single-wall carbon nanotubes possessing metallic properties. Eigenwaves in arrays of infinitely long carbon nanotubes as well as waves in arrays of finite-lengths nanotubes were investigated.

14:20 - **A new class of optical materials based networks of coupled sub-wavelength waveguides**[Regular oral]
Author(s): Eyal Feigenbaum, *Applied Physics, California Institute of Technology, Pasadena, California 91125, USA;*
Harry A. Atwater, *Applied Physics, California Institute of Technology, Pasadena, California 91125, USA*

Abstract: We study novel networks of plasmonic waveguides and their cross-junctions (X-nets). A wavelength-scale resonator based on phase effects in the network is demonstrated and from this emerges a new class of photonic materials, having two length-scales for controlling wave propagation and dispersion.

14:40 - **Resonant tunneling of light in Ag/SiO_2 multilayer metamaterials**[Regular oral]
Author(s): Satoshi Tomita, *NAIST, Japan;*
Motonobu Matsunaga, *NAIST, Japan;*
Hisao Yanagi, *NAIST, Japan;*
John Pendry, *Imperial College London, UK;*
Shinji Hayashi, *Kobe University, Japan*

Abstract: We have experimentally and numerically studied resonant photon tunneling (RPT) through silver/dielectric multilayer metamaterials. Surface plasmon polaritons (SPPs) at a silver/dielectric interface are excited using attenuated total reflection (ATR) method. Around an incident angle for the SPPs excitation, RPT is observed. Moreover, we find a small shift of the RPT peak from the SPPs excitation angle. Silver/dielectric multilayers show a smaller shift than aluminum/dielectric multilayers, indicating that the shift variation is originated from the intrinsic losses in the RPT process. The present study demonstrates that simultaneous ATR/RPT measurements enable us to estimate the losses in a super-lens.

15:00 - **Electrodynamic analogue of the Borrmann effect in photonic crystals**[Regular]
Author(s): Alexander Dorofeenko, *Institute forTheoretical and Applied Electromagnetics RAS, Russia;*
Alexey Vinogradov, *Institute forTheoretical and Applied Electromagnetics RAS, Russia;*
Alexander Merzlikin, *Institute forTheoretical and Applied Electromagnetics RAS, Russia;*
Alexander Lisyansky, *Physics Department, Queens College of the City University of New York, USA;*
Alexander Granovsky, *Faculty of Physics, Moscow State University, Russia;*
Yuriy Lozovik, *Institute of Spectroscopy of the Russian Academy of Sciences, Russia*

Abstract: The Borrmann effect, which is related to the microscopic distribution of the electromagnetic field inside the primitive cell, is studied in photonic and magnetophotonic crystals. It is shown that by design of the primitive cell this effect can be suppressed and even inverted.

15:40 – Coffee break (Octagon Room)

Special Session 2 - Metamaterial antennas

(Skeel Theatre)

Organizer(s): Filiberto Bilotti, Richard Ziolkowski
Session chairperson(s): Richard Ziolkowski, Filiberto Bilotti

16:00 - **Electrically small metamaterial-inspired antennas: The next generation**[Invited]
Author(s): Richard Ziolkowski, *University of Arizona, USA;* Peng Jin, *University of Arizona, USA;*
Chia-Ching Lin, *University of Arizona, USA*

Abstract: Electrically small antennas are a critical enabling technology for a variety of wireless applications. A variety of metamaterial-inspired antenna systems have been designed, fabricated and tested recently that meet many of the performance demands for these applications, including high efficiency, broad bandwidth, and multi-functionality. These designs and their operating characteristics will be reviewed.

16:20 - **Metamaterial-inspired electrically small radiators: it is time to draw preliminary conclusions and depict the future challenges**[Invited]
Author(s): Filiberto Bilotti, *University "Roma Tre", Italy;* Lucio Vegni, *University "Roma Tre", Italy*

Abstract: The role of metamaterials in microwave antenna technology is nowadays rather controversial. Almost ten years have passed from the beginning of the metamaterial era and a few months less from the first proposed antenna setups based on metamaterials. It is time, thus, to draw some preliminary conclusions, in terms of benefits and impact to the microwave and antenna communities and of the possible role which metamaterials can play in the near future. In this contribution, we discuss these aspects through several examples of previously and new antenna configurations proposed by our group in collaboration with other researchers.

16:40 - **Small wideband antennas based on magnetic photonic crystals**[Invited]
Author(s): K. Sertel, *The Ohio State University, USA;* John (Yiannis) Volakis, *The Ohio State University, USA;*
E. Irci, *The Ohio State University, USA*

Abstract: This paper will present several successful narrowband metamaterial antennas by exploiting anisotropy, including magnetic substrates for the first with experimental verifications. Concurrently, new concepts will be presented to increase bandwidth by arraying metamaterial elements and exploiting their coupling characteristics to enable large bandwidth for conformal installations. This is a unique concept that delivers real impedance over large bandwidth as much as 20:1in a conformal setting. Specifically, the paper will cover: 1. Optimal antenna elements of wider bandwidth using small magnetic material insertions (limiting potential losses). 2. Biasing and voltage control for large bandwidth tuning (as much as 30% in bandwidth). This allows formultiband, but optimal antenna performance. 3. Concatenation of the metamaterial elements in an array/aperture to enable wideband radiation. In this case, the metamaterial elements allow wave slow down (via capacitive and inductive loading) to miniaturize a broadband aperture.

17:00 - ***A single metamaterial-based leaky-wave antenna for both convex and concave surface applications*** [Invited]
Author(s): Tatsuo Itoh, UCLA, USA; Mohammed Reza Hashemi, UCLA, USA

Abstract: In this paper we will introduce a novel composite right/left-handed (CRLH) leaky-wave antenna (LWA) that can be used for both convex and concave surface applications.

17:20 - **Planar meta-surfaces for coupling reduction between antenna elements**[Invited]
Author(s): Elena Saenz, *Electrical and Electronic Engineering Department, Public University of Navarra, Spain;*
Iñigo Ederra, *Electrical and Electronic Engineering Department, Public University of Navarra, Spain;*
Ramón Gonzalo, *Electrical and Electronic Engineering Department, Public University of Navarra, Spain;*
Sergey Pivnenko, *Department of Electrical Engineering, ElectroScience Section, Technical University of Denmark, Denmark;*
Olav Breinbjerg, *Department of Electrical Engineering, ElectroScience Section, Technical University of Denmark, Denmark;*
Peter de Maagt, *European Space Research and Technology Centre, ESTEC, The Netherlands*

Abstract: In this paper, the mutual coupling between dipole antenna array elements using a planar meta-surface as superstrate is experimentally investigated. The meta-surface is based on grids of short metal strips and continuous wires. A comparison between the mutual coupling when the dipoles are radiating in free space and in presence of the superstrate is presented. On average, between 3 to 14 dB reduction of the mutual coupling is achieved when the superstrate is used.

17:40 – Welcome reception (Octagon Room)

Regular Session 2A - Terahertz metamaterials: New phenomena

(People's Palace 1)

Session chairperson(s): Mario Sorolla, Didier Lippens

16:00 - **Taming the blackbody with metamaterials**[Invited]
Author(s): Willie Padilla, *Boston College, USA*

Abstract: We demonstrate metamaterial absorbers which control the emissivity spectrum of a body at a particular temperature over a bandwidth of 50%, and may be applied as coatings to materials to control their blackbody emission spectra.

16:20 - **The marriage of MEMS and metamaterials at THz frequencies**[Invited]
Author(s): Richard Averitt, *Boston University, USA;*
Hu Tao, *Boston University, USA;*
Drew Strikwerda, *Boston University, USA;*
Kebin Fan, *Boston University, USA;*
Chris Bingham, *Boston College, USA;*
Nathan Landy, *Boston College, USA;*
Willie Padilla, *Boston College, USA;*
Xin Zhang, *Boston University, USA*

Abstract: The marriage of MEMS-based fabrication techniques with metamaterial concepts enables the creation of novel electromagnetic structures that are resonant at terahertz frequencies. We present recent examples of such metamaterials including compact functional waveplates and thermally responsive metamaterial cantilever arrays which are an important step towards dynamically reconfigurable metamaterials.

16:40 - **Fresh metamaterials ideas for metallic lenses**[Invited]
Author(s): Mario Sorolla, *Millimeter & THz Waves Lab. EE Dept. UPNA , Spain;*
Miguel Navarro-Cia, *Millimeter & THz Waves Lab. EE Dept. UPNA , Spain;*
Miguel Beruete, *Millimeter & THz Waves Lab. EE Dept. UPNA , Spain;*
Igor Campillo, *CIC Nanogune, Spain*

Abstract: Further advances of Metamaterials concepts into the clas-sical field of metallic lenses are given. Some of the limitations that metallic lenses have, such as imperfect matching with free space, can be overcome, making them powerful tools in lens design. Particular attention is given to Extraordinary Transmission Metamaterial due its low-losses and its potential scaling to any range of the spectrum. The design of planoconcave and bicon-cave lenses is done and experimental results confirm initial assumptions.

17:00 - **Cherenkov emission of broadband terahertz radiation from an ultrashort laser pulse in a sandwich structure with nonlinear core and left-handed cladding**[Regular oral]
Author(s): Rostislav Mikhaylovskiy, *University of Nizhny Novgorod, Russia;*
Michael Bakunov, *University of Nizhny Novgorod, Russia*

Abstract: Terahertz Cherenkov emission by a femtosecond laser pulse propagating in a planar sandwich like structure has been investigated theoretically. The structure consists of a thin nonlinear core cladded with a material which is left-handed at terahertz frequencies and right-handed at optical ones. It is shown that the power of Cherenkov radiation propagates backward in this structure.

17:20 - **Resonant magnetoelectric coupling in split ring resonators**[Regular oral]
Author(s): Andrei Pimenov, *University of Wuerzburg, Germany*

Abstract: In this work we utilize the bianisotropy of the split rings resonators to excite the electron spin resonance (ESR) in gadolinium gallium garnet by electric field of light. Surprisingly, the observed signal is inverted in nature, i.e., brought to the resonance the electrons give the energy to the electromagnetic field instead of absorbing it. In addition, classical anti-crossing of ESR mode and split ring resonance can be observed as well. These effects can be well explained within the model of coupled oscillators.

17:40 – Welcome reception (Octagon Room)

Regular Session 2B - Extraordinary transmission

(People's Palace 2)

Session chairperson(s): Francisco J. Garcia-Vidal, Dries van Oosten

16:00 - **Transmission of light through hole arrays in "unconventional" regimes** Invited

Author(s): Luis Martin-Moreno, Instituto de Ciencia de Materiales de Aragon, Spain;
Sergio G. Rodrigo, Instituto de Ciencia de Materiales de Aragon, Spain;
S. Carretero-Palacios, Instituto de Ciencia de Materiales de Aragon, Spain;
A. Mary, Departamento de Fisica Teorica de la Materia Condensada, Universidad Autonoma de Madrid, Spain;
F.J. Garcia-Vidal, Departamento de Fisica Teorica de la Materia Condensada, Universidad Autonoma de Madrid, Spain

Abstract: The resonant transmission of light through arrays of holes is investigated at two unusual regimes of structural parameters: rectangular holes with high aspect ratio holes and/or optically thin films. In both situations, attention it is paid to the dependence on the different geometrical and material parameters defining the system.

16:20 - **The fundamental physics of directive beaming at broadside and the role of leaky waves** Invited

Author(s): David Jackson, University of Houston, USA; Filippo Capolino, University of California Irvine, USA;
Ji Chen, University of Houston, USA; Giampiero Lovat, University of Rome La Sapienza, Italy;
Paolo Burghignoli, University of Rome La Sapienza, Italy; Arthur Oliner, Polytechnic University, USA

Abstract: The fundamental mechanism behind directive beaming at broadside for various structures will be explored. These include Fabry-Pérot type of resonant-cavity antennas, low-permittivity metamaterial substrate antennas composed of a wire medium slab, and optical directive beaming due to plasmonic effects. In all cases it will be shown that the fundamental explanation for the directive beaming effect is the excitation of one or more leaky waves. Leaky-wave theory predicts a simple condition for maximum directive beaming at broadside, namely that the phase and attenuation constants of the leaky wave(s) are equal.

16:40 - **Formation of a non-diffractive Bessel-like beam from a metallic subwavelength aperture** Regular oral

Author(s): Zhaofeng Li, *Nanotechnology Research Center,Bilkent University, Turkey;* Kamil Boratay Alici, *Nanotechnology Research Center, Bilkent University, Turkey;* Humeyra Caglayan, *Nanotechnology Research Center,Bilkent University, Turkey;* Ekmel Ozbay, *Nanotechnology Research Center,Bilkent University, Turkey*

Abstract: An electromagnetic non-diffractive Bessel-like beam from a subwavelength aperture is generated by placing a metallic circular grating-like structure in front of the aperture. The full width at half maximum of the beam remains less than two wavelengths over nearly ten wavelengths. Our experimental results are in good agreement with the simulation results.

17:00 - **Enhanced transmission response from subwavelength slits in semiconductors in the UV range** Regular oral

Author(s): Maria Antonietta Vincenti, *Dipartimento di Elettrotecnica ed Elettronica - Politecnico di Bari, Italy;*
Michael Scalora, *Charles M. Bowden Research Center, AMSRD-AMR-WS-ST, RDECOM, Redstone Arsenal, USA;*
Vito Roppo, *Departament de Fisica I Enginyeria Nuclear, Universitat Politecnica de Catalunya, Spain;*
Domenico de Ceglia, *Charles M. Bowden Research Center, AMSRD-AMR-WS-ST, RDECOM, Redstone Arsenal, USA;*
Antonella D'Orazio, *Dipartimento di Elettrotecnica ed Elettronica - Politecnico di Bari, Italy;*
Mark J. Bloemer, *Charles M. Bowden Research Center, AMSRD-AMR-WS-ST, RDECOM, Redstone Arsenal, USA*

Abstract: In this paper we describe a new way to achieve the extraordinary transmission regime from subwavelength slits carved on semiconductor substrates. It is well-known that the dielectric permittivity of typical semiconductors like GaAs is negative beginning in the extreme UV range ($\lambda < 250$nm). The clear implication here is that this metal-like response may be used to excite surface waves that lead to extraordinary transmission in the linear regime, and to novel nonlinear plasmonic phenomena for UV and soft X-ray ranges.

17:20 - **Acoustical wave phenomena - Extraordinary transmission, beaming and subwavelength imaging** Regular oral

Author(s): Johan Christensen, *UAM Madrid, Spain;* Luis Martin-Moreno, CSIC, *Universidad Zaragosa, Spain;*
Francisco Jose Garcia-Vidal, *UAM Madrid, Spain*

Abstract: In this work, a host of acoustical wave phenomena is presented, ranging from the extraordinary acoustical transmission to subwavelength wave focusing and beaming. Similarities and differences to its optical counterpart are given by means of theoretical analysis. In addition we present a new type of waveguide to perform acoustical full 3D subwavelength imaging able to recover objects, 10 times smaller than the wave-length and beyond.

17:40 – Welcome reception (Octagon Room)

Registration

8:30 (Registration Office)

Special Session 3 - Optical meta-devices

(Skeel Theatre)

Organizer(s): Hossein Mosallaei
Session chairperson(s): Hossein Mosallaei

09:00 - **Wave-front engineering of light sources by plasmonic metamaterials**[Keynote]
Author(s): Federico Capasso, *Harvard University, USA;*
Nanfang Yu, *Harvard University, USA*

Abstract: Metamaterials allow one to design the far-field and near field of active and passive light sources (from lasers to optical fibers) for greatly improved performance and new functionalities. Results on plasmonic collimators and polarizers, optical antennas and new directions in beam engineering will be presented.

09:40 - **Active plasmonic devices and active infrared metamaterials based on tunable split ring resonators**[Invited]
Author(s): Harry Atwater, *California Institute of Technology, USA*

Abstract: Dispersion control and active materials integration have yielded plasmonic components including i) three-dimensional single layer plasmonic metamaterials ii) field effect modulation of plasmon propagation iii) tunable active infrared metamaterials.

10:00 - **Metacomponents for Metactronics**[Invited]
Author(s): Nader Engheta, University of Pennsylvania, USA

Abstract: Plasmonic phenomena, when combined with the notion of metamaterials, may facilitate the merging of two fields of the circuit theory and design and the nano-optics and nanophotonics. In this new paradigm, new “alphabets” can be envisioned for nano-optics, and this provides us with “circuits with light at the Nanoscale”, an alternative approach to information processing at the nanoscale. In this talk, I will give an overview of some of the efforts in my group in developing the topic of “metactronics” and “metacomponents”.

10:20 - **Strong light confinement with and without periodicity**[Invited]
Author(s): Masaya Notomi, *NTT Basic Research Laboratories, Japan*

Abstract: In this talk, we will describe various ways to strongly confine light in a small volume. Although 3D photonic crystals were long thought to be required for this purpose, it has been recently clarified that 2D photonic crystals or even 1D photonic crystals are enough for making ultrahigh-Q nanocavities. The current status and possible applications of ultrahigh-Q nanocavities based on 2D/1D photonic crystals will be reviewed. We will also discuss the possibility of strong light confinement even without any periodicity, and our recent studies on photonic amorphous diamonds will be presented.

Regular Session 3A - Microwave applications of metamaterials

(People's Palace 1)

Session chairperson(s): Manuel Freire, Ramon Gonzalo

09:00 - **Magnification and demagnification with subwavelength resolution by hyperlenses from arrays of metallic wires**[Keynote]

Author(s): Pavel Belov, *Queen Mary University of London, UK;*
George Palikaras, *Queen Mary University of London, UK;*
Yan Zhao, *Queen Mary University of London, UK;*
Atiqur Rahman, *Queen Mary University of London, UK;*
Rostyslav Dubrovka, *Queen Mary University of London, UK;*
Constantin Simovski, *Helsinki University of Technology, Finland;*
Yang Hao, *Queen Mary University of London, UK;*
Clive Parini, *Queen Mary University of London, UK*

Abstract: The possibility to use tapered arrays of wires as devices capable of transmission, magnification and demagnification of microwave images with subwavelength resolution is discussed. Three fold magnification, three fold demagnification and transmission of an image with lambda/30 resolution over a distance 3.5 times greater than the wavelength is demonstrated experimentally. The device is capable of transmitting images from one planar interface to another one in contrary to the hyperlens geometries operating with spherical or cylindrical interfaces.

09:40 - **Analysis of radiation in a metamaterial leaky wave antenna based on complementary split ring resonator**[Regular oral]

Author(s): Stéphanie Eggermont, *Université Catholique de Louvain, Belgium;*
Robert Platteborze, *Université Catholique de Louvain, Belgium;*
Isabelle Huynen, *Université Catholique de Louvain, Belgium*

Abstract: This paper aims at designing an RF tag planar antenna around 2.45 GHz enabling a frequency beam steering simultaneously in the plane of the substrate and in its normal plane. The structure is based on a leaky-wave antenna topology using a transmission line with series capacitive gaps and Complementary Split Ring Resonators periodically loading a host microstrip line. Full-wave simulations of radiation pattern with IE3D software show that radiation can be viewed as a combination of leaky wave and TM surface wave mode predicted by Helmotz equations.

10:00 - **Left-handed stepped impedance resonator for WLAN applications**[Regular oral]

Author(s): Shokrollah Karimian, *PhD Student, University of Manchester, United Kingdom;*
Mahmoud Abdalla, *PhD student, University of Manchester, United Kingdom;*
Zhirun Hu, *Senior Lecturer, University of Manchester, United Kingdom*

Abstract: A novel microstrip Stepped Impedance Resonator (SIR) based on Composite Right/Left-Handed (CRLH) transmission line is presented to resonate at 2.25 GHz for Wireless Local Area Network (WLAN) applications. Supported by theory and full-wave simulations, a comparison is made between this design and its conventional counterpart. The CRLH SIR design presented in this paper is not only a successful design, but indeed the first attempt towards designing such resonators.

10:20 - **Assessment of antenna arrays with nonlinear lumped loads for microwave phase conjugation for 2D near field imaging**[Regular oral]

Author(s): Oleksandr Malyuskin, *ECIT, Queens University Belfast, United Kingdom;*
Vincent Fusco, *ECIT, Queens University Belfast, United Kingdom*

Abstract: EM wave mixing and phase conjugation production in wire arrays loaded with nonlinear lumped loads is analysed in the paper. Two dimensional near field focussing with one-third wavelengths resolution has been demonstrated for the phase conjugating lens half-wavelength by half-wavelength size.

Regular Session 3B - New concepts

(People's Palace 2)

Session chairperson(s): Luk Arnaut, Clive Parini

09:00 - **Negative refractive Index in natural, non-magnetic media** Regular oral

Author(s): Martin McCall, *Imperial College, UK;*
Paul Kinsler, *Imperial College, UK;*
Dan Censor, *Ben Gurion University of the Negev, Israel*

Abstract: We report that an effective negative refractive index is achievable in a non-magnetic dielectric moving medium. If a velocity field is present a kind of negative refraction is possible. Calculation of ray trajectories yields prospects for observable phenomena in astrophysical contexts.

09:20 - **On a possibility to imitate media moving with superluminal velocity** Regular oral

Author(s): Sergei Tretyakov, *Helsinki University of Technology, Finland;*
Igor Nefedov, *Helsinki University of Technology, Finland*

Abstract: In this presentation we show that it appears to be possible to realize an artificial material (metamaterial), in which the electric displacement D and the magnetic induction B are expressed via the electric field intensity E and the magnetic field intensity H as in a medium which moves with a relativistic or even superluminal velocity. Such an ``artificial moving medium'' is a bi-anistropic nonreciprocal material, which can be in principle constructed from small magnetized ferrite spheres and metal particles of special shapes and sizes.

09:40 - **A new geometric perspective on bianisotropy using Clifford algebra** Regular oral

Author(s): Sérgio Matos, *Instituto de Telecomunicações and Department of Electrical and Computer Engineering, Portugal;*
Carlos Paiva, *Instituto de Telecomunicações and Department of Electrical and Computer Engineering, Portugal;*
Afonso Barbosa, *Instituto de Telecomunicações and Department of Electrical and Computer Engineering, Portugal*

Abstract: Clifford (geometric) algebra sheds new light on linear algebra by prompting a fresh coordinate-free approach, thereby providing a geometric alternative to the classical methods of tensor (or dyadic) analysis. In this communication, we develop a general framework for reciprocal bianisotropic media through this fresh perspective. As a result, the interplay between anisotropy and magnetoelectric coupling emerges. Namely, the eigenwaves associated with the (electric and magnetic) anisotropy and bianisotropy (i.e., the magnetoelectric coupling) are fully characterized through the functional invariants which receive a complete geometric interpretation.

10:00 - **Possibilities offered by non-homogeneous materials** Regular oral

Author(s): Fabio Bovino, *Elsag Datamat, Italy*

Abstract: In this presentation we describe possible and potential applications of non-homogeneous materials as metamaterials for quantum information applications, such as novel sources , novel devices and concepts

10:20 - **Metamaterial nanotips** Regular oral

Author(s): Constantin Simovski, *TKK, Finland;*
Carsten Rockstuhl, *Friedrich-Schiller-Universität , Germany;*
Falk Lederer, *Friedrich-Schiller-Universität , Germany;*
Sergei Tretyakov, *TKK, Finland*

Abstract: Nanostructured metamaterials, especially arrays of metallic nanoparticles provide unique opportunities for moulding the light without nonlinear effects. We suggest a metamaterial structure whose properties are deter-mined by both inner geometry and the entire shape of the array. This structure was called a metamaterial nanotip. We discuss the promises of such strucrtures to control the size and the location of the domain where the field is enhanced and to form so-called photonic nanojects. Two-dimensional implementations of this metamaterial nanotip were comprehensively numerically simulated and confirm the expected regimes of operation.

Poster Session II - Experimental

(10:40 – 11:40) Octagon Room

Session chairperson(s): Natalia Litchinitser

1 - **MIR filters based on extraordinary optical transmission through nanostructured gold films**[Poster]

Author(s): Rubén Ortuño Molinero, *Nanophotonics Technology Center, Spain;*
Andreas Hakansson, *DAS Photonics, Spain;*
Juan Hurtado, *Nanophotonics Technology Center, Spain;*
Laurent Bellieres, *Nanophotonics Technology Center, Spain;*
Pedro Javier Rodríguez, *Nanophotonics Technology Center, Spain;*
Amadeu Griol, *Nanophotonics Technology Center, Spain;*
José Ángel Ayúcar, *Nanophotonics Technology Center, Spain;*
Francisco López, *Nanophotonics Technology Center, Spain;*
Carlos García Meca, *Nanophotonics Technology Center, Spain;*
Francisco José Rodríguez Fortuño, *Nanophotonics Technology Center, Spain;*
Javier Martí, *Nanophotonics Technology Center, Spain;*
Alejandro Martínez, *Nanophotonics Technology Center, Spain*

Abstract: We experimentally studied the enhanced optical transmission of nanostructured gold films in the middle-infrared region. The optical transmission of the samples is affected by both the periodicity and the aperture shape. Our results indicate that the excitation of surface plasmon polaritons due to the periodicity plays a funda-mental role in the extraordinary optical transmission.

2 - **Transmission characteristics of terahertz metamaterials fabricated on polyethlene terephthalate films**[Poster]

Author(s): Fumiaki Miyamaru, *Faculty of Science, Shinshu University, Japan;*
Mitsuo Takeda, *Faculty of Science, Shinshu University, Japan;*
Keisuke Takano, *Osaka University, Japan; Masanori Hangyo, Osaka University, Japan*

Abstract: Electromagnetic characteristics of a split-ring resonator (SRR) fabricated on thin polyethylene terephthalate films are investigated for the purpose of developing three-dimensional (3D) metamaterials in the terahertz region. Electric and magnetic resonances are observed at frequencies determined by the structure of the SRR. We observe that each layer operates independently without interlayer interaction. This result indicates that the properties of the metamaterial are determined only by the unit cell design and a diffraction effect can be avoided.

3 - **Design of compact multiple wideband EBG fractal structure**[Poster]

Author(s): Rajkumar Rajkumar, *DIAT(DU), India;*
Goerge Mathai, *DIAT(DU), India*

Abstract: This paper presents the investigation of Electromagnetic Bandgap (EBG) structure using fractals. EBG structure has the unique property to prevent the propagation of electromagnetic waves of specific frequency band which are useful to improve performance of microwave antenna, circuits and systems. The EBG structure has been designed and fabricated on substrate of dielectric constant εr= 4.3 and thickness h = 1.53 mm. The EBG structure has been tested using Vector Network analyzer. The experimental results of EBG structure have been observed in multiple bands in frequency range from 2.45 to 3.36GHz and 8.52 to 11.02 GHz respectively. The results indicate that this design has multiple wideband bandgaps and wide bandwidth in the stopband. The proposed design is a compact one. This structure can be utilized to improve the antenna or circuit performance.

4 - **Study of antenna gain enhancement using a near-zero refractive Index and fabry-perot cavity resonance**[Poster]

Author(s): Dongho Kim, *Electronics & Telecommunications Research Institute, Korea (South);*
Jaeick Choi, *Electronics & Telecommunications Research Institute, Korea (South)*

Abstract: We have investigated enhancement behaviours of a patch and a horn antenna covered with a metamaterial superstrate. We have examined how much the effectively near-zero n affects gain properties of the two antennas, which yields somewhat different aspect. To more increase antenna gain, we have also used the well-known Fabry-Perot resonance, which results in large enhancement in gain for both antennas.

5 - **A novel ultra-wideband antenna with individual CSRR structure**[Poster]

Author(s): XiaoYang He, *Institute of Electronic Engineering, China Academy of Engineering Physics, China;*
Qi Chen, *Institute of Electronic Engineering, China Academy of Engineering Physics, China;*
Chun Yang, *Institute of Electronic Engineering,China Academy of Engineering Physics, China;*
BangHua Zhou, *Institute of Electronic Engineering,China Academy of Engineering Physics, China*

Abstract: In this presentation we propose a novel ultra-wideband antenna design by using an individual complementary split ring resonator and microstrip line structure. The return loss of the antenna has been experimentally measured, which agrees with the simulation. The frequency band is found to be across the spectrum from 1.6 to 22.6 GHz.

6 - **Experimental study of the temperature dependence of plasmonic resonances**[Poster]

Author(s): Liming Ji, *University of Arkansas, USA;*
Vasundara Varadan, *University of Arkansas, USA*

Abstract: In this paper, we study for the first time, the temperature dependence of plasmonic resonances. Experiments are performed in a free space measurement system with the plasmonic sample placed in a furnace. Systematic changes are found with rising temperature.

7 - **Simple asymmetric cut wire pairs producing negative index**[Poster]

Author(s): Shah Nawaz Burokur, *IEF, Univ. Paris-Sud, CNRS, UMR 8622, France;*
André de Lustrac, *IEF, Univ. Paris-Sud, CNRS, UMR 8622, France*

Abstract: In this paper, we propose an easy way to manipulate the magnetic and electric resonances of cut wire pairs metamaterials to produce a negative index. We show that judiciously breaking the symmetry of the structure allows a tuning of both resonances leading to an overlapping between the negative permeability and negative permittivity regions. Numerical and experimental parametric studies of several cut wire pairs metamaterials are presented to validate our method at microwave frequencies.

8 - **Eigenmodes of diatomic metamaterials with electric and magnetic coupling**[Poster]

Author(s): Anna Radkovskaya, *Magnetism Division, Faculty of Physics, Moscow State University, Russia;*
Oleksiy Sydoruk, *SAOT, University of Erlangen-Nuremberg, Germany;*
Eugen Tatartschuk, *SAOT, University of Erlangen-Nuremberg, Germany;*
Christopher J. Stevens, *Oxford University, UK;*
Grahame Faulkner, *Oxford University, UK;*
David J. Edwards, *Oxford University, UK*

Abstract: We studied waves that propagate on chains of coupled singly-split single ring resonators where the coupling alternated between electric and magnetic in a diatomic manner. This paper reports on the theoretical and experimental dispersion characteristic of the waves propagating around 2 GHz.

9 - **Ferromagnetic microwires enabled field tunable composites for structural health monitoring**[Poster]

Author(s): Faxiang Qin, *Advanced Composite Centre for Innovation and Science, Department of Aerospace Engineering, University of Bristol, United Kingdom;*
Hua-Xin Peng, *Advanced Composite Centre for Innovation and Science, Department of Aerospace Engineering, University of Bristol, United Kingdom*

Abstract: E-glass fibre/epoxy composites containing periodic array of ferromagnetic microwires have been designed and investigated in terms of dielectric properties in the presence of permanent magnetic field at microwave frequency range. The field tunability of the composites is found to depend intimately on the intrinsic properties and concentration of the wires and there exists a remarkable field dependence of scattering spectra. The realization of electromagnetic functionalities in the structural composite makes it promising candidate for innovative structural health monitoring applications.

10 - **Experimental investigation of extended cylindrical cloak**[Poster]

Author(s): Colin Brewitt-Taylor, *QinetiQ ltd, United Kingdom;*
Peter Lederer, *QinetiQ ltd, United Kingdom;*
Frank Smith, *QinetiQ ltd, United Kingdom;*
Stefan Szwarnowski, *QinetiQ ltd, United Kingdom*

Abstract: We have constructed a cylindrical cloak, extended along the cylinder axis, and measured its forward scatter in free-space. A reduction of about 3 dB was observed at the intended cloaking frequency, relative to a metal cylinder of the same outer radius. The cloaking effectiveness appears to be limited by losses in the structure.

11 - **Experimental investigation of left-handed medium properties of semiconductor-ferrite composite in millimetre waveband**[Poster]

Author(s): Aleksey Girich, *Institute radiophysics and electronics NAS of Ukraine, Ukraine;*
Mikhail Khodzitsky, *Institute radiophysics and electronics NAS of Ukraine, Ukraine;*
Sergey Tarapov, *Institute radiophysics and electronics NAS of Ukraine, Ukraine*

Abstract: The paper is devoted to experimental research of left-handed medium (LHM) properties of ferrite-semiconductor composite in millimeter waveband. The transparency peak associated with simultaneous negativity of effective permeability and permittivity of composite has been revealed in spectrum of the composite. The Bragg resonance peaks associated with Bragg diffraction were registered. The peaks position tuning by magnetic field was shown.

12 - **Resonance phenomena in opal matrices with ferrite-spinel nanoparticles embedded**[Poster]

Author(s): Anatoly Rinkevich, *Institute of Metal Physics, Russia;*
Vladimir Ustinov, *Institute of Metal Physics, Russia;*
Dmitry Perov, *Institute of Metal Physics, Russia;*
Mikhail Samoylovich, *Central Research Technological Institute "TECHNOMASH", Russia;*
Svetlana Kleshcheva, *Central Research Technological Institute "TECHNOMASH", Russia*

Abstract: Giant magnetic antiresonance has been observed in 3D-nanocomposite based on opal matrices with embedded nanoparticles composed of Ni0:5Zn0:5Fe2O4 or Co0:5Zn0:5Fe2O4 ferrite-spinel. Microwave antiresonance manifests itself at frequencies of millimeter waveband and leads to a maximum in the reflection coefficient of electromagnetic wave. Measurements are carried out in frequency range of 26 to 38 GHz. Measurements both the reflection and transmission coefficients allow to determine the absorbed power. It was shown that antiresonance results in minimum of absorption coefficient. The reasons of physical nature of antiresonance are discussed. Microwave data are compared to structural and magnetic characterization data.

13 - **Simulation and measurements responses from combined circular SRR and wire mediums versus combined equilateral triangle SRR and wire mediums both on PTFE substrate at X band**[Poster]

Author(s): José Everardo Julião Ferreira, *Instituto Tecnológico de Aeronáutica - ITA, Brazil;*
José Edimar Barbosa Oliveira, *Instituto Tecnológico de Aeronáutica - ITA, Brazil;*
Luiz Alberto de Andrade, *Instituto de Aeronáutica e Espaço - IAE, Divisão de Materiais (AMR-C), Brazil;*
Mirabel Cerqueira Rezende, *Instituto de Aeronáutica e Espaço - IAE, Divisão de Materiais (AMR-C), Brazil;*
Antônio Carlos da Cunha Migliano, *Instituto de Estudos Avançados - IEAv, Brazil;*
Marcelo Bender Perotoni, *Universidade Federal do ABC - UFABC, Brazil*

Abstract: In this paper we consider two kinds of 1D Structures made with ten Circular Split-Ring Resonators (SRRs) boards with 7 x 7 matrix each board and ten wires boards with 7 x 7 matrix each board, similarly we did the same arrangement for Equilateral Triangle SRR, both structures with Polytetrafluoroethylene (PTFE)/Woven Fiberglass substrate, all of them regarding their frequencies responses from free-space for transmission magnitude coefficient S21 for a normally incident plane wave in numerical simulation situation and free-space measurement in X Band. Then, will compare those results from both mediums.

14 - **Investigation of resonant metamaterials elements for MHz frequency**[Poster]

Author(s): Janis Valdmanis, *leader researcher, Institute of Physics, Latvia;*
Aleksandrs Cipijs, *scientific asisstant, Institute of Physics, Latvia*

Abstract: Result of metamaterials elements investigations in MHz range are presented. Experimentally characteristics of separate element as well as interaction process dynamic between two elements are given. Measuring process influence on experimentally results and theoretical aspects of physical processes are discussed.

15 - **Dielectric-graphite composite electrodynamical characteristics**[Poster]

Author(s): Ilya Zotov, *Chelyabinsk State University, Russia;*
Igor Bychkov, *Chelyabinsk State University, Russia;*
Alexander Fediy, *Chelyabinsk State University, Russia*

Abstract: Super high frequency radiation absorbing materials attract much attention because they can serve as a base for creation of electromagnetic wave absorbing coatings that have a low reflection coefficient. In many cases cheap coating of absorbing materials are needed to protect rooms, for example in which some electronic medical equipment works. Composites with metallic inclusion are very efficient. But the cheaper composites will be those in which metallic particles are substituted with graphite powder.

16 - **Microwave response of multi-layer metamaterial-dielectric stacks**[Poster]

Author(s): Celia Butler, *University of Exeter, United Kingdom;*
James Parsons, *University of Exeter, United Kingdom;*
Roy Sambles, *University of Exeter, United Kingdom;*
Alastair Hibbins, *University of Exeter, United Kingdom*

Abstract: Multilayered metamaterial-dielectric stacks are studied experimentally and numerically. Counterintuitively, the low frequency band edge of the first transmission band does not tend to the wavelength corresponding to the length of the overall structure but is dictated primarily by the geometry of the unit cell.

17 - **Frequency selective surfaces for filtering radiation harmonics of Novosibirsk terahertz free electron laser**[Poster]

Author(s): Sergey Kuznetsov, *Budker Institute of Nuclear Physics SB RAS & Novosibirsk State University, Russia;*
Vitaly Kubarev, *Budker Institute of Nuclear Physics SB RAS, Russia;*
Alexander Gelfand, *Institute of Semiconductor Physics SB RAS, Novosibirsk Branch "TDIAM", Russia;*
Nina Fedorinina, *Institute of Semiconductor Physics SB RAS, Novosibirsk Branch "TDIAM", Russia;*
Petr Kalinin, *Budker Institute of Nuclear Physics SB RAS, Russia;*
Boris Goldenberg, *Budker Institute of Nuclear Physics SB RAS, Russia;*
Nikolay Vinokurov, *Budker Institute of Nuclear Physics SB RAS, Russia*

Abstract: In this presentation we describe the results of development of frequency selective surfaces designed for selecting radiation harmonics of Novosibirsk terahertz free electron laser. Single layer FSS with resonant and nonresonant elements of different topologies are considered: thin-film inductive crosses and capacitive loops, thick self-bearing inductive meshes with round openings etc. Technological aspects of FSS fabrication by techniques of conventional photolithography, electroforming and LIGA are discussed. The obtained experience is used in further development of more sophisticated FSS both for filter and metamaterials applications at subterahertz and terahertz frequencies.

18 - **Nonreciprocal multiple splitting of giant ferromagnetic resonance in "ferrite plate - wire grating" planar metasandwiches**[Poster]

Author(s): Galina Kraftmakher, *Institute of Radioengineering & Electronics RAS, Russia;*
Valery Butylkin, *Institute of Radioengineering & Electronics RAS, Russia*

Abstract: New effect - nonreciprocal multiple splitting of a ferromagnetic resonance peak and giant nonreciprocity in a wide frequency range - is revealed in "ferrite plate-grating composed of closely spaced finite-length parallel microwires within isotropic host medium" metasandwiches. The effect is investigated in rectangular waveguides in which electromagnetic waves propagate along the plane of a metasandwich in a transverse magnetic field. The effect depends on the length of the wires and on the magnitude and direction of the applied magnetic field.

19 - ***Shielded stripline left-handed transmission lines***[Poster]

Author(s): Ruo Feng Xu, *University of Kent, UK;*
Paul Young, *University of Kent, UK*

Abstract: This paper presents two types of left-handed transmission lines based on the shielded stripline structure. Simulated and measured results demonstrate left-handed propagation around 10-15 GHz.

20 - **Extraordinary optical transmission through hole-particle arrays**[Poster]

Author(s): Anna Ushanova, *Helsinki University of Technology, Finland;*
Harri Lipsanen, *Helsinki University of Technology, Finland*

Abstract: We present measurements of transmission through hole-particle coupled arrays. We show that the extraordinary transmission of light through the complex arrays is strongly affected by the size of the hole-particle pairs. The position of the transmission maxima significantly redshifts when the size of scatterers is decreased. The arrays provide additional degrees of freedom to optimize the optical response.

21 - **The anomalous transmission of the laser beam with the anisotropic matter**[Poster]

Author(s): Ivetta Bodnar, *State Scientific and Production Association «Scientific-Practical Materials Research Centre of the National Academy of Sciences of Belarus », Belarus;*
Sergej Guretsky, *State Scientific and Production Association «Scientific-Practical Materials Research Centre of the National Academy of Sciences of Belarus », Belarus*

Abstract: The results of the nonlinear with Nd3+ and Yb3+ doped KGW crystals polarization transformation are presented. The intensity of the laser beam changes periodically depending on the oblique incidence angle, while the laser beam passes through the flat parallel plates that are differently positioned. The plate cut of the KGW crystal doped 4% Yb and placed between the crossed polarizers does not pass radiation in the broad range of angles except for the region of ~1° where full transmission is observed. There is a substantial difference between intensity modulation and the state of the laser beam polarization at the beams' initial polarization of 45° or 90°.

22 - **Nanocomposite of metal nanoparticles and dielectric designed for photonics - fabrication and characterization**[Poster]

Author(s): Andrzej Klos, *Institute of Electronic Materials Technology, Poland;*
Marcin Gajc, *Institute of Electronic Materials Technology, Poland;*
Dorota Pawlak, *Institute of Electronic Materials Technology, Poland;*
Krzysztof Orlinski, *Institute of Electronic Materials Technology, Poland;*
Ryszard Diduszko, *Institute of Electronic Materials Technology, Poland*

Abstract: In present work metallodielectric materials designed for photonics, obtained by directional growth of dielectric crystal with incorporated metallic nanoparticles, were investigated. Description of novel fabrication system together with experimental results will be presented.

23 - **An interdigitated split ring resonator for low frequency metamaterials**[Poster]

Author(s): Sungmin Sohn, *Electrical and Computer Science Engineering, University of Minnesota, USA;*
J. Thomas Vaughan, *Center for Magnetic Resonance, University of Minnesota, USA;*
Anand Gopinath, *Electrical and Computer Science Engineering, University of Minnesota, USA*

Abstract: An interdigitated split ring resonator (IR) has been proposed to obtain negative magnetic permeability (Ì) and also negative refractive index (n) by itself. Its electromagnetic properties have been characterized using a numerical simulator (HFSS). The experimental results show that the resonators exhibit a negative permeability and refractive index and may be used for planar metamaterial structures at low frequency ranges below a few GHz.

24 - **Tunable perfect lens based on ferroelectrics**[Poster]

Author(s): Susanne Kehr, *University of California, Berkeley, USA*

Abstract: The implementation of ferroelectric materials in metamaterial structures may allow for tuning the wavelength regime of negative refraction by applying an external electric field. We study the tunability of a ferroelectric perfect lens for electric fields in the mid-infrared regime by near-field optical microscopy in combination with a free-electron laser.

25 - **Planar tri-layer Ag/SiO2/Ag plasmonic thermal emitter with coherent thermal emission**[Poster]

Author(s): Yi-Tsung Chang, *Graduate Institute of Electronics Engineering , Taiwan*

Abstract: The tri-layer Ag/SiO2/Ag plasmonic thermal emitter was applied to emit sharp and coherent waveguide mode. The excitation of Fabry-Pérot type standing waves within the Ag/SiO2/Ag waveguide was possible when the SiO2 thickness exceeds 0.9 Ìm. It is found that position of emission peak in planar Ag/SiO2/Ag plasmonic thermal emitter is dependent on the cavity thickness, and the intensity increased when the temperature increased

26 - **Spontaneous emission of rhodamine 6G molecules in synthetic opal photonic crystals under low dielectric contrast**[Poster]

Author(s): Mykhailo Dergachov, *Dnipropetrovsk National University, Ukraine;*
Vasilij Moiseyenko, *Dnipropetrovsk National University, Ukraine;*
Vladimir Shvachich, *Dnipropetrovsk National University, Ukraine;*
Tatyana Shvets, *Dnipropetrovsk National University, Ukraine*

Abstract: Spontaneous emission of rhodamine 6G molecules embedded into synthetic opal photonic crystals were studied in a spectral range of 520 – 620 nm. The emission intensity was found to be suppressed within a spectral region relative to the photonic stop-band and to be amplified at its “blue” side. The fluorescence spectra of rhodamine 6G molecules into pores of synthetic opals filled with a mix of glycerine with water were measured. Significant "blue" shift of the rhodamine 6G emission spectrum dependent of the glycerine concentration in comparison with the spectrum position in the pure glycerine measured in optical cavity is revealed. It has been found that the dye luminescence arises in spectral range near to the high-frequency edge of a photonic stop-band and the spectral position of fluorescence maximum follows the stop-band position.

27 - **On the nature of the secondary emission of globular SiO2 photonic crystals** [Poster]

Author(s): Mykhailo Dergachov, *Dnipropetrovs'k National University, Ukraine;*
Vasilij Moiseyenko, *Dnipropetrovs'k National University, Ukraine;*
Vladimir Shvachich, *Dnipropetrovs'k National University, Ukraine;*
Anton Yevchik, *Dnipropetrovs'k National University, Ukraine*

Abstract: Emission of the bare and dielectrics infiltrated synthetic opals under excitation at λ = 400 nm is observed in the Stokes spectral region. The first part of the secondary emission spectrum is situated in the vicinity of the excitation line and corresponds to the vibrational spectrum range. The second one is at the stop-band edge. Interpretation of the secondary emission nature is given in terms of enhanced Raman scattering, impurity luminescence and the three photon parametric luminescence in synthetic opal.

28 - **Self-action of light in photonic crystals**[Poster]

Author(s): Ilya Razdolski, *Moscow State University, Russia;*
Oleg Aktsipetrov, *Moscow State University, Russia*

Abstract: Self-action effects of light are observed in PBG structures. Large values of the third-order nonlinear- ity in MC and PC structures made of Bi-doped YIG are estimated, showing the enhancement of the effective self-action effect magnitude. Spectral dependences of the effective third-order nonlinearity of PC at the red PBG edge is obtained, while no self-action on the blue PBG edge is detected.

29 - **Effective optical properties of a Swiss cross metamaterial beyond normal incidence**[Poster]

Author(s): Christoph Menzel, *Institute of Solid State Theory and Optics, Friedrich-Schiller-Universität Jena, Germany;*
Christian Helgert, *Institute of Applied Physics, Friedrich-Schiller-Universität Jena, Germany;*
Johannes Üpping, *Institute of Physics, ÌMD group, Martin-Luther-Universität Halle-Wittenberg, Germany;*
Carsten Rockstuhl, *Institute of Solid State Theory and Optics, Friedrich-Schiller-Universität Jena, Germany;*
Thomas Paul, *Institute of Solid State Theory and Optics, Friedrich-Schiller-Universität Jena, Germany;*
Ernst-Bernhard Kley, *Institute of Applied Physics, Friedrich-Schiller-Universität Jena, Germany;*
Thomas Pertsch, *Institute of Applied Physics, Friedrich-Schiller-Universität Jena, Germany;*
Ralf Wehrspohn, *Institute of Physics, ÌMD group, Martin-Luther-Universität Halle-Wittenberg, Germany;*
Falk Lederer, *Institute of Solid State Theory and Optics, Friedrich-Schiller-Universität Jena, Germany*

Abstract: We investigate experimentally and theoretically the effective properties at almost arbitrary angles of incidence for a recently proposed metamaterial supporting negative refraction. We reveal how the effective properties depend on the chosen incidence polarization and incidence plane and on the angle of incidence. Implications on possible applications will be discussed.

30 - **Amplification of intensity of Tamm peak on the boundary LHM/photonic crystal**[Poster]

Author(s): Sergey Tarapov, *Institute of Radiophyscis and Electronics NAS Ukraine, Ukraine;*
Tatyana Kalmykova, *Institute of Radiophyscis and Electronics NAS Ukraine, Ukraine;*
Mikhail Khodzitsky, *Institute of Radiophyscis and Electronics NAS Ukraine, Ukraine;*
Dmitry Belozorov, *Institute for Theoretical Physics NSC "Kharkov Institute of Physics & Technology" NAS of Ukraine, Ukraine;*
Anatoly Pogorily, *Institute of Magnetism, Ukraine; Anatoly Belous, Institute of General and Inorganic Chemistry, Ukraine;*
Sergey Solopan, *Institute of General and Inorganic Chemistry, Ukraine*

Abstract: The paper is devoted to the research of surface effects appear on the boundary between various electro-magnetic materials. Namely, we studied experimentally in the millimeter waveband the process of amplification of the Tamm peak (surface state) appeared on the boundary between 1D photonic crystal and left handed medium, formed by composite structure based on perovskite-manganite. The improving of the transparency of the medium on the frequency of Tamm peak has been detected and analyzed

31 - **Using nanoimprint lithography for aligned stacking of fishnet structures**[Poster]

Author(s): Iris Bergmair, *Profactor GmbH, Austria;* Michael Mühlberger, *Profactor GmbH, Austria;*
Babak Dastmalchi, *CD Laboratory for Surface Optics and Center for Surface and Nanoanalytics, Johannes Kepler Universität, Austria;* Michael Bergmair, *CD Laboratory for Surface Optics and Center for Surface and Nanoanalytics, Johannes Kepler Universität, Austria;* Ulrich Dobramysl, *CD Laboratory for Surface Optics and Center for Surface and Nanoanalytics, Johannes Kepler Universität, Austria;* Ekaterina Psheney-Severin, *Center for Innovation Competence »ultra optics«, Institute of Applied Physics, Friedrich-Schiller-University, Jena, Germany;* Thomas Pertsch, *Center for Innovation Competence »ultra optics«, Institute of Applied Physics, Friedrich-Schiller-University, Jena, Germany;* Holger Schmidt, *Microstructure Technology & Microoptics, Institute of Applied Physics, Friedrich-Schiller-University, Jena, Germany;* Ernst-Bernhard Kley, *Microstructure Technology & Microoptics, Institute of Applied Physics, Friedrich-Schiller-University, Jena, Germany;* Kurt Hingerl, *CD Laboratory for Surface Optics and Center for Surface and Nanoanalytics, Johannes Kepler Universität, Austria;* Rainer Schöftner, *Profactor GmbH, Austria*

Abstract: In this work we show large area fabrication of fishnet structures by Nanoimprint Lithography (NIL) and aligned stacking of such layers on top of each other to achieve a 3D material.

32 - **Nanolithography based on an atom pinhole camera for practical applications** Poster

Author(s): Pavel Melentiev, *Institute of Spectroscopy, Russia;*
Alexey Zablotskiy, *Moscow Institute of Physics and Technology, Russia;*
Anton Afanasiev, *Institute of Spectroscopy, Russia;*
Artur Kuzin, *Moscow Institute of Physics and Technology, Russia;*
Dmitry Lapshin, *Institute of Spectroscopy, Russia;*
Andrey Baturin, *Moscow Institute of Physics and Technology, Russia;*
Victor Balykin, *Institute of Spectroscopy, Russia*

Abstract: We will present up to date results of nanolithography based on atom pinhole camera. With the use of the approach we have built on a Si surface an array of identical arbitrary-shape atomic nanostructures with the minimum size of an individual nanostructure element down to 30 nm. The possibility of the 30 nm lithography by means of atoms, molecules and clusters for practical use in metamaterials development as well as for plasmonic applications will be shown.

33 - **Terahertz metamaterials fabricated with the super-fine ink-jet printer** Poster

Author(s): Keisuke Takano, *Inst. of Laser Engineering, Osaka Univ., Japan;*
Taku Kawabata, *Inst. of Laser Engineering, Osaka Univ., Japan;*
Cho-Fan Hsieh, *Department of Electrophysics, National Chiao Tung Univ., Taiwan;*
Fumiaki Miyamaru, *Department of Physics Faculty of Science, Shinsyu Univ., Japan;*
Mitsuo Takeda, *Department of Physics Faculty of Scienc, Shinsyu Univ., Japan;*
Ru-Pin Pan, *Department of Electrophysics, National Chiao Tung Univ., Taiwan;*
Ci-Ling Pan, *Department of Physics and Inst. of Photonics, National Tsing-Hua Univ., Taiwan;*
Masanori Hangyo, *Inst. of Laser Engineering, Osaka Univ., Japan*

Abstract: A super-fine ink-jet (SIJ) printing technology has been applied to the fabrication of terahertz metamaterials. The terahertz responses of the printed samples agree with those expected from the structures. The SIJ printing has a potential to accelerate the developments of the terahertz metamaterial researches.

Plenary Session II

(Great Hall)

Session chairperson(s): Filiberto Bilotti

11:40 - **Optical metamaterials and nano-plasmonics**[Plenary]
Author(s): Xiang Zhang, *University of California Berkeley, USA*

12:40 – Lunch (The Hive – Catering Building)

Abstract: Metamaterials are artificially designed subwavelength composites that possessextraordinary properties not existing in naturally occurring materials. In particular, they can alter the propagation of electromagnetic waves resulting in negative refraction, subwavelength focusing and even in cloaking of macroscopic objects. Such unusual properties can be obtained by a careful design of dielectric or metal-dielectric composites on a deep sub-wavelength scale. The metamaterials may have profound impact in wide range of applications such as nano-scale imaging, nanolithography, and integrated nano photonics. I will discuss a few recent experiments demonstrating intriguing phenomena associated with Metamaterials. These include subdiffraction limit imaging and focusing, low-loss and broad-band negative-refraction of visible light, negative-index metamaterials and the first cloak operating at optical frequencies; an all-dielectric "carpet cloak" with broad-band and low-loss performance. I will also present our recent demonstration of a deep sub-wavelength plasmonic laser.

Bio: Professor Xiang Zhang is Chancellor's Professor at UC Berkeley and the Director of NSF Nano-scale Science and Engineering Center (NSEC) which includes Berkeley-Stanford-UCLA-UNCC-HP Labs. He also serves as Director of Department of Defense MURI Center on Metamaterials and Devices that includes Berkeley-MIT-UCLA-UCSD-Duke-Imperial College (UK) and as a faculty scientist in the Lawrence Berkeley National Laboratory. Professor Zhang's current research focused on nano-scale science and technology, meta-materials, nano-photonics and bio-technologies. He has published more than 80 technical papers including publications in Science and Nature Materials. He has given over 80 invited or keynote talks at international conferences and institutions. Professor Zhang is on editorial boards of three journals. He is a co-chair of NSF Nanoscale Science and Engineering Annual Grantee Conference in 2004-2005, Chair of Technical Program of IEEE 2nd International Conference on Micro and Nano Engineered and Molecular Systems in 2007.

Special Session 4 - Applications to Magnetic Resonance Imaging

(Skeel Theatre)

Organizer(s): Ricardo Marqués
Session chairperson(s): Ricardo Marqués

14:00 - **Preliminary experiments on a CRLH metamaterial zeroth-order resonant coil (ZORC) element for 7 Tesla MRI applications with large field of view**[Invited]

Author(s): Andre Rennings, *University of Duisburg-Essen, Germany;*
Philipp Schneider, *University of Duisburg-Essen, Germany;*
Christophe Caloz, *Ecole Polytechnique de Montreal, Canada;*
Stephan Orzada, *University of Duisburg-Essen, Germany*

Abstract: Preliminary experimental magnetic resonance imaging (MRI) results based on a novel composite right/left-handed (CRLH) zeroth-order resonant coil (ZORC) are presented. These results demonstrate, using an homogeneous flat phantom emulating the human body, that the ZORC can achieve very large fields of view, corresponding to the length of the ZOR structure, which is of approximately 30 cm in the prototype presented.

14:20 - **Curved wire-medium: simulation and experimental results** [Invited]

Author(s): Xavier Radu, *Université catholique de Louvain, Belgium;*
Christophe Craeye, *Université catholique de Louvain, Belgium*

Abstract: This paper shows, numerically and experimentally, that imaging is realizable with a curved wire- medium, with curvature up to 90 degrees. In a first part, simulation results obtained for various curvatures are shown and sub-wavelength imaging on a wide bandwidth is demonstrated. In a second part, transmission of a medical image through a 63 degrees curved wire-medium is presented.

14:40 - **A practical parametric magneto-inductive ring detector**[Invited]

Author(s): Richard Syms, *Imperial College London, United Kingdom;*
Floume Timmy, *Imperial College London, United Kingdom;*
Laszlo Solymar, *Imperial College London, United Kingdom;*
Ian Young, *Imperial College London, United Kingdom*

Abstract: A parametrically amplified detector for MRI based on an octagonal arrangement of PCBs is presented. Each carries L-C resonators for signal, idler and pump. The signals interact via varactors, allowing amplification of signals from a rotating dipole. Uniform gain is demonstrated in a system suitable for 1H imaging at 1.5T.

15:00 - **Developing Swiss rolls for MRI**[Invited]

Author(s): Michael Wiltshire, *Imperial College London, United Kingdom*

Abstract: The Swiss Roll structure is a strongly magnetic metamaterial at radiofrequency but is constructed from non-magnetic materials. This makes it an attractive candidate for use in the magnetic resonance environment. In this presentation I will review the performance of the material with particular emphasis on its imaging capability, and describe how the structure can be tuned to alter its magnetic properties. Its potential for use in MRI will be discussed.

15:20 - **Potential applications of mu=-1 metamaterial superlenses for magnetic resonance imaging**[Invited]

Author(s): Manuel Freire, *University of Seville, Spain;* Ricardo Marqués, *University of Seville, Spain;*
Lukas Jelinek, *University of Seville, Czech Republic;* Vicente Delgado, *University of Seville, Spain*

Abstract: This work shows some new potential applications in magnetic resonance imaging (MRI) for the mu=-1 metamaterial lens reported by the authors in a previous paper. In one of these applications, the penetration depth of MRI surface coils is increased due to the combination of the lens with a magnetic wall which works as a mirror for the radiofrequency magnetic field. It is also investigated the capability of the lens to localize the field pattern of each of the coils of an array with application to parallel imaging.

15:40 – Coffee break (Octagon Room)

Regular Session 4A - Applications of metasurfaces

(People's Palace 1)

Session chairperson(s): George Goussetis, Filippo Capolino

14:00 - **Towards metasurfaces for wideband systems**[Invited]
Author(s): J(Yiannis) Vardaxoglou, *Loughborough University, United Kingdom*

Abstract: This paper covers some investigations of planar and conformal metamaterial surfaces (Metasurfaces) as conductor structures for exhibiting Electromagnetic Band Gap (EBG) properties having wide bandwidth characteristics. Resonant periodic structures are known to interact well with radiating elements provided such elements are suitably integrated. In order to meet some practical demands in areas of modern communication systems and on-body electronics, metamaterial techniques can be employed to realise simple compact and simple antennas with superior performance compared to conventional antennas. In this paper, we review some examples of metasurfaces capable of enhancing antennas' performance.

14:20 - **Engineered-response surfaces for power transmission enhancement through electrically small apertures**[Regular oral]
Author(s): Luca Scorrano, *University Roma Tre, Dept. of Applied Electronics, Italy;*
Filiberto Bilotti, *University Roma Tre, Dept. of Applied Electronics, Italy;*
Lucio Vegni, *University Roma Tre, Dept. of Applied Electronics, Italy;*
Ekmel Ozbay, *Bilkent University, Nanotechnology Research Center, Turkey*

Abstract: The role of complex surfaces in increasing the power transmission through sub-wavelength apertures is discussed. Some resonant approaches based on FSSs and SRRs, capable to increase the aperture equivalent electric and magnetic dipole moments and consequently the power transmission, are shown. The performances of the proposed setups are then illustrated and compared through the use of full-wave simulations.

14:40 - **Low-profile high-directivity conformal antennas based on high impedance and EBG metamaterial surfaces**[Regular oral]
Author(s): George Palikaras, *Queen Mary University of London, United Kingdom;*
Alexandros Feresidis, *Lougborough University, UK; Yang Hao, Queen Mary University of London, UK*

Abstract: The ability of novel and emergent high impedance conformal metamaterial surfaces to reduce the diameter of cylindrical microwave antennas while improving antenna operating performance characteristics will be experimentally explored for various structures. The proposed structures include resonant-cavity type antennas, of different profile thickness: $\lambda/2$, $\lambda/4$ and $\lambda/6$ operating around 2.3GHz.

15:00 - **Multisource embedding in metamaterial-based cavities for directivity enhancement**[Regular oral]
Author(s): Shah Nawaz Burokur, *IEF, Univ. Paris-Sud, CNRS, UMR 8622, France;*
André de Lustrac, *IEF, Univ. Paris-Sud, CNRS, UMR 8622, France*

Abstract: The analysis and design of subwavelength metamaterial-based resonant cavity antennas are presented. The antennas under investigation are formed by embedding a feeding source in a Fabry-Perot (FP) cavity composed of a Perfect Electrical Conductor (PEC) surface and a metasurface reflector. The embedded feeding source used in this study is a 2 × 2 microstrip patch array. The influence of the inter-element spacing of the patch array feed on the radiation patterns is investigated and reported. The effect of the cavity thickness is also considered. Finally, the design of highly directive subwavelength cavity antennas is presented.

15:20 - **Electromagnetic scattering by an impedance sheet with a 1-D inhomogeneity in a rectangular waveguide**[Regular oral]
Author(s): Keith Whites, *South Dakota School of Mines and Technology, USA;*
Brian Glover, *Los Alamos National Laboratory, USA*

Abstract: Traditional methods for the characterization of impedance sheets usually require a nearly uniform sheet impedance for the characterization process. In this paper, we present a solution for the scattering by an impedance sheet that is inhomogeneous (in the long dimension) and located in a rectangular waveguide, which can be used in such a characterization.

15:40 – Coffee break (Octagon Room)

Regular Session 4B - Plasmonics I

(People's Palace 2)

Session chairperson(s): Gennady Shvets, Harry Atwater

14:00 - **Spectral and spatial mode engineering of plasmonic nanocavities: Subradiant Modes and tunable Fano resonances for metamaterials applications**[Keynote]
Author(s): Stefan Maier, *Imperial College, United Kingdom*

Abstract: We demonstrate control over the spatial and spectral properties of plasmonic nanocavities in the form of structures sustaining phenomena such as super- and subradiance, and Fano-type resonances, in the optical regime. Such structures show high promise for applications ranging from refractive index sensing to slow-light metamaterials.

14:40 - **Dispersion of surface plasmons in noble metal films**[Invited]
Author(s): Alex Schuchinsky, *Queen's University Belfast, United Kingdom*

Abstract: The surface plasmons (SP) in the films of noble metals on glass substrate have been studied in the optical range. The properties of SP guided by Au, Cu and Ag films are analysed using the rigorous solutions of the full-wave dispersion equation with the measured optical constants of the metals. It is shown that the attainable delay of SP in the Au and Cu films is limited not by losses but the actual frequency dispersion (non-Drude) of permittivity that precludes the SPs from reaching the plasmonic resonance.

15:00 - **Ultrafast and nonlocal effects in optical properties of plasmonic nanorod arrays**[Invited]
Author(s): Anatoly Zayats, *The Queen's University of Belfast, United Kingdom;*
Robert Pollard, *The Queen's University of Belfast, UK;*
Gregory Wurtz, *University of North Florida, USA;*
Viktor Podolskiy, *Oregon State University, USA*

Abstract: Linear and nonlinear optical properties of plasmonic nanorod arrays are discussed. The influence of nonlocal effects leading to the excitation of additional wave in nanorod metamaterials in epsilon-near-zero regime and its consequences for applications are considered. Ultrafast nonlinear optical response of such metamaterials has also been studied showing all-optical modulation of transmission with sub-picosecond time response at low intensities of control light.

15:20 - **Plasmonic particles patterns manipulating efficient radiation and wave incoupling**[Invited]
Author(s): Hossein Mosallaei, *Northeastern University, USA;*
Shabnam Ghadarghadr, *Northeastern University, USA*

Abstract: The focus of this paper is to demonstrate field characterization and physics of non-periodic plasmonic particles located above the layered structures. Green's function analysis along with Sommerfeld type integrals are developed to effectively manipulate the physical performance. Two applications, namely effective beam radiation and energy-coupling in layered materials are explored.

15:40 – Coffee break (Octagon Room)

Special Session 5 - Extreme-parameter metamaterials

(Skeel Theatre)

Organizer(s): Andrea Alù, Nader Engheta
Session chairperson(s): Andrea Alù, Nader Engheta

16:00 - **Supercoupling and enhanced transmission in ENZ structures**[Invited]
Author(s): Nader Engheta, *University of Pennsylvania, USA;* Andrea Alù, *University of Texas at Austin, USA;*
Mario Silveirinha, *University of Coimbra, Portugal;* Brian Edwards, *University of Pennsylvania, USA*

Abstract: The ability to engineer and tailor material parameters has expanded the palette of available materials in electromagnetics and optics. In addition to conventional parameter values, it is now possible to design and construct materials with parameters possessing unusual values, e.g., negative, near zero, and very high permittivity or permeability. We have explored various features of epsilon-near-zero (ENZ) or mu-near-zero (MNZ) metamaterials, and have investigated several potential applications of these materials. In this talk, we give an overview of some of these ENZ phenomena, particularly the concepts of "supercoupling" and ENZ-based enhanced transmission and image transport and their potential applications.

16:20 - **Focusing with aperiodic array of metal-dielectric-metal plasmonic waveguides**[Invited]
Author(s): Shanhui Fan, Department of Electrical Engineering, Stanford University, USA;
Lieven Verslegers, *Department of Electrical Engineering, Stanford University, USA;*
Peter B. Catrysse, *Department of Electrical Engineering, Stanford University, USA;*
Zongfu Yu, *Department of Electrical Engineering, Stanford University, USA*

Abstract: In a metal-dielectric-metal waveguide, the effective index of the propagating modes is strongly tunable by varying the width of the dielectric region. Exploiting this effect, here we demonstrate a far-field plasmonic microlens using an array of metallic slits. We also introduce a mechanism for far-field focusing an incident plane wave into a deep-subwavelength-scale spot inside a coupled aperiodic array of metal-dielectric-metal waveguides.

16:40 - **Extreme-parameter materials and boundary conditions**[Invited]
Author(s): Ari Sihvola, *Helsinki University of Technology, Finland;*
Henrik Wallén, *Helsinki University of Technology, Finland;*
Ismo Lindell, *Helsinki University of Technology, Finland*

Abstract: This presentation emphasizes the distinction between boundaries and interfaces. In electromagnetics, boundary conditions can be used to narrow down the computation domain of complex problems. The presentation raises also the synthetic point of view where boundary conditions are approximated by materials with extreme-parameter materials.

17:00 - **An array of crossed metallic wires as a metamaterial with extreme Index of refraction**[Invited]
Author(s): Mário Silveirinha, *Universidade de Coimbra - Instituto de Telecomunicações, Portugal;*
Carlos Fernandes, *Technical University of Lisbon, Instituto Superior Técnico - Instituto de Telecomunicacões, Portugal;*
Jorge Costa, *Technical University of Lisbon, Instituto Superior Técnico - Instituto de Telecomunicacões, Portugal*

Abstract: In a recent work [Phys. Rev. B, 78, 033108, 2008] we have suggested that an array of crossed metallic wires may interact with an electromagnetic wave as a material with an extreme index of refraction. Here, we will present our ongoing work on such metamaterials, and discuss the physics of the extreme index of refraction property and possible applications.

17:20 - **Graded-index metamaterials: From linear to nonlinear optics**[Invited]
Author(s): Natalia Litchinitser, *The State University of New York at Buffalo, USA;*
Tolanya Gibson, *The State University of New York at Buffalo, USA;*
Ildar Gabitov, *University of Arizona, USA; Vladimir Shalaev, Purdue University, USA;*
Andrei Maimistov, *Moscow Engineering Physics Institute, Russia*

Abstract: We discuss our recent results on linear and nonlinear phenomena taking place in graded-index metamaterial structures with refractive index gradually changing between positive and negative values. We perform a detailed study of the effect of anomalous field enhancement taking place at oblique incidence of the electromagnetic waves in such metamaterials structures.

17:40 – Evening reception (Octagon Room)

Regular Session 5A - Applications of tunable metamaterials

(People's Palace 1)

Session chairperson(s): Ferran Martin, Lucio Vegni

16:00 - **Multiband tuneable microwave resonators and filters on a combination of right/left-handed transmission line sections**[Invited]

Author(s): Irina Vendik, *St. Petersburg Electrotechnical University, Russia;* Dmitry Kholodnyak, *St. Petersburg Electrotechnical University, Russia;* Polina Kapitanova, *St. Petersburg Electrotechnical University, Russia;* Kirill Zemlyakov, *St. Petersburg Electrotechnical University, Russia*

Abstract: A combination of the right/left-handed transmission line sections as applied to multiband filter design is used to control the position of the individual pass-bands. The implementation of variable capacitors in unit cells of artificial transmission lines provides frequency tuning. The theoretical approach to the design of multiband resonators and filters controlled by variable capacitors is described. The results of numerical simulation and experimental investigation are presented and discussed.

16:20 - **Voltage tunable split-ring-resonators for waveguide applications**[Regular oral]

Author(s): Matthias Maasch, *Technische Universität Darmstadt, Microwave Engineering, Germany;* Martin Schüßler, *Technische Universität Darmstadt, Microwave Engineering, Germany;* Erick González Rodíguez, *Technische Universität Darmstadt, Microwave Engineering, Germany;* Christian Damm, *Technische Universität Darmstadt, Microwave Engineering, Germany;* Grzegorz Lubkowski, *Technische Universität Darmstadt, Institut für Theorie Elektromagnetischer Felder, Germany;* Rolf Jakoby, *Technische Universität Darmstadt, Microwave Engineering, Germany*

Abstract: A concept for a voltage tunable varactor-loaded split-ring-resonator array in a waveguide is described. By tuning the semiconductor varactors the left-handed transmission band below the waveguide cutoff frequency can be shifted in the range of 0.9...2.2GHz. The parasitic effects of the biasing network are investigated. Experimental results are compared to theory to validate the biasing concept.

16:40 - **Ferrite supported antenna with CRLH cells tuned by magnetic bias field**[Regular oral]

Author(s): Gheorghe Sajin, National Research Institute for Microtechnology, Romania; Stefan Simion, National Research Institute for Microtechnology, Romania; Florea Craciunoiu, National Research Institute for Microtechnology, Romania; Andrei Muller, National Research Institute for Microtechnology, Romania; Alina Cristina Bunea, National Research Institute for Microtechnology, Romania

Abstract: This paper presents the results of the frequency tuning of a ferrite supported resonating CPW antenna based on CRLH (Composite Right/Left-Handed) transmission lines. The tuning is obtained by magnetically polarizing the ferrite substrate with a magnetic biasing field, which can be varied between 0 T and 0.26 T. Data obtained by simulation with a suitable microwave software indicate a frequency shift of 530 MHz at a working frequency of 12.88 GHz, in very good agreement with the experimental results, showing a frequency shift of 450 MHz.

17:00 - **Dual band-pass active filters based on recursive topologies and CRLH transmission lines**[Regular oral]

Author(s): Oscar Garcia-Perez, *Carlos III University in Madrid, Spain; Daniel Segovia-Vargas, Carlos III University in Madrid, Spain;* Vicente Gonzalez-Posadas, *Universidad Politecnica de Madrid, Spain*

Abstract: In this paper, the non-linear phase response exhibited by the composite right/left-handed (CRLH) transmission lines is used to achieve dual band response in a first order recursive active filter topology. This line is used to compensate the phase in the feedback structure, so the output signal can be combined with the input constructively. Two different designs are proposed. The first one uses dual-band branch line couplers as power combiners. The second approach, in a more compact design, uses broadband coupled line combiners.

17:20 - **Application of right and left-handed transmission lines to design of highly integrated and tuneable directional couplers**[Regular oral]

Author(s): Polina Kapitanova, *Dept. of Microelectronics & Radio Engineering, St. Petersburg Electrotechnical University, Russia;* Dmitry Kholodnyak, *Dept. of Microelectronics & Radio Engineering, St. Petersburg Electrotechnical University, Russia;* Irina Vendik, *Dept. of Microelectronics & Radio Engineering, St. Petersburg Electrotechnical University, Russia;* Ruben Perrone, *Institute for Micro- and Nanotechnologies, Ilmenau University of Technology, Germany;* Stefan Humbla, *Institute for Micro- and Nanotechnologies, Ilmenau University of Technology, Germany;* Jens Mueller, *Institute for Micro- and Nanotechnologies, Ilmenau University of Technology, Germany;* Matthias Hein, *Institute for Micro- and Nanotechnologies, Ilmenau University of Technology, Germany*

Abstract: Microwave devices based on a combination of metamaterial left-handed and traditional right-handed transmission line sections are considered. Artificial implementation of transmission line sections as lumped-element T or ¶-unit cells based on modern multilayer technology is favourably used to design highly integrated microwave devices. At the same time, involving variable capacitors in artificial transmission lines allows design-ing tuneable devices. Novel designs and results of experimental verification of highly integrated and tuneable directional couplers are presented.

17:40 – Evening reception (Octagon Room)

Regular Session 5B - Plasmonics II

(People's Palace 2)

Session chairperson(s): Nikolay Zheludev, Alastair Hibbins

16:00 - **The plasmonic Talbot effect**[Invited]

Author(s): Dries van Oosten, *Center for Nanophotonics, FOM Institute AMOLF, Netherlands;* Marko Spasenoviç, *Center for Nanophotonics, FOM Institute AMOLF, Netherlands;* Kobus Kuipers, *Center for Nanophotonics, FOM Institute AMOLF, Netherlands*

Abstract: We present phase-sensitive near-field measurements of the surface plasmon polariton (SPP) field close to a chain of subwavelength sized holes in a gold film. The SPPs are launched by illuminating the chain of holes under perpendicular incidence. We investigate how the field pattern close to the chain evolves into diffraction orders in the far field. We observe self-images of the chain in the SPP field. These self-images are caused by the plasmonic equivalent of the Talbot effect.

16:20 - C**ross-conversion between surface plasmon polaritons and quasi-cylindrical waves**[Regular oral]

Author(s): Philippe Lalanne, *Institut Optique, France;* Haitao Liu, *3Key Laboratory of Opto-electronic Information Science and Technology, Ministry of Education, Institute of Modern Optics, Nankai University, Tianjin 300071, P. R. China., china;* Xiaoyan Yang, *School of Optoelectronics Science and Engineering, Huazhong University of Science and Technology, Wuhan 430074, china*

Abstract: The optical properties of textured metallic surfaces are governed by the scattering of surface plasmon polaritons (SPPs) and of quasi-cylindrical waves (CWs), which are both excited by the nanoobjects located on the surface. We study here a fundamental scattering process of these fields, namely the cross-conversion of a CW into a SPP.

16:40 - **Plasmonic nanoantennae for efficient and ultrahigh resolution optical microscopy**[Regular oral]

Author(s): Xuewen Chen, *ETH, Zurich, Switzerland;* Hadi Eghlidi, *ETH, Zurich, Switzerland;* Kwang-Geol Lee, *ETH, Zurich, Switzerland;* Stephan Götzinger, *ETH, Zurich, Switzerland;* Mario Agio, *ETH, Zurich, Switzerland;* Vahid Sandoghdar, *ETH, Zurich, Switzerland*

Abstract: We investigate plasmonic nanoantennae as probes for near-field fluorescence microscopy. We present de-tailed theoretical and experimental studies on the interplay between field enhancement and spatial resolution and examine novel schemes for the efficient conversion of propagating light into the near field of nanoantennae.

17:00 - **Plasmonic EIT at the Drude damping limit**[Regular oral]

Author(s): Na Liu, *4th Physics Institute, University of Stuttgart, Germany;* Lutz Langguth, *4th Physics Institute, University of Stuttgart, Germany;* Thomas Weiss, *4th Physics Institute, University of Stuttgart, Germany;* Jürgen Kästel, *Fachbereich Physik and research center OPTIMAS, Technische Universität Kaiserslautern, Germany;* Michael Fleischhauer, *Fachbereich Physik and research center OPTIMAS, Technische Universität Kaiserslautern, Germany;* Tilman Pfau, *5th Physics Institute, University of Stuttgart, Germany;* Harald Giessen, *5th Physics Institute, University of Stuttgart, Germany*

Abstract: In this paper, we experimentally demonstrate a nanoplasmonic analog of electromagnetically induced transparency utilizing a stacked optical metamaterial. Specifically, we achieve a very narrow transparency window with high modulation depth due to nearly complete suppression of radiative losses.

17:20 - **Surface plasmon resonances of a half-disk**[Regular oral]

Author(s): Henrik Kettunen, *Dept. of Radio Science and Engineering, Helsinki University of Technology, Finland;* Henrik Wallen, *Dept. of Radio Science and Engineering, Helsinki University of Technology , Finland;* Ari Sihvola, *Dept. of Radio Science and Engineering, Helsinki University of Technology , Finland*

Abstract: This presentation studies the quasistatic response of a negative-permittivitty half-disk. The polarizability of the half-disk is computed using a semianalytical method. Furthermore, the surface plasmon modes, or the electrostatic resonances supported by the sharp corners and the smooth contour of a half-disk are discussed.

17:40 – Evening reception (Octagon Room)

Registration

8:30 (Registration Office)

Special Session 6 - Optical metamaterials

(Skeel Theatre)

Organizer(s): Stefan Maier
Session chairperson(s): Stefan Maier

09:00 - **Coherent metamaterials**[Keynote]
Author(s): Nikolay Zheludev, *University of Southampton, United Kingdom;*
Vassili Fedotov, *University of Southampton, United Kingdom;*
Eric Plum, *University of Southampton, United Kingdom;*
Nikitas Papasimakis, *University of Southampton, United Kingdom*

Abstract: We introduce "coherent" metamaterials as a platform for passive and gain-assisted photonic devices.

09:40 - **Designing optical metamaterials**[Invited]
Author(s): Maria Kafesaki, *Foundation for Research and Technology Hellas (FORTH), Institute of Electronic Structure and Laser (IESL), Greece;* Raluca Penciu, *FORTH-IESL, Greece;* Jianfeng Zhou, *Iowa State University, USA;*
Thomas Koschny, *Iowa State University, USA;* Eleftherios Economou, *FORTH-IESL, Greece;*
Costas Soukoulis, *FORTH-IESL & Iowa State University, USA*

Abstract: Based on the behavior of high frequency negative permittivity and negative permeability materials, we present simple design rules to create and optimize such metamaterials.

10:00 - **Terahertz spoof surface plasmons**[Invited]
Author(s): Francisco J. Garcia-Vidal, *Universidad Autonoma de Madrid, Spain*

Abstract: In this presentation we will show how all the capabilities of surface plasmon polartons found in the optical range of the electromagnetic spectrum can be safely transferred to lower frequencies (for example, terahertz frequencies) by taking advantage of the spoof surface plasmon concept, i.e., surface electromagnetic modes in a nearly perfect electric conductor can be built up by periodically structuring its surface in a length scale much smaller than the operating wavelength.

10:20 - **Transforming light and cloaking with photonic metamaterials**[Invited]
Author(s): Vladimir M. Shalaev, *Purdue University, USA;* Alexander V. Kildishev, *Purdue University, USA;*
Vladimir P. Drachev, *Purdue University, USA;* Uday K. Chettiar, *Purdue University, USA;*
Wenshan Cai, *Purdue University, USA*

Abstract: We review recent progress in developing metamaterials for the optical part of the spectrum as well as the new emerging field of transformation optics. A new paradigm of engineering space for light with transformation optics and its applications for cloaking and “super-imaging” will be also discussed.

Regular Session 6A - Metamaterial transmission lines and waveguides

(People's Palace 1)

Session chairperson(s): Silvio Hrabar, Ekaterina Shamonina

09:00 - **Metamaterial transmission lines with right-handed wave propagation at low frequencies and left-handed wave propagation at high frequencies: application to dual-band microwave components** Regular oral

Author(s): Gerard Sisó, *Universitat Autònoma de Barcelona, Spain;* Jordi Bonache, *Universitat Autònoma de Barcelona, Spain;* Ferran Martín, *Universitat Autònoma de Barcelona, Spain*

Abstract: A novel strategy for the design of composite right/left handed (CRLH) transmission lines exhibiting the right handed transmission band at low frequencies and the left handed transmission band at high frequencies is presented in this paper. The key idea is to parallel connect a right handed unit cell operating at the lower band, and a left handed unit cell designed to exhibit left handed propagation at the upper band. Due to the diplexing action of such configuration (related to the frequency selective characteristics of the unit cells), the required functionality is achieved. To illustrate the application of such CRLH lines, a dual-band rat race hybrid coupler based on them has been designed and fabricated. The different artificial lines of this dual-band device are implemented by means of complementary split ring resonators (CSRRs).

09:20 - **MR-safe cables – an application of magneto-inductive waves?** Regular oral

Author(s): Richard Syms, *Imperial College London, UK;*
Laszlo Solymar, *Imperial College London, UK;*
Ian Young, *Imperial College London, UK*

Abstract: An analysis is presented of transmission lines periodically interrupted by transformers. In MRI, the transformers are used to block common-mode signals from the transmitter while passing differential signals from a detector. Dispersion characteristics are derived, and it is shown that the line supports magneto-inductive waves. Multiple bands are confirmed experimentally.

09:40 - **The Radiation of antennas based on metamaterial waveguides** Regular oral

Author(s): Alexey Basharin, *Institute for theoretical and applied electromagnetics, Russia, Russia;*
Nikolay Balabukha, *Institute for theoretical and applied electromagnetics, Russia, Russia*

Abstract: The radiation of antennas based on metamaterials waveguides is investigated in the work. It is shown, that such antennas can radiate in forward, backward and simultaneously in both directions. Results of antennas measurements in anechoic chamber are presented. The experiment results prove the opportunity for such antennas to radiation in the backward direction. The research results for wideband waveguides antenna with the radiation pattern of the special form are also shown.

10:00 - **Frequency selective transmission in EBG structures** Regular oral

Author(s): Irina Khromova, *Public University of Navarra, Spain;*
Ramón Gonzalo, *Public University of Navarra, Spain;*
Karu Esselle, *Macquarie University, Australia*

Abstract: In this work a new integrated scheme of frequency selective transmission based on EBG technology is presented. In the proposed configuration the signal is received by an EBG horn antenna and filtered by an EBG resonant cavity via waveguide-to-cavity-to-waveguide coupling.

10:20 - **Surface waves on the interface of magneto-photonic crystal and semiconductor** Regular oral

Author(s): Mikhail Khodzitsky, *Institute of Radiophysics and Electronics NAS Ukraine, Ukraine;*
Olga Kostylyova, *Institute of Radiophysics and Electronics NAS Ukraine, Ukraine;*
Sergey Tarapov, *Institute of Radiophysics and Electronics NAS Ukraine, Ukraine;*
Alexey Girich, *Institute of Radiophysics and Electronics NAS Ukraine, Ukraine;*
Alexey Bulgakov, *Institute of Radiophysics and Electronics NAS Ukraine, Ukraine;*
Oksana Shramkova, *Institute of Radiophysics and Electronics NAS Ukraine, Ukraine*

Abstract: We study the surface waves appeared on the interface of the magneto-photonic crystal (periodic structure formed by the alternating of the dielectric and ferrite layers) and semiconductor layer. The magnetic field tuning of the surface state peak position in transmission spectrum due to ferrite permeability changing for TE polarization and due to semiconductor permittivity changing for TM polarization was experimentally and theoretically demonstrated.

Regular Session 6B - Theoretical aspects: Defining boundaries

(People's Palace 2)

Session chairperson(s): Ismo Lindell, Sébastien Guenneau

09:00 - **Whither metamaterial research?** Invited

Author(s): Raj Mittra, *Pennsylvania State University, USA*

Abstract: Metamaterials have captured considerable attention of the physics and engineering communities during the last few years. The purpose of this paper is to ask some probing questions about the properties of metamaterials, whose answers would hopefully lead us to the right path when we strategize the direction of future research on these materials.

09:20 - **Broadband invisibility from electromagnetic to elastic waves.** Invited

Author(s): Stefan Enoch, *CNRS, France;* Sébastien Guenneau, *University of Liverpool, UK;*
Mohamed Farhat, *CNRS, France;* Alexander Movchan, *University of Liverpool, University, UK*

Abstract: We make a review of recent results we obtained on effective properties of structured cloaks with applications to control of linear surface waves in shallow water, transverse electric waves in metallic photonic crystal fibers and elastic waves in thin-plates. We emphasize that all these cloaks are broadband and the underlying physical mechanism is described using the mathematical theory of homogenization. It is noticed that square shaped structured cloaks display more forward scattering than circular ones.

09:40 - **Symmetry and reciprocity constraints on optical activity in 2D-chiral metamaterials** Regular oral

Author(s): Stanislav Maslovski, *Dept. de Engenharia Electrotécnica, Instituto de Telecomunicações, Portugal;*
Dmitry Morits, *Radiophysics Department, St. Petersburg State Polytechnical University, Russia;*
Sergei Tretyakov, *Department of Radio Science and Engineering, Helsinki Univ. of Technology, Finland*

Abstract: Symmetry and reciprocity constraints on polarization state of the field penetrated trough gratings of 2D-chiral particles on dielectric substrates are considered. It is shown that the optical activity observed in such structures is caused by an additional excitation of the grating by the higher-order Floquet modes of the same grating that are reflected back at the interface with the dielectric substrate.

10:00 - **Poynts of the compass: a flux vector that's going your way** Regular oral

Author(s): Paul Kinsler, *Imperial College London, United Kingdom;* Alberto Favaro, *Imperial College London, United Kingdom;*
Martin McCall, *Imperial College London, United Kingdom*

Abstract: We consider four distinct electromagnetic flux vectors, each dressed differently by the propagation medium, and derive their continuity equations. Our comparison sheds light on the debate over the "correct" definition of the Poynting vector, and on whether ExB forbids negative refraction.

10:20 - **General relation between transmission phase and amplitude for negative refractive index devices** Regular oral

Author(s): Colin Brewitt-Taylor, *QinetiQ ltd, United Kingdom*

Abstract: Based on causality, a connection is found between the phase and amplitude of the transmission for any planar metamaterial screen. Negative phase requires an amplitude increasing with frequency, so that good transmission and negative phase cannot be achieved together oer a broad band.

Poster Session III - Modelling and simulations

(10:40 – 11:40) Octagon Room

Session chairperson(s): Stefano Maci

1 - **Filtering structure based on SRRs for conical horn antennas in the low terahertz band**[Poster]

Author(s): Belén Andrés-García, *Universidad Carlos III de Madrid, Spain;*
Luis-Enrique García-Muñoz, *Universidad Carlos III de Madrid, Spain;*
Vicente González-Posadas, *Universidad Politécnica de Madrid, Spain;*
Daniel Segovia-Vargas, *Universidad Carlos III de Madrid, Spain*

Abstract: A filtering lens for conical horns based on SRRs is presented. The metamaterial structure consists of a printed layer of SRRs on a substrate. When the SRRs are excited, a filter performance and a symmetrisation of the radiation pattern up to 3dB arises. This allows simplifying the system based on a conical horn by unifying the filter and lens in one electromagnetic element.

2 - **Multiple extraordinary optical trnasmission peaks from evanescent coupling in perforated metal plates surrounded by dielectric**[Poster]

Author(s): Rubén Ortuño Molinero, *Nanophotonics Technology Center, Spain;*
Carlos García-Meca, *Nanophotonics Technology Center, Spain;*
Francisco José Rodríguez-Fortuño, *Nanophotonics Technology Center, Spain;*
Javier Martí, *Nanophotonics Technology Center, Spain;*
Alejandro Martínez, *Nanophotonics Technology Center, Spain*

Abstract: We numerically and theoretically study the optical transmission of nanostructured gold films embedded in dielectric claddings. We show how multiple transmission peaks appear as the claddings thickness increases. These transmission peaks come not only from surface plasmon polaritons excitations but also from evanescent coupling through the metal of the Fabry-Perot modes sustained at the claddings.

3 - **Split-ring resonators achieve transmission through a photonic crystal bandgap**[Poster]

Author(s): F. J. Rodríguez-Fortuño, *Valencia Nanophotonics Technology Center, Spain;*
R. Ortuño, *Valencia Nanophotonics Technology Center, Spain;*
C. García-Meca, *Valencia Nanophotonics Technology Center, Spain;*
M Navarro-Cía, *Millimeter and Terahertz Waves Laboratory, Universidad Pública de Navarra, Spain;*
F. Falcone, *Millimeter and Terahertz Waves Laboratory, Universidad Pública de Navarra, Spain;*
J. Martí, *Valencia Nanophotonics Technology Center, Spain;*
A. Martínez, *Valencia Nanophotonics Technology Center, Spain*

Abstract: We present simulation results on split-ring resonators introduced inside a one-dimensional photonic crystal. If the SRR resonant frequency is within the bandgap of the photonic crystal, a narrow passband arises. This result resembles the insertion of SRRs inside a negative permittivity material, although in this case the passband that arises is not observed to be left-handed.

4 - **Theoretical investigations on two-dimensional array of circular cylinders using the gaussian beam formalism**[Poster]

Author(s): Stefan Varault, *ONERA Toulouse, France;*
Sylvain Bolioli, *ONERA Toulouse, France;*
Sokoloff Jerôme, *UPS - LAPLACE, France*

Abstract: In this paper, a fast, flexible, and accurate method that combines the scattering matrix method and the gaussian beam formalism is proposed for the characterization of the scattering of an arbitrary field by an electromagnetic bandgap device consisting of a finite cylinders array.

5 - **Dynamic and circuit theory models for the analysis of sub-wavelength transmission through patterned screens** [Poster]

Author(s): Alexander B. Yakovlev, *University of Mississippi, Department of Electrical Engineering, USA;*
Chandra S. R. Kaipa, *University of Mississippi, Department of Electrical Engineering, USA;*
Yashwanth R. Padooru, *University of Mississippi, Department of Electrical Engineering, USA;*
Francisco Medina, *University of Seville, Department of Electronics and Electromagnetism, Spain;*
Francisco Mesa, *University of Seville, Department of Applied Physics, Spain*

Abstract: In this paper, sub-wavelength transmission resonances with obliquely incident TE and TM-polarized plane waves are studied in patterned screens formed by symmetric capacitive or inductive grids printed on a dielectric slab. The analysis is based on the dynamic model of the grid with two-sided impedance boundary conditions and a circuit theory model, resulting in the same analytical expressions for the reflection and transmission coefficients. It is shown that the apparent sub-wavelength resonances of complete transmission correspond to Fabry-Perot type resonances of a dielectric slab loaded with the effective grid admittances.

6 - **Electromagnetically-induced-transparency-like metamaterial with magnetic quadrupole resonance**[Poster]
Author(s): Toshihiro Nakanishi, *Kyoto University, Japan;* Yasuhiro Wakasa, *Kyoto University, Japan;* Yasuhiro Tamayama, *Kyoto University, Japan;* Tetsuo Kanazawa, *Kyoto University, Japan;* Kazuhiko Sugiyama, *Kyoto University, Japan;* Masao Kitano, *Kyoto University, Japan*

Abstract: We propose and design metamaterial that shows similar properties to the electromagnetically induced transparency (EIT) in atomic systems using electric dipole antennas and double ring resonators as meta-atoms. In simulations, a sharp transparency window is observed in a broad absorption spectrum.

7 - **Compact bandpass waveguide filter using CSRR**[Poster]
Author(s): Saeed Fallahzadeh, *Iran University of science and technology, Iran;* Hadi Bahrami, *Tarbiat Modares University, Iran;* Hamid Bahrami, *amirkabir University of Technology, Iran;* Majid Tayarani, *Iran University of science and technology, Iran*

Abstract: Two compact bandpass waveguide filters are investigated. The first structure is made of Complementary Split Ring Resonator and conventional quarter wavelength line inverters. Further decrease in the filter size is achieved by replacing the inverters by a suitable compact admittance inverter. The various types of the admittance inverter are studied.

8 - **Investigating planar random metal dielectric composite materials as substrates in a patch antenna**[Poster]
Author(s): Zhiyuan Duan, *QUB, United Kingdom*

Abstract: In this document we start to investigate cubic metal particles randomly embedded in solid planar PTFE laminates. This work is then extended into simulation and development of patch antenna based on double layer metal-dielectric laminates. Different sizes, density and layers of particles are also studied in the simulations to identify their effect.

9 - **Reflection polarization behaviour of EBG with a square spiral element on its top surface**[Poster]
Author(s): Zhiyuan Duan, *QUB, United Kingdom*

Abstract: In this paper, we introduce a square spiral element on a via-less EBG (Electromagnetic Band Gap) top surface in place of a solid square patch. This structure could effectively adjust polarization of reflection waves for linear polarization (LP) incidence instead of its original identical polarization reflection, or keep the same reflection polarization for circular polarization (CP) incidence instead of its original opposite polarization reflection. Final surface current and electrical near field distributions are investigated to indentify their relationship with reflection polarization behaviour.

10 - **Theoretical and experimental investigation of anisotropic artificial dielectrics**[Poster]
Author(s): Jafar Shaker, *Communications Research Centre Canada, Canada*

Abstract: The class of artificial dielectrics composed of anisotropic implants of conducting ellipses or dipoles are presented. An extensive set of simulations are performed to characterize the permittivity of the artificial dielectric with respect to the dipole length for different cell sizes. The relationship of the permittivity and structural parameters of the cell are verified experimentally using a quasi-optical measurement apparatus.

11 - **A method to assess the efficiency of active metamaterials**[Poster]
Author(s): Thierry LAGUTERE, *CEA, France;* Olivier ACHER, *CEA, France;* Carmen *TAHMI, CEA, France;* Jean RUSSAT, *CEA, France*

Abstract: Metamaterials offer new opportunities for the conception of high permeability microwave materials. Active metamaterials may offer further possibilities by combining advantages of both metamaterial structures and active RF circuits. An active negative inductance circuit was designed, and the permeability of a metamaterial made from such circuits was computed. In order to benchmark different types of high loss magnetic materials, it is shown that the integral of μ'' times frequency is an appropriate figure of merit. This figure of merit helps comparing active circuits to passive circuits.

12 - **Miniaturised surfaces for antenna applications**[Poster]
Author(s): Kenneth Lee Ford, *University of Sheffield, United Kingdom;* Huilai Liu, *University of Sheffield, UK;* Richard Langley, *University of Sheffield, UK*

Abstract: This paper discusses the design and manufacture of miniaturised Artificial Magnetic Conductors (AMC) using lumped capacitors. Simulated and measured data are presented which illustrate unit cell sizes of lambda/50 with no reduction in bandwidth compared with the classic AMC design approach.

13 - **Beam deflection and optical switching from subwavelength slits in metallic substrates**[Poster]

Author(s): Maria Antonietta Vincenti, *Dipartimento di Elettrotecnica ed Elettronica -Politecnico di Bari, Italy;*
Michael Scalora, *Charles M. Bowden Research Center, AMSRD-AMR-WS-ST, RDECOM, Redstone Arsenal, USA;*
Antonella D'Orazio, *Dipartimento di Elettrotecnica ed Elettronica -Politecnico di Bari, Italy*

Abstract: Resonant subwavelength slits carved on an opaque metallic substrate filled with a nonlinear material and operating in the enhanced transmission regime offer the possibility to effectively deflect light. Both the phase mismatch of the surface waves at the exit of the slits and field localization phenomena inside the cavity allow efficient control of transmittance and beam deflection.

14 - **One hybrid method application on complex media** [Poster]

Author(s): Nebojsa Raicevic, *Faculty of electronic engineering, Serbia;* Sasa Ilic, *Faculty of electronic engineering, Serbia*

Abstract: Aim of this paper is to investigate the influence of the strip conductor position, placed in infinite complex media (chiral, bi-isotropic, bianisotropic, and metamaterial materials), between two grounded plates, on effective dielectric permittivity and magnetic permeability, characteristic impedance of the system, and electric and magnetic field distribution. One hybrid method, equivalent electrodes method (EEM) is applied for numerical calculations.

15 - **Numerical analysis of a novel tunable ferrite-wire chessboard left-handed metamaterial**[Poster]

Author(s): Zhen Yan Hu, *Electromagnetical Field and Microwave Engineering Laboratory,Peking University, China;*
Le Zhu Zhou, *Electromagnetical Field and Microwave Engineering Laboratory,Peking University, China*

Abstract: This paper proposes a novel ferrite-wire composite LHM. Simulation results by using FEM incorporated with Floquet's theorem show that this structure exists transmission property at a certain frequency band, in which both wire effective permittivity and ferrite effective permeability are negative. Another simulation results demonstrate the property-tunablity of the structure.

16 - **Photonic crystal beam splitters based on hexagonal lattice** [Poster]

Author(s): JH Shi, *Harbin Engineering University, China;* CY Guan, *Harbin Engineering University, China;*
LB Yuan, *Harbin Engineering University, China*

Abstract: A polarizing beam splitter (PBS) and a non-polarizing beam splitter (NPBS) based on a photonic crystal (PC) directional coupler (DC) are demonstrated. The photonic crystal directional coupler with a complete photonic band gap consists of a hexagonal lattice of dielectric pillars in air. The splitting properties of the splitter are investigated numerically using the finite difference time domain method.

17 - **Full-wave parallel dispersive finite-difference time-domain modeling of three-dimensional electromagnetic cloaks**[Poster]

Author(s): Yan Zhao, *Queen Mary, University of London, United Kingdom;*
Yang Hao, *Queen Mary, University of London, United Kingdom*

Abstract: A parallel dispersive finite-difference time-domain (FDTD) method for the modeling of three dimensional (3-D) electromagnetic cloaking structures is presented in this paper. The permittivity and permeability of the cloak are mapped to the Drude dispersion model and taken into account in simulations using a dispersive FDTD method. Numerical simulation results are validated using those obtained from analytical solutions. To the authors' knowledge, it is the first time that the 3-D cloaks are modeled using the FDTD method.

18 - **Metamaterials for effective narrow band frequency selection in the 1-5 THz spectral region**[Poster]

Author(s): Elia Palange, *Department of Electric and Information Engineering, Italy;*
Carlo Rizza, *Department of Electric and Information Engineering, Italy;*
Alessia Priante, *Department of Electric and Information Engineering, Italy;*
Domenico Doddi, *Department of Electric and Information Engineering, Italy;*
Francesco De Paulis, *Department of Electric and Information Engineering, Italy;*
Antonio Orlandi, *Department of Electric and Information Engineering, Italy;*
Pasquale Carelli, *Department of Electric and Information Engineering, Italy*

Abstract: In this communication we present and discuss the design and the spectral response of metamaterials for an effective frequency selection of electromagnetic radiation in the 1-5 THz spectral region. These metametarials behave like split-ring-resonators positioned on flat Si substrates and present a single frequency resonance of the transmission curves in the spectral region of interest. By varying the shape and size of the metamaterial constitutive circuits, it is possible to change the resonance frequency and obtain filter Q-factors up to 18. This result represents an important improvement respect to other attempts reported in literature since it will make possible to foresee the possibility to obtain narrow band THz beams from incoherent sources. Moreover, the metamaterials have been designed to be easily implemented on Si substrates using conventional electron beam lithography.

19 - **Novel CRLH cell based on robust planar design in CPW technology** Poster

Author(s): Badreddine Ouagague, *LAAS-CNRS, France;* Fabio Coccetti, *LAAS-CNRS, France;* Robert Plana, *LAAS-CNRS, France*

Abstract: New modified CRLH unit cell is presented. The cell exploits the simplicity of single metal layer planar technology by combining interdigitated capacitors (IDC) with open circuit stub in order to provide new degree of freedom and a more agile and robust control of the dispersion characteristic.

20 - **Design of grating couplers using topology optimization for the efficient excitation of surface plasmons** Poster

Author(s): Jacob Andkjær, *Department of Mechanical Engineering, Technical University of Denmark, Denmark;*
Ole Sigmund, *Department of Mechanical Engineering, Technical University of Denmark, Denmark;*
Shinji Nishiwaki, *Department of Aeronautics and Astronautics, Kyoto University, Japan;*
Tsuyoshi Nomura, *Toyota Central R&D Laboratories Inc., Japan*

Abstract: A 2D topology optimization problem is formulated based on Helmholtz's scalar equation and implemented in order to design grating couplers for the efficient excitation of surface plasmons at a Ag-SiO2 interface. In this work a coupling efficiency of 66.1% for an optimized grating coupler is achieved.

21 - **Direct simulations of metamaterial absorbing and refracting layers** Poster

Author(s): Lorena Basilio, *Sandia National Laboratories, USA;* Larry Warne, *Sandia National Laboratories, USA;*
William Johnson, *Sandia National Laboratories, USA;* Michael Sinclair, *Sandia National Laboratories, USA*

Abstract: Direct numerical simulations of absorption and refraction effects within a finite metamaterial layer are performed. Unit-cell structures comprising dielectric spheres, as well as simple metallic circuits are considered. In order to focus on remnant effects due to the metamaterial cell structure, impedance matching will be designed to suppress reflection for each of these layers.

22 - **Multi-chip-module-based micropyrometer with an IR metamaterials lens and bandpass optical filter** Poster

Author(s): João Carmo, *University of Minho, Industrial Electronics, Portugal;*
Luis Gonçalves, *University of Minho, Industrial Electronics, Portugal;*
Higino Correia, *University of Minho, Industrial Electronics, Portugal*

Abstract: This paper presents a complete microsystem micropyrometer, composed by the electronic system built in CMOS technology added by Multi-chip-module (MCM) techniques, the pyrometer subsystem and a low-loss optical lens and bandpass optical filters (1-4 µm) with inhomogeneous graded index metamaterials to simultaneously focus the light on the micropyrometer and for filtering in the desired range. The final goal is to obtain a miniaturised self-calibrated micropyrometer to detect the infrared radiation (IR) in the 1-4 µm wavelength, for measure the temperature of objects without the need of contact. The structure of micropyrometer consists of a thermally insulated absorbing area and two thermopiles with the hot junctions placed in the absorbing area and the cold junctions on the silicon bulk, which acts as heat sink. The complete microsystem is fabricated in silicon planar technology and each thermopile has a different reference temperature, which is biased by a Peltier microstructure near the cold junction of the thermopile. The ground floor of all microsystem consists on a silicon die with a passivation membrane made of silicon nitride. The absorbing area consists on a black gold strip on the silicon nitride membrane, and it is obtained by anisotropic etching of the bulk silicon from the back of wafer.

23 - S**pectral characteristics of the 2D photonic crystals with nano-size dielectric and metal roads** Poster

Author(s): Olga Kozina, *Institute of Radio-Engineering and Electronics of Russian Academy of Science,*
Saratov Branch, *Russia; Leonid Melnikov, Saratov State University, Russia*

Abstract: We presented the theoretical and numerical approach to the computation of the optical characteristics of two-dimensional photonic crystal structure with active medium and metallic nano-roads. The results of calcula-tions of the spectral characteristics of these structures are presented. The plane wave expansion method has been used.

24 - **Novel bandpass filters based on grounded hilbert fractal resonators** Poster

Author(s): Nikolina Jankoviç, *Faculty of Technical Sciences, Serbia;* Vasa Radoniç, *Faculty of Technical Sciences, Serbia;*
Vesna Crnojeviç-Bengin, *Faculty of Technical Sciences, Serbia*

Abstract: In this paper, novel bandpass filter based on directly tapped grounded Hilbert fractal resonators is presented. By changing the via size and position, as well as by using multiple Hilbert fractal curves, the central frequency tuning range equal to 70% is obtained.

25 - **Manipulating optical signals at a sub-wavelength scale by planar arrays of nanospheres**[Poster]

Author(s): Victor Malyshev, *Zernike Institute for Advanced Materials, University of Groningen, Netherlands;*
Andrey Malyshev, *Departamento de Fisica de Materiales, Universidad Complutense de Madrid, Spain;*
Jasper Knoester, *Zernike Institute for Advanced Materials, University of Groningen , Netherlands*

Abstract: Theoretical results are presented for the transmission properties of two types of plasmonic waveguides: bent chains and Y-shaped configurations of closely packed metallic nanospheres. Efficient bending over any angle is demonstrated. The Y-shaped geometry allows for efficient mixing of signals, using phase control.

26 - **Ultra-wideband microstrip monopole antenna by using unequal arms V- shaped slot printed on metamaterial surface**[Poster]

Author(s): Dalia Elsheakh, *1. Hawaii Center for Advanced Communication, University of Hawaii, USA;*
Hala Elsadek, *Electronics Research Institute, National Research Centre Buildings, EL- Tahrir St, Dokki, Cairo, Egypt;*
Esmat Abdallah, *Electronics Research Institute, National Research Centre Buildings, EL- Tahrir St, Dokki, Cairo, Egypt;*
Magdy Iskander, *1. Hawaii Center for Advanced Communication, University of Hawaii, Honolulu, USA;*
Hadia Elhenawy, *Faculty of Engineering, Ain Shams University, Cairo, Egypt*

Abstract: Novel ultra-wideband monopole microstrip patch antenna with unequal V-shaped slot arms and modified ground plane is presented. The bandwidth from 2 to 30GHz and 40% size reduction. Improvement antenna performance is obtained by using embedded metamaterial structures namely metallo-bandgap structure with and without via. Bandwidth extended from 0.5GHz to 40GHz.

27 - **Planar 2D-isotropic negative index metamaterial made of tightly coupled tripole conductor pairs**[Poster]

Author(s): Andrea Vallecchi, *University of California, Irvine, USA;* Filippo Capolino, *University of California, Irvine, USA*

Abstract: We present a fully printable effective negative refractive index (NRI) metamaterial responsive to arbitrarily linearly polarized incident waves. This metamaterial design is based on the concept of using as the constitutive particle two closely paired metallic conductors supporting both symmetric and antisymmetric resonance modes as a result of their tight coupling. The superposition of these modes can potentially lead to an effective NRI medium. Namely, the proposed structure is composed by a periodic arrangement of pairs of face-coupled loaded tripoles printed on the opposite sides of a single dielectric substrate. The transmission and dispersion properties of such metamaterial highlight that the medium exhibits effective NRI properties over rather a broad frequency range.

28 - **A study on cutoff at 1.55 um for LR-SPP modes in strip waveguides** [Poster]

Author(s): Marco Paolo Bolzoni, *Politecnico di Milano, Italy;* Gian Guido Gentili, *Politecnico di Milano, Italy;*
Silvia Maria Pietralunga, *Politecnico di Milano, Italy*

Abstract: We present a systematic analysis of the cutoff condition for long-range plasmon in strip waveguide at 1.55 µm. The main effect considered is the dielectric asymmetry due to mismatch between upper and lower cladding and we show that propagation is limited to a rather narrow range of physical parameters.

29 - **Fast dipole modes in metal-dielectric optical nanocables**[Poster]

Author(s): Olga Kozina, *Institute of Radio-Engineering and Electronics of Russian Academy of Science, Saratov Branch, Russia;*
Leonid Melnikov, *Saratov State University, Russia; Andrey Soloviev, Saratov State University, Russia;*
Igor Nefedov, *Helsinki University of Technology, Finland*

Abstract: In this presentation we propose new optical waveguides, made of glasses and noble metals. Such waveguides are like coaxial cables where inner metal rods are replaced by thin metal annuluses filled with a glass inside. Numerical simulations demonstrate that the proposed waveguide, having nanosize cross-section, supports propagation of modes, which phase velocity is close to the speed of light and which field is localized outside the metal. These modes are dipole-like modes and are characterized by comparatively low losses.

30 - **Enhanced reflection from arrays of metal patches**[Poster]

Author(s): Melita Taylor, *University of Exeter, United Kingdom; James Edmunds, University of Exeter, United Kingdom;*
Euan Hendry, *University of Exeter, United Kingdom; Alastair Hibbins, University of Exeter, United Kingdom;*
Roy Sambles, *University of Exeter, United Kingdom*

Abstract: A modal matching technique is employed to predict the microwave response of two-dimensional arrays of square metal patches. For relatively low filling fractions, a near-complete reflection condition is predicted: a counter-intuitive response shown to be associated with the role played by evanescent diffracted orders.

31 - **Zeroth-order resonating wire (ZORW) antenna** Poster

Author(s): Edvaldo Silva Pires, *Universidade Federal de Campina Grande, Brazil;*
Glauco Fontgalland, *Universidade Federal de Campina Grande, Brazil;*
Marcos A. B. de Melo, *Universidade Federal de Campina Grande, Brazil;*
Rômulo M. Valle, *Universidade Federal de Campina Grande, Brazil*

Abstract: In this paper we present a novel zeroth-order resonating wire (ZORW) antenna which uses a composite right/left-handed (CRLH) and LTCC technology. The resonant frequency in the mode zeroth-order (infinite wavelength) is independent of the physical length so that the resonator can be arbitrarily of small length.

32 - **Gold nano-rod antennas in linearly modulated array** Poster

Author(s): Valeria Marrocco, DEE, *Politecnico di Bari, Italy;* Maria Antonietta Vincenti, *DEE, Politecnico di Bari, Italy;*
Anna Mongiello, *DEE, Politecnico di Bari, Italy;* Marco De Sario, *DEE, Politecnico di Bari, Italy;*
Vincenzo Petruzzelli, *DEE, Politecnico di Bari, Italy;* Francesco Prudenzano, *DIASS, Politecnico di Bari, Italy;*
Antonella D'Orazio, *DEE, Politecnico di Bari, Italy*

Abstract: Nanorods of noble metals are able to operate as optical nano-antennas in the visible and IR regimes. The transmission and the radiation pattern peculiarities of those structures rely in the sizing of single particles and in the engineering of the mutual interaction among them. When single elements are arranged in an array, an increase of the enhancement of the near field is expected, along with a significant variation in the far field distribution. In particular, arrays having constant and linearly modulated lateral gap value (relative distance among each coupled nanoparticle) are compared in order to find the structures that exhibit the best near-field enhancement and radiated field pattern.

33 - **Realizing thin electromagnetic absorbers for wide incidence angles from commercially available planar circuit materials** Poster

Author(s): Brian Glover, *Los Alamos Natl. Lab, USA;* Matthew J. Radway, *University of Colorado at Boulder, USA;*
Keith W. Whites, *SDSMT, USA*

Abstract: A thin electromagnetic absorber for incidence angles ranging from 0 to 60 degrees and both polarizations is computationally demonstrated. This absorber utilizes high-permittivity, low-loss microwave substrate in conjunction with an engineered, lossy sheet impedance. The lossy sheet impedance is easily engineered with simple analytical approximations and can be manufactured from commercially available laminate materials on microwave substrate.

34 - **Patch antenna miniaturization using H-fractal PBG structure substrate** Poster

Author(s): Qi Chen, *Institute of Electronic Engineering , China Academy of Engineering Physics, China;*
XiaoYang He, *Department of Engineering Physics, Tsinghua University, China;*
Chun Yang, *Institute of Electronic Engineering , China Academy of Engineering Physics, China;*
Lin Cui Li, *Institute of Electronic Engineering , China Academy of Engineering Physics, China*

Abstract: In this paper, we present the design for a miniature patch antenna with an H-Fractal Photonic Bandgap (HF-PBG) structure substrate. The HF-PBG is using to replace the ground plane of a conventional microstrip-fed patch antenna. By using this method, the operating frequency of the antenna is modified from 8.9 GHz to 1.75 GHz. Accordingly, a size reduction of 80% is obtained.

35 - **Modal analysis of a metamaterial layer formed by arrayed pairs of planar conductors** Poster

Author(s): Paolo Baccarelli, *SAPIENZA University of Rome, Italy;* Filippo Capolino, *University of California, USA;*
Simone Paulotto, *SAPIENZA University of Rome, Italy;* Alexander B. Yakovlev, *University of Mississippi, USA*

Abstract: In this paper, the dispersion analysis is proposed for the characterization of natural modes of a metamaterial formed by pairs of metallic Jerusalem crosses separated by a thin dielectric layer. It is shown that the modal spectrum includes bound (proper real) and leaky (proper and improper complex) waves. An interesting observation is that at low frequencies a peculiar dominant TM improper leaky wave occurs, which is shown to be related to peaks of complete transmission.

36 - **Design of a broadside longitudinal slot array antenna on a composite right/left-handed waveguide** Poster

Author(s): María Navarro-Tapia, *Departamento de Ingeniería de Comunicaciones, Universidad de Málaga, Spain;*
Jaime Esteban, *Departamento de Electromagnetismo y Teoría de Circuitos, Universidad Politécnica de Madrid, Spain;*
Carlos Camacho-Peñalosa, *Departamento de Ingeniería de Comunicaciones, Universidad de Málaga, Spain*

Abstract: Research work on metamaterial-based slotted antennas is presently focused on the analysis. Nevertheless, the synthesis process of slotted antennas on composite right/left-handed waveguides should be investigated. This contribution proposes a guideline in order to successfully overcome the slotted antenna design problem. A broadside four-slots design confirms the validity of the synthesis approach suggested.

37 - **Strong magnetism at visible wavelengths via coupled silver nano-hoops**[Poster]

Author(s): Carlos Garcia-Meca, *Valencia Nanophotonics Technology Center, Spain;*
Ruben Ortuño, *Valencia Nanophotonics Technology Center, Spain;*
Francisco Jose Rodriguez-Fortuño, *Valencia Nanophotonics Technology Center, Spain;*
Javier Marti, *Valencia Nanophotonics Technology Center, Spain;*
Alejandro Martinez, *Valencia Nanophotonics Technology Center, Spain*

Abstract: We study the optical properties of a metamaterial made up of close silver nanohoops. Under normal incidence, this metamaterial exhibits a strong magnetic response. A highly negative real part of the permeability is achieved in the visible spectrum, even at blue light.

38 - **A novel low profile dual-polarization metamaterial antenna ra-dome design for 2.6 GHz WiMAX applications**[Poster]

Author(s): Chun-Yih Wu, *ITRI, Taiwan;* Hung-Hsuan Lin, *ITRI, Taiwan;* Jui-Hung Chen, *ITRI, Taiwan*

Abstract: The paper presents a novel low profile (only 0.12 free-space wavelength, λ0) high gain radiation structure that is formed by an air-substrate dual-polarization patch antenna as well as a dual-polarization metamaterial antenna radome composed by 3-layered of 4 × 4 Jerusalem cross array fabricated on the FR4 substrate. Simulation results show that the maximum antenna gain can be reached to 11.8 dBi and the impedance bandwidth of the proposed radiation structure is about 120 MHz (2.58-2.70 GHz) when using 2.5:1 VSWR definition. Furthermore, the dimension of the proposed high gain structure is only 164 mm × 164 mm × 7.9 mm and it is suitable for commercial WiMAX access point applications with polarization diversity function.

39 - **Study and modeling of enhanced transmission through plasmonic sub-wavelength structures**[Poster]

Author(s): Jan Fiala, *Czech Technical University in Prague, Faculty for Nuclear Sciences and Physical Engineering, Department of Physical Electronics, Czech;* Ivan Richter, *Czech Technical University in Prague, Faculty for Nuclear Sciences and Physical Engineering, Department of Physical Electronics, Czech*

Abstract: The interaction of an electromagnetic wave with various classes of sub-wavelength plasmonic structures is modeled, using several approximate and rigorous approaches. A detailed rigorous modeling is performed using the FDTD method to study the transmission properties aperture-types and apertureless types of plasmonic structures).

40 - **The potential of single-slit split-ring resonators for optical trapping**[Poster]

Author(s): Martin Ploschner, *School of Physics and Astronomy, University of St Andrews, St Andrews, United Kingdom;*
Andrea Di Falco, *School of Physics and Astronomy, University of St Andrews, St Andrews, United Kingdom;*
Michael Mazilu, *School of Physics and Astronomy, University of St Andrews, St Andrews, United Kingdom;*
Thomas F. Krauss, *School of Physics and Astronomy, University of St Andrews, St Andrews, United Kingdom*

Abstract: We present a comparison of the field enhancement topology for two types of gold nanostructures - single split-ring resonators (SRRs) and nanoantennas and we conclude, from a comparison of the field enhancement profiles, that SRRs could be superior to nanoantennas in optical trapping applications.

41 - **Nonlocal homogenization using a finite-difference-frequency- domain numerical code**[Poster]

Author(s): João Tiago Costa, *Departamento de Engenharia Electrotécnica e de Computadores - Universidade de Coimbra, Portugal;*
Mário Silveirinha, *Departamento de Engenharia Electrotécnica e de Computadores - Universidade de Coimbra, Portugal*

Abstract: In this work we describe a Finite-Difference-Frequency-Domain implementation of the homogenization approach recently proposed by our group. We validate the application of the proposed method, extracting the effective parameters of a composite material formed by high-index dielectric cylinders and comparing the results with those yielded by the Clausius-Mossotti formula.

42 - **High-impedance surfaces with graphene patches as absorbing structures at microwaves** [Poster]

Author(s): Alexander B. Yakovlev, *University of Mississippi, Department of Electrical Engineering, USA;*
George W. Hanson, *University of Wisconsin-Milwaukee, Department of Electrical Engineering and Computer Science, USA;*
Arash Mafi, *University of Wisconsin-Milwaukee, Department of Electrical Engineering and Computer Science, USA*

Abstract: In this paper, high-impedance surfaces with graphene patches (or, in general, frequency-selective surface elements) are proposed as thin absorbing structures at microwaves. The analysis of reflection properties is based on the dynamic model of the grid, which takes into account the surface conductivity of graphene. It is shown that the proposed absorbing structures can be used as tunable high-impedance surfaces, where the reflection minima can be achieved at different incident angles by varying the conductivity of graphene.

Plenary Session III

(Great Hall)

Session chairperson(s): Sergei Tretyakov

11:40 - **Three-dimensional metallic metamaterials: From simple to complex – coupling games**[Plenary]
Author(s): Harald Giessen, *Universitat Stuttgart, Germany*

12:40 – Lunch (The Hive – Catering Building)

Abstract: We are going to discuss the optical properties of three-dimensional metallic metamaterials and investigate their coupling properties. Metallic metamaterials have shown a number of fascinating properties over the last few years. A negative refractive index, negative refraction, superlenses, and optical cloaking are some of the ambitious applications where metamaterials hold great promise.

Bio: Prof. Harald Giessen is the director of the 4th physics institute at the University of Stuttgart in Germany. His research focus is on ultrafast nano-optics, with emphasis on metamaterials and plasmonics as well as on white-light lasers. He graduated from University of Kaiserslautern in 1992 with a diploma in Phyiscs, and got his M.S. and Ph.D. as J.W. Fulbright scholar in Optical Sciences from the Optical Sciences Center at the University of Arizona in 1994 and 1995, respectively, studying femtosecond carrier dynamics in strongly confined semiconductor quantum dots. He was a post-doc at the Max-Planck-Institute for solid state research in 1996, investigating self-induced transparency in excitonic systems. From 1997-2000, he was assistant professor at the Physics Department at the University of Marburg, researching spatiotemporal carrier dynamics in nanoscopic systems. From 2001-2004, he was Associate Professor at the University of Bonn, where he focused on femtosecond white light lasers and metallic photonic crystals. Since 2005, he has been Full Professor at the University of Stuttgart. He was elected fellow of the Optical Society of America in 2008.

Special Session 7 - Progress of ECONAM project

(Skeel Theatre)

Organizer(s): Alex Schuchinsky, Constantin Simovski
Session chairperson(s): Alex Schuchinsky, Constantin Simovski

14:00 - **Applicability of classical mixing rules: from positive to negative parameters**[Invited]
Author(s): Henrik Wallén, *Helsinki University of Technology, Finland;* Henrik Kettunen, *Helsinki University of Technology, Finland;* Ari Sihvola, *Helsinki University of Technology, Finland*

Abstract: We present a review of classical mixing rules for composites with spherical inclusions, and discuss their applicability and limitations for different kinds of mixtures. Especially important are the plasmonic resonances in negative parameter composites.

14:20 - **Weakly and strongly coupled optical metamaterials**[Invited]
Author(s): Costas Soukoulis, *Ames Lab and IESL-FORTH, Greece;* J. Zhou, *Iowa State University – Ames Lab and Physics Department, USA;* M. Kafesaki, *Foundation for Research and Technology Hellas (FORTH), Greece;* Th. Koschny, *Foundation for Research and Technology Hellas (FORTH), Greece*

Abstract: We study the convergence of the optical parameters as the number of layers increases for the weakly and strongly coupled metamaterials. Is the properties of one layer significant different from the many layers?

14:40 - **Characterization of plasmonic metamaterials using effective parameters** [Invited]
Author(s): Chris Fietz, *Department of Physics, The University of Texas at Austin, USA; Dmitriy Korobkin, Department of Physics, The University of Texas at Austin, USA;* Burton Neuner, *Department of Physics, The University of Texas at Austin, USA;* Chihui Wu, *Department of Physics, The University of Texas at Austin, USA;* Gennady Shvets, *Department of Physics, The University of Texas at Austin, USA*

Abstract: Challenges and opportunities for creating magnetically active metamaterials in the optical part of the spectrum will be described. The emphasis is on the sub-wavelength periodic metamaterials whose unit cell is much smaller than the optical wavelength. The conceptual differences between microwave and optical metamaterials are demonstrated. Miniaturization limits of metallic metamaterials will be discussed, and the role of plasmonic effects (electrostatic resonances) explained. The importance of plasmonic effects will be quantified using a recently introduced by us plasmonic parameter. We also describe several theoretical techniques used for calculating the effective parameters of plasmonic metamaterials: the effective dielectric permittivity and magnetic permeability. Several examples of negative permittivity and negative permeability plasmonic metamaterials are used to illustrate the theory. We will also discuss a new application of complimentary metamaterials to developing ”perfect absorbers” of infrared and visible light and present supporting experimental results. Such metamaterials are characterized by a complex reflectivity that can be extracted from transmission/reflection coefficients and validated using semi-analytic theory.

15:00 - **On the locality of Drude transition layers for metamaterials**[Invited]
Author(s): Constantin Simovski, *TKK, Finland*

Abstract: In this presentation the previously developed homogenization model of metamaterials formed by resonant electric and magnetic dipoles is complemented by the study of Drude transition layers. It is shown that the material parameters of Drude transition layers satisfy to the basic physical requirement of locality. The locality means that these parameters should not depend on the incidence angle and must be helpful to formulate the boundary problem for a metamaterial slab.

15:20 - **On non-Maxwellian boundary conditions for metamaterial interface**[Invited]
Author(s): Alexey Vinogradov, *ITAE RAS, Russia;* Alexander Merzlikin, *ITAE RAS, Russia;* Said Zouhdi, *Laboratoire de Génie Electrique de Paris LGEP-Supélec, France*

Abstract: In this presentation we consider the problem of the boundary conditions for metamaterial interface. Since metamaterials are, in general, inhomogeneous media, this problem is tightly connected with the homogenisation theory. It is shown that any homogenisation theory of infinitely extended media is, strictly speaking, inadequate in solutions of scattering problems. The reason is that it is possible to homogenize the refraction index but not the impedance, which behaves as a mesoscopic quantity. For metamaterials with electrically non-negligible cell sizes and small numbers of cells in a sample, this leads to serious disagreements with experiments and numerical simulations. Different approaches to fix the problem are considered (introduction of a transition layer or of the dependence of the permittivity operator kernel on the surrounding medium).

15:40 – Coffee break (Octagon Room)

Regular Session 7A - New metamaterial particles

(People's Palace 1)

Session chairperson(s): Steven Russell, Richard Syms

14:00 - **Open complementary split ring resonators (OCSRRs): the missing particle**[Invited]

Author(s): Adolfo Velez, *CIMITEC, Spain;* Francisco Aznar, *Universitat Autonoma de Barcelona, Spain;*
Miguel Duran Sindreu, *Universitat Autonoma de Barcelona, Spain;*
Jordi Bonache, *Universitat Autonoma de Barcelona, Spain;* Ferran Martin, *Universitat Autonoma de Barcelona, Spain*

Abstract: In this paper, it is shown that by applying duality to a split ring resonator (SRR) and by opening it, we obtain the open complementary split ring resonator (OCSRR). This new open resonator can also be considered to be the dual counterpart of the open split ring resonator (OSRR), or the open version of the complementary split ring resonator (CSRR). With this new particle (OCSRR), we have a complete set of metamaterial resonant particles, including open and closed particles in metallic or slot configuration. It is shown that these particles are electrically small (actually as small as the OSRRs), and can be applied to the synthesis of composite right/left handed (CRLH) transmission lines and other microwave components. Several examples indicative of the potentiality of these particles are proposed.

14:20 - **Numerical and experimental investigation of field distribution inside four-arm spherical resonator that mimics plasmonic nanosphere**[Regular oral]

Author(s): Silvio Hrabar, *Faculty of Electrical Engineering and Computing, University of Zagreb, Croatia;*
Zoran Eres, *Rugjer Boskovic Institute Zagreb, Croatia;* Davor Zaluski, *Faculty of Electrical Engineering and Computing, University of Zagreb, Croatia;* Damir Muha, *Faculty of Electrical Engineering and Computing, University of Zagreb, Croatia*

Abstract: It is shown both theoretically and experimentally that electric field distribution inside Best's spherical resonator resembles distribution inside a plasmonic sphere. Although the resonator obeys Lorentz dispersion model, within a wide frequency band it can be approximated with Drude model needed for scaled plasmonic experiments in RF regime.

14:40 - **Extreme chirality in Swiss roll metamaterials**[Regular oral]

Author(s): Angela Demetriadou, *Imperial College of London, United Kingdom;*
John Pendry, *Imperial College of London, United Kingdom*

Abstract: Chiral Swiss Roll metamaterials are magnetically resonant structures that exhibit extreme chirality, about 100 times higher than other chiral structure discussed in literature. The combination of magnetic resonance and chirality, result to a negative band for a 2D structure. The extreme chiral behaviour of Swiss Rolls is discussed with both numerical and analytical results.

15:00 - **Cube composed of DNA-like helices displays polarization selectivity properties in microwave**[Regular oral]

Author(s): Igor Semchenko, *Gomel State University, Belarus;* Sergei Khakhomov, *Gomel State University, Belarus;*
Alexei Balmakov, *Gomel State University, Belarus*

Abstract: An opportunity of constructing of 2D and 3D figures from DNA branches has been recently reported by Prof. Seeman. It allows us to talk about discovering of a new field of nanotechnology – design of artificial DNA-like crystals. Probably such crystals will display very interesting electromagnetic properties including the property of polarization selectivity. We think that the effect of polarization selectivity is very important for all living beings in nature because it is directly connected with infringement of mirror symmetry in natural structures and phenomenon. In this article, by the example of the cube composed of DNA-like helices, we proved that complex 3D DNA-like structures can also display the effect of circular polarization of reflected electromagnetic waves.

15:20 - **Homogenization of metamaterials by fractaloid hybrid structures**[Regular oral]

Author(s): Ernst Lenz, *Technische Universität Berlin, Germany;* Heino Henke, *Technische Universität Berlin, Germany*

Abstract: The usual split-ring resonator is substituted by a fractaloid hybrid structure. Theoretical and numerical results of this structure lead to a decrease of the resonance frequency and thus to a higher homogenization.

15:40 – Coffee break (Octagon Room)

Regular Session 7B - Transformational electromagnetics

(People's Palace 2)

Session chairperson(s): Vladimir M. Shalaev, John Pendry

14:00 - **An optical cloak composed of identical chalcogenide glass resonators** Invited

Author(s): Elena Semouchkina, *The Pennsylvania State University, USA;* Douglas Werner, *The Pennsylvania State University, USA;* Carlo Pantano, *The Pennsylvania State University, USA*

Abstract: We demonstrate the performance of an optical cloak formed by concentric arrays of identical cylindrical resonators from chalcogenide glass. The spatial dispersion of the effective permeability is obtained due to different fraction of the air filled volume in the layers. Full-wave simulations are performed for the actual cloak structure over the entire frequency range of the effective parameter dispersion. The effects of coupling between the resonators are strictly accounted for.

14:20 - **Dispersive and bandwidth effects using non-monochromatic pulses for ground-plane quasi-cloaks** Invited

Author(s): Efthymios Kallos, *Queen Mary University of London, United Kingdom;*
Christos Argyropoulos, *Queen Mary University of London, United Kingdom;*
Yang Hao, *Queen Mary University of London, United Kingdom*

Abstract: We investigate through FDTD simulations bandwidth issues for ground-plane cloaks by launching non-monochromatic pulses against a metal object placed on a ground plane. We find that the cloak designs can be placed in free space while still maintaining excellent cloaking potential over a broad frequency range. Small regions that require dispersive materials have little effect in the performance. The tradeoffs between the design detail of the device and its bandwidth are also examined.

14:40 - **Super-scatterers** Regular oral

Author(s): Wei Hsiung Wee, *Imperial College London, United Kingdom*

Abstract: The intent is to demonstrate the use of Negative Refractive Index Materials to create Super-Scatterers (SS) - scatterers with such an enhanced scattering cross section that they are larger than the physical size of the scatterer. This will be shown through two examples - the Absorber and Retro-reflector SS.

15:00 - **Enhancement of antenna directivity via transformation optics using Mercator and Lambert mapping functions** Regular oral

Author(s): Charles Croënne, *IEMN/USTL, France;* Didier Lippens, *IEMN/USTL, France*

Abstract: A transformation optics procedure, using two consecutive transformations with an intermediate curved space is developed in order to improve the directivity of an antenna. The impedance of the resulting device is matched with free space and its material parameters correspond to a strongly anisotropic medium with varying orientation.

15:20 - **Axion-skewon media in generalized transformation optics** Regular oral

Author(s): Luzi Bergamin, *Department of Radio Science and Engineering, TKK Helsinki, Finland*

Abstract: Standard transformation optics does not offer the possibility to design media that violate the Post constraint. In this paper we show that this is possible in the generalized setup of so-called triple spacetime metamaterials and derive a geometric interpretation of a class of axion-skewon media. An example is presented to illustrate this approach.

15:40 – Coffee break (Octagon Room)

Special Session 8 - Nonlinear metamaterials

(Skeel Theatre)

Organizer(s): Michael Scalora, Natalia Litchinitser
Session chairperson(s): Michael Scalora, Natalia Litchinitser

16:00 - **Nonlinear propagation through plasmonic materials**[Invited]
Author(s): Joseph Haus, *University of Dayton, USA*

Abstract: In this presentation I talk about recent results examining phase-locked second- and third-harmonic wave generation and propagation through lossy semiconductor materials, especially with regard to harmonic conversion in short wavelength regimes. This is a report of recent results on this topic with experimental results also presented.

16:20 - **Nonlinear interactions in backward wave media**[Invited]
Author(s): Ilya Shadrivov, *Australian National University, Australia*

Abstract: We overview nonlinear wave interactions in structures supporting backward waves. We consider nonlinear effects in backward-wave transmission lines as well as in nonlinear metamaterials.

16:40 - **Modelling and theory of nonlinear or gyroelectric nanoscale metamaterials**[Invited]

Author(s): Allan Boardman, *University of Salford, United Kingdom;* Peter Egan, *University of Salford, United Kingdom;* Rhiannon Mitchell-Thomas, *University of Salford, United Kingdom;* Larry Velasco, *University of Salford, United Kingdom;* Yuriy Rapoport, *University of Salford, United Kingdom*

Abstract: A theoretical discussion of nonlinear or gyroelectric nanoscale metamaterials is developed and illustrated with dramatic simulations. Strongly nonlinear guides are investigated that immediately exhibit new kinds of surface waves that are tuneable with the applied electromagnetic power to the extent that the group velocity of a guiding system can be manipulated at very modest power levels. It is emphasized that magnetooptics is an excellent tool for tunability and a detailed application to planar and more complex structures are discussed.

17:00 - **Non-linear effects in optical metamagnetics: numerical modelling in time and frequency domains**[Invited]
Author(s): Alexander Kildishev, *Birck Nanotechnology Center, School of ECE, Purdue University, USA*

Abstract: This presentation gives an overview of our simulation approaches to modelling the non-linear optical responses of nanostructured optical materials with a strong effective magnetic susceptibility (optical metamagnetics). The non-linear effects cover non-linear absorption, Kerr non-linearity, gain material inclusions, and magnetically induced second-harmonic generation.

17:20 - **Phase locked harmonics etalon localization**[Invited]
Author(s): V. Roppo, *Universitat Politècnica de Catalunya, Spain;* Fabrice Raineri, *Laboratoire de Photonique et de Nanostructures, CNRS UPR20, France;* C. Cojocaru, *Universitat Politècnica de Catalunya, Spain;* J. Trull, *Universitat Politècnica de Catalunya, Spain;* R. Vilaseca, *Universitat Politècnica de Catalunya, Spain;* R. Raj, *Laboratoire de Photonique et de Nanostructures, CNRS UPR20, France;* G. D'Aguanno, *C. M. Bowden Research Facility, Redstone Arsenal, USA;* M. Scalora, *C. M. Bowden Research Facility, Redstone Arsenal, USA*

Abstract: In this work, phase locked harmonics generation is obtained in a GaAs-based cavity. Both theoretical and experimental investigations have been carried out and show an increase of efficiency due to cavity effect at the fundamental field frequency.

17:40 - Social tour by classic buses (Bancroft Road)

19:00 - Conference banquet (St Katharine's Dock)

Regular Session 8A - Homogenization and bulk metamaterials

(People's Palace 1)

Session chairperson(s): Anthony Grbic, Henrik Wallén

16:00 - **Time-domain homogenization of bianisotropic media**[Invited]
Author(s): Hicham Belyamoun, *LGEP, France;* Said Zouhdi, *LGEP, France*

Abstract: We propose a time-domain homogenization technique for complex media. By using the periodic unfolding method and the finite element method, we simulate the electromagnetic behaviour of a composite bianisotropic material and compute its homogenized electromagnetic parameters. In particular, numerical results are obtained for a Debye-like bianisotropic material.

16:20 - **Magnetic plasmon-polaritons in split-ring metamaterials with strong coupling**[Invited]
Author(s): Ekaterina Shamonina, *University of Erlangen-Nuremberg, Germany;* Anna Radkovskaya, *Moscow State University, Russia;* Eugen Tatartschuk, *University of Erlangen-Nuremberg, Germany;* Chris Stevens, *University of Oxford, UK;* David Edwards, *University of Oxford, UK;* Laszlo Solymar, *Imperial College London, UK*

Abstract: A two-dimensional equivalent circuit model of coupled lumped elements is introduced and linked to the effective-medium description of magnetic metamaterials. Correspondence is established between the two existing approaches, one based on effective permeability and the other one on the parameters of the equivalent circuit. Within this method, bulk and surface plasmon-polaritons can be related to circuit characteristics of the metamaterial structure. Coupling is shown to considerably influence the frequency range of negative permeability. Experimenal data on 2D split-ring structures are compared with predictions of the model. The method enables one to design structures with controllable effective material parameters. Generalisation to different types of unit cells, including metamaterials with negative refractive index, is also discussed.

16:40 - **Creating negative refractive index medium based on non-uniform**[Regular oral]
Author(s): Yue Jun Lai, *National Hsing Hua University MSE department, Taiwan (R.O.C);*
Ta Jen Yen, *National Hsing Hua University MSE department, Taiwan (R.O.C)*

Abstract: This study reports the construction of negative refractive index media based on full dielectric particles. We experimentally realize NRIM by combination of two different- sized ZrO_2 particles. The measured left-handed pass-band was verified by retrieval and simulation results.

17:00 - **Experimental realization of low-loss 3D isotropic DNG materials**[Regular oral]
Author(s): Jacques Loui, *Sandia National Laboratories, USA; James Carroll, Sandia National Laboratories, USA;*
Paul Clem, *Sandia National Laboratories, USA; Michael Sinclair, Sandia National Laboratories, USA*

***Abstract*:** In this presentation we will use numerical and experimental results to demonstrate approaches in achieving low-loss 3D isotropic materials with negative permittivity and permeability. Isotropic DNG materials offer polarization and direction independent electromagnetic wave propagation. Cubic lattices of dielectric core-shell and multi-sphere unit-cells are studied. Advantages and disadvantages of Ku band designs are compared.

17:20 - **Do hole dimensions change dramatically refraction in stacked perforated metallic plates with wedge shape?**[Regular oral]
Author(s): Miguel Navarro-Cía, *Millimeter and Terahertz Waves Laboratory, Universidad Pública de Navarra, Spain;*
Miguel Beruete, *Millimeter and Terahertz Waves Laboratory, Universidad Pública de Navarra, Spain;*
Igor Campillo, *CIC nanoGUNE Consolider, Spain; Francisco Falcone, Millimeter and Terahertz Waves Laboratory, Universidad Pública de Navarra, Spain;* Mario Sorolla, *Millimeter and Terahertz Waves Laboratory, Universidad Pública de Navarra, Spain*

***Abstract*:** In this presentation we provide physical insight of the transmission properties of the subwavelength hole arrays prism, alongside a comparison between this metaprism and a propagating hole arrays prism. The analysis is both numerical and experimental.

17:40 - Social tour by classic buses (Bancroft Road)

19:00 - Conference banquet (St Katharine's Dock)

Regular Session 8B - Fabrication of artificial materials

(People's Palace 2)

Session chairperson(s): Alexandra Boltasseva, Anatoly Zayats

16:00 - **Making plasmonic structures and metamaterials via lithography and nanoimprint** Invited

Author(s): Alexandra Boltasseva, *Purdue University, USA*

Abstract: Different lithographical approaches will be discussed for fabrication of plasmonic components and optical metamaterials. Experimental realization of different metal-dielectric structures used as plasmonic components for guiding of electromagnetic radiation along metal-dielectric interfaces via excitation of surface plasmon polaritons (SPPs) and as plasmonic metamaterials will be reported.

16:20 - **Fabrication of 3-D cubic metamaterials through directional evaporation** Regular oral

Author(s): D. Bruce Burckel, *Sandia National Laboratories, USA;* Paul S. Davids, *Sandia National Laboratories, USA;* Greg A. Ten Eyck, *Sandia National Laboratories, USA;* A. Rob Ellis, *Sandia National Laboratories, USA;* Brandon S. Passmore, *Sandia National Laboratories, USA;* Eric A. Shaner, *Sandia National Laboratories, USA;* Joel R. Wendt, *Sandia National Laboratories, USA;* Igal Brener, *Sandia National Laboratories, USA;* Michael B. Sinclair, *Sandia National Laboratories, USA*

Abstract: We present a new fabrication technique capable of creating 3-D cubic arrays of metamaterial resonators. A membrane is formed and patterned over a cubic cavity. Multiple directional evaporations through the patterned membrane deposit metallic resonator structures on the interior faces of the cavity.

16:40 - **Effect of oxide layers on the performance of split ring resonator metamaterials** Regular oral

Author(s): David Peters, *Sandia National Laboratories, USA;* David Shelton, *CREOL/University of Central Florida, USA;* James Ginn, *CREOL/University of Central Florida, USA;* Michael Sinclair, *Sandia National Laboratories, USA;* Greg Ten-Eyck, *Sandia National Laboratories, USA;* Joel Wendt, *Sandia National Laboratories, USA;* William Langston, *Sandia National Laboratories, USA;* Lorena Basilio, *Sandia National Laboratories, USA;* Larry Warne, *Sandia National Laboratories, USA;* Brandon Passmore, *Sandia National Laboratories, USA;* Igal Brener, *Sandia National Laboratories, USA;* Glenn Boreman, *CREOL/University of Central Florida, USA*

Abstract: The presence of very thin native oxide layers are shown to have a large effect on the spectral location of the resonance of a split ring resonator design. We show simulation and measurement results illustrating this shift.

17:00 - **Optical properties of metallic nanotubes** Regular oral

Author(s): Antony Murphy, *Queen's University Belfast, United Kingdom;* Robert Pollard, *Queen's University Belfast, United Kingdom*

Abstract: Substrate bound gold nanotubes have been grown. The method leads to control over the nanotube dimensions. Optical extinction measurements show a peak excited at normal incidence. Peak position is highly sensitive to nanotube geometry. Increasing the core diameter will red-shift the extinction peak. Modeling was used to rationalise experimental results.

17:20 - **Reflection and transmission coefficients of nano-metamaterial antennas at microwave frequencies** Regular oral

Author(s): William Whittow, *Loughborough University, United Kingdom;* Yiannis Vardaxoglou, *Loughborough University, United Kingdom;* Chris Toprakcioglu, *University of Patras, Greece;* Nikos Spiliopoulos, *University of Patras, Greece*

Abstract: Simulations, based on actual samples composed of nano-metamaterials, show the behaviour of the reflection and transmission coefficients of antennas. The resonant frequency can increase or decrease depending on the geometry.

17:40 - Social tour by classic buses (Bancroft Road)

19:00 - Conference banquet (St Katharine's Dock)

Registration

8:30 (Registration Office)

Special Session 9 - Cloaking and coordinate-transformation applications

(Skeel Theatre)

Organizer(s): Nader Engheta, Andrea Alù
Session chairperson(s): Nader Engheta, Andrea Alù

09:00 - **Cloaking a sensor with plasmonic materials**[Invited]
Author(s): Andrea Alù, *University of Texas at Austin, USA;* Nader Engheta, *University of Pennsylvania, USA*

Abstract: In this contribution, we discuss the possibility of applying the scattering-cancellation-based plasmonic cloaking technique to reduce the scattering from a sensing device, lowering its disturbance on sensing without affecting its ability to measure and "sense" the external world.

09:20 - **Anisotropic metamaterials emulated by tapered waveguides: application to optical cloaking**[Invited]
Author(s): Vladimir M. Shalaev, *Purdue University, USA; Vera N. Smolyaninova, Towson University, USA;*
Alexander V. Kildishev, *Purdue University, USA; Igor I. Smolyaninov, BAE Systems, USA*

Abstract: We demonstrate that metamaterial devices requiring anisotropic dielectric permittivity and magnetic permeability may be emulated by specially designed tapered waveguides. This approach leads to low-loss, broadband performance. Based on this technique, we demonstrate broadband electromagnetic cloaking in the visible frequency range on a scale ~100 times larger than the wavelength.

09:40 - **Broadband invisibility by non-Euclidean cloaking**[Invited]
Author(s): Ulf Leonhardt, *University of St Andrews, United Kingdom;* Tomas Tyc, *University of St Andrews, United Kingdom*

Abstract: We show how implementations of the geometry of curved space may lead to broadband invisibility.

10:00 - **Surface singularities in spherical and cylindrical cloaks**[Invited]
Author(s): Arthur Yaghjian, *Self Employed, USA*

Abstract: The singularities in the fields and polarization densities at the inner surfaces of spherical and circular cylindrical cloaks illuminated by sources inside the cloaks are determined from a plane-wave analysis of fields incident on a half space of material characterized by a relative permittivity-permeability dyadic equal to that of the inner material surfaces of the cloaks.

10:20 - **Cloaking potentials formulated by non-radiating sources**[Invited]
Author(s): Stefano Maci, *University of Siena, Italy*

Abstract: This paper presents single-frequency conditions on the constitutive dyads of a bianisotropic linear metamaterial that are sufficient to ensure cloaking for arbitrary shape and illumination. The volumetric equivalence theorem is first formulated for a bianisotropic metamaterial scatterer. Under assumption that the volumetric equivalent currents are non-radiating, the constitutive dyads are written as a function of two vector potentials respecting simple boundary conditions. The special known cases derived from Transformation Optics are re-obtained as a particular choice of these vector potentials. New solutions are investigated.

Regular Session 9A - Metasurfaces

(People's Palace 1)

Session chairperson(s): Pavel Belov, Tatsuo Itoh

09:00 - **Plasmonic resonance in artificial impedance surfaces** Regular oral

Author(s): Olli Luukkonen, *Department of Radio Science and Engineering, TKK Helsinki Univeristy of Technology, Finland;*
Pekka Alitalo, *Department of Radio Science and Engineering, TKK Helsinki Univeristy of Technology, Finland;*
Filippo Costa, *Department of Information Engineering, University of Pisa, Italy;*
Constantin Simovski, *Department of Radio Science and Engineering, TKK Helsinki Univeristy of Technology, Finland;*
Agostino Monorchio, *Department of Information Engineering, University of Pisa, Italy;*
Sergei Tretyakov, *Department of Radio Science and Engineering, TKK Helsinki Univeristy of Technology, Finland*

Abstract: In this presentation we discuss the occurrence of plasma resonance in artificial impedance surface structures independent from the incident angle. The surface comprises wire medium in which the spatial dispersion has been suppressed. In consequence, the plasma resonance of the wire medium can be detected at the plasma frequency of the wire medium independently from the incidence angle. The analytical results predicting the plasma resonance are in very good agreement with the experimental results. The results presented in this presentation are the first unambiguous verification of the non-spatially dispersive plasma resonance.

09:20 - **Sub-wavelength resonances in mushroom-type surfaces in connection with leaky waves** Regular oral

Author(s): Alexander B. Yakovlev, *University of Mississippi, Department of Electrical Engineering, USA;*
Mario G. Silveirinha, *Department of Electrical Engineering – Instituto de Telecomunicações, University of Coimbra, Portugal;* Paolo Baccarelli, *Electronic Engineering Department, Sapienza University of Rome, Italy*

Abstract: In this paper, sub-wavelength reflection/transmission resonances are studied in a metamaterial formed by paired arrays of metallic grids connected by vias. The analysis is based on the non-local homogenization model, which takes into account spatial dispersion effects and additional boundary conditions. It is observed that sub-wavelength resonances of complete transmission occur below and above the plasma frequency of the wire medium, which, in turn, are related to proper complex (backward) and improper complex (forward) leaky waves of the corresponding mushroom structure.

09:40 - **Miniaturization of inductance-enhanced EBG structures using thin film technology** Regular oral

Author(s): Noriaki Ando, *NEC Corporation, Japan;* Koichi Takemura, *NEC Corporation, Japan;*
Hiroshi Toyao, *NEC Corporation, Japan;* Tsuneo Tsukagoshi, *NEC Corporation, Japan*

Abstract: We have demonstrated that inductance-enhanced EBG structures make it possible to miniaturize the dimensions of the unit cell. In this work, we explored miniaturization of the unit cell using thin film technology. We reduced to 1 mm the unit cell size with a stopband that included 2.4 GHz.

10:00 - **Behaviour of surface currents on truncated FSS arrays** Regular oral

Author(s): Jean-Baptiste Robertson, *Department of Electronics, University of Kent, United Kingdom;*
Ted Parker, *Department of Electronics, University of Kent, United Kingdom;*
Benito Sanz-Izquierdo, *Department of Electronics, University of Kent, United Kingdom;*
John Batchelor, *Department of Electronics, University of Kent, United Kingdom*

Abstract: Anomalous surface waves specific to truncated frequency selective surfaces are know to exist in a reduced range below an array's resonant frequency. We characterise such waves on a truncated array of dipoles and, using an array of square loops, show that such waves can also exist in different frequency ranges.

10:20 - **Surface-plasmon-like modes on ultra-thin metamaterials** Regular oral

Author(s): Alastair Hibbins, *University of Exeter, United Kingdom;* Matthew Lockyear, *University of Exeter, United Kingdom;*
Roy Sambles, *University of Exeter, United Kingdom*

Abstract: Previous studies have demonstrated that perfect conductors patterned with arrays of deep, subwavelength holes will support strongly bound surface-plasmon-like modes ("spoof surface plasmons"). Here, we show that much thinner (« wavelength) "Sievenpiper mushroom" metamaterials will also exhibit plasmonic behavior at frequencies close to their fundamental resonance.

Regular Session 9B - State-of-the-art overviews

(People's Palace 2)

Session chairperson(s): Ross McPhedran, Andre Rennings

09:00 - **The almost magical world of metamaterials**[Invited]
Author(s): Ekmel Ozbay, *Bilkent University, Turkey*

Abstract: We review experimental and theoretical studies performed on left-handed metamaterials (LHM). The metamaterials exhibit quite unusual electromagnetic properties such as negative refraction, negative phase velocity, subwavelength focusing, subwavelength cavities and enhanced transmission.

09:20 - **Metamaterial based microwave devices**[Regular oral]
Author(s): Kamil Boratay Alici, *Bilkent University, Turkey;* Filiberto Bilotti, *University of Rome Tre, Italy;*
Lucio Vegni, *University of Rome Tre, Italy;* Ekmel Ozbay, *Bilkent University, Turkey*

Abstract: We studied metamaterial based microwave devices and investigated the effect of electrical size of the constituting elements on the device performance. First, we identify and characterize the suitable subwavelength resonators that are used to create metamaterials. We continued by demonstrating electrically small, metamaterial loaded monopole and patch antennas, miniaturized microwave absorbers, and flat metamaterial lenses with increased resolution.

09:40 - **Negative index metamaterials operating at terahertz frequencies**[Invited]
Author(s): Didier Lippens, *IEMN/USTL, France*

Abstract: We review the various routes successfully developed so far for the fabrication of negative index metamaterials at Terahertz frequencies.

10:00 - **Isotropic optical metamaterials**[Regular oral]
Author(s): Thomas Paul, *Institut of Condensed Matter Theory and Solid State Optics, Germany;*
Carsten Rockstuhl, *Institut of Condensed Matter Theory and Solid State Optics, Germany;*
Christoph Menzel, *Institut of Condensed Matter Theory and Solid State Optics, Germany;*
Falk Lederer, *Institut of Condensed Matter Theory and Solid State Optics, Germany*

Abstract: We introduce a genuine approach to obtain bulk metamaterials that possess an isotropic optical response. On the example of a fishnet metamaterial we show that by modifying geometrical parameters of subsequent functional layers the optical response can be optimized such that it exhibits an isotropic negative refractive index.

10:20 - **Microwave and photonic properties of engineered quasicrystals**[Invited]
Author(s): Antonello Andreone, *Physics Department, University "Federico II", Naples, Italy;*
Giancarlo Abbate, *Physics Department, University "Federico II", Naples, Italy;*
Emiliano Di Gennaro, *Physics Department, University "Federico II", Naples, Italy;*
T. Priya Rose, *Physics Department, University "Federico II", Naples, Italy;*
Salvatore Savo, *Physics Department, University "Federico II", Naples, Italy;*
Gianluigi Zito, *Physics Department, University "Federico II", Naples, Italy;*
Giampiero Castaldi, *Department of Engineering, University of Sannio, Italy;*
Vincenzo Galdi, *Department of Engineering, University of Sannio, Italy;*
Maria Rosaria Masullo, *INFN Naples, Italy*

Abstract: By using numerical simulations and experimental measurements in the microwave region, we present a comprehensive study of a number of peculiar electromagnetic features exhibited by aperiodically-ordered artificially constructed quasicrystals, with particular emphasis on their use as superlenses, point-defect cavities, low-index-contrast photonic devices.

Poster Session IV- General Topics and student paper competition

10:40 – 11:40 Octagon Room

Session chairperson(s): Igor Nefedov

1 - **Bending integrated EBG antennas**[Poster]

Author(s): Richard Langley, *University of Sheffield, United Kingdom;* Qiang Bai, *University of Sheffield, UK*

Abstract: In this paper, we present the performance of a dual-band textile EBG antenna under bending and crumpling conditions. Both input impedance and radiation patterns are investigated based on numerical and experimental methods at 2.45 GHz and 5.8 GHz.

2 - **A design of Fabry-Pérot cavity antenna surrounded with metallic walls**[Poster]

Author(s): Jeongho Ju, *Electronics and TelecommunicationsReseach Institute, Korea (South)*

Abstract: A Fabry-Pérot cavity (FPC) antenna with a partially reflecting surface (PRS), which is enclosed with metallic walls in all the lateral directions, is proposed to enhance a gain and to get a adequate beam width. In addition, back lobes are considerable reduced and the total antenna efficiency is more than 90%. Effects of cavity sizes on the beam width are also investigated. A new analysis method is presented to more precisely calculate the resonant frequency of our antenna. The good agreement between the measured and predicted result verify that our proposed design method is correct and useful to design the cavity antenna.

3 - **Tuneable dielectric properties of composites with arrays of magnetic wires**[Poster]

Author(s): Valentina Zhukova, *Dpto. de Fisica de Materiales, Fac. Quimicas, Universidad del Pais Vasco, Spain;* Larissa Panina, *School of Computing, Communications and Electronics, University of Plymouth, Drake Circus, PL4 AA, Plymouth, United Kingdom;* Mihail Ipatov, *Dpto. de Fisica de Materiales, Fac. Quimicas, Universidad del Pais Vasco, Spain;* Julian Gonzalez, *Dpto. de Fisica de Materiales, Fac. Quimicas, Universidad del Pais Vasco, Spain;* Arcady Zhukov, *Dpto. de Fisica de Materiales, Fac. Quimicas, Universidad del Pais Vasco, Spain*

Abstract: We have demonstrated a strong effect of an external magnetic field on scattering from 2D arrays of magnetic wires at GHz frequencies. The effective permittivity of the wire-systems is characterised by a plasma-like dispersion with the damping parameter depending on the wire surface impedance. Utilising amorphous magnetic wires of Co-rich composition having large magnetoimpedance (MI) effect the losses and the dispersion of the effective permittivity can be controlled externally by applying a magnetic field to change the wire magnetic properties. The reflection/transmission spectra are obtained in the free space in the frequency region 1-18 GHz and they are satisfactorily described by theory treating the wire system as effective medium and bringing the wire magnetic properties into the electromagnetic problem through impedance boundary conditions. These tuneable composite materials are foreseen to have a potential for large-scale applications in secure wireless systems and microwave non-destructive testing.

4 - **Reducing mutual coupling between loaded PIFA antennas by using planar soft surfaces**[Poster]

Author(s): Eva Rajo-Iglesias, *Universidad Carlos III de Madrid, Spain;* Oscar Quevedo-Teruel, *Universidad Carlos III de Madrid, Spain;* Antonio Fernandez-Herrera, *Universidad Carlos III de Madrid, Spain;* Luis Inclan-Sanchez, *Universidad Carlos III de Madrid, Spain*

Abstract: In this paper, the metasurfaces known as soft surfaces are used for reducing the mutual coupling between some special Planar Inverted F antennas (PIFA) which are loaded with Left Handed (LH) cells to allow new radiation modes at lower frequencies. These antennas present a high level of mutual coupling when those modes are used, thereby it is necessary to reduce it for a suitable use of these antennas as array elements. To this aim, a multi-layer substrate with soft surfaces printed on a high permittivity layer has been employed, obtaining 7dB of mutual coupling reduction.

5 - **Extraction of effective electromagnetic parameters of microstrip complementary split-ring resonators**[Poster]

Author(s): Svetislav Ponjavic, *METATEC, Serbia;* Branka Jokanovic, *Institute IMTEL, Serbia*

Abstract: Extraction procedure of effective electromagnetic parameters of planar left-handed unit cells is shown. Two unit cells are simulated: microstrip CSRR (MCSRR) and a novel grounded MCSRR. It is shown that both structures exhibit a negative index of refraction as well as a negative μ_{eff} and ε_{eff} around the first resonance.

6 - **A simple mixed analytical-numerical method for modelling and design planar periodic structures**[Poster]

Author(s): Michaël Grelier, *TELECOM ParisTech, France;* Anne Claire Lepage, *TELECOM ParisTech, France;*
Xavier Begaud, *TELECOM ParisTech, France;* Jean Marc Lemener, *THALES Systèmes Aéroportés, France*

Abstract: A simple unidirectional model is introduced to help along the design process of periodic structures using transmission lines theory. The validity of this method is verified by a comparison between circuit representation, measurements and numerical results. Using both AMC and EBG characterizations, this study provides further understanding of the mechanisms involved.

7 - **Studies on multiple inclusion magnetic structures useful for millimeter-wave LHM applications**[Poster]

Author(s): Tapashree Roy, *Institute of Radio Physics and Electronics, University of Calcutta, India;*
Debashree Banerjee, *Institute of Radio Physics and Electronics, University of Calcutta, India;*
Subal Kar, *Institute of Radio Physics and Electronics, University of Calcutta, India*

Abstract: A generic model equation has been derived for effective permeability of multiple-inclusion magnetic structures like MSRR, SR, and LR for LHM applications. Suitability of the structures for operation at millimeter-wave frequency has been explored. In periodic-array, the dependence of resonant-frequency and bandwidth on the lattice parameter has also been studied.

8 - **Rigorous correlation between magnetic and electric responses for the left-handed behavior of combined metamaterial**[Poster]

Author(s): Tung Nguyen Thanh, *Quantum Photonic Science Research Center, Hanyang University, Seoul, Korea (South);*
Lam Vu Dinh, *Quantum Photonic Science Research Center, Hanyang University, Seoul, Korea (South);*
Park Jin Woo, *Quantum Photonic Science Research Center, Hanyang University, Seoul, Korea (South);*
Cho Min Hyung, *Quantum Photonic Science Research Center, Hanyang University, Seoul, Korea (South);*
Lee Sang Jae, *Quantum Photonic Science Research Center, Hanyang University, Seoul, Korea (South);*
Jang Won Ho, *Korea Communication Commission Radio Research Laboratory, Seoul, Korea (South);*
Lee YoungPak, *Quantum Photonic Science Research Center, Hanyang University, Seoul, Korea (South)*

Abstract: We study the transmission spectra of a planar combined metamaterial which consists of cut-wire pairs and continuous wires. By changing the distance between continuous wires, different electromagnetic properties of the combined structure are observed, either to enhance the left-handed behavior or to make it disappear, which depend on the correlation of magnetic resonance and plasma frequency.

9 - **Design of simple M-PRS superstrates for different applications to sectoral base station antennas**[Poster]

Author(s): Mohamad Hajj, *XLIM-UMR 6172-CNRS, University of Limoges-France, France;*
Dina Serhal, *XLIM-UMR 6172-CNRS, University of Limoges-France, France;*
Bernard Jecko, *XLIM-UMR 6172-CNRS, University of Limoges-France, France*

Abstract: This paper presents a new method to realize sectoral base station antennas by incorporating metallic partially reflecting surface (M-PRS) as a superstrate. The simple M-PRS used is flexible to be adapted to different antenna applications including high directivity solution, Dual Polarization and Dual Band devices.

10 - **Bandwidth improvement of microstrip antenna using zero-order mode resonance** [Poster]

Author(s): Yaxuan Zhu, *Hong Kong Polytechnic University EIE Department, Hong Kong*

Abstract: The intrinsic narrow bandwidth is a main disadvantage of microstrip antenna. The existent bandwidth improve methods are always accompanied with decrease in gain, adding complexity to structure or deterioration in radiation pattern. In this paper, a method by introducing the zero-order mode in DNG metamaterial to couple with the other resonant mode to improve impedance bandwidth is proposed. In numerical simulation, the impedance bandwidth of 5.5% to 8% is achieved for the case that host material is either common dielectric or the other DNG metamaterial without deterioration in radiation pattern or adding complexity by employ multi-layer structures. The gain is also increased by about 1.5 dBi in the two cases.

11 - **Effects of gyromagnetic anisotropy on the directive radiation of a line source within a LHM hollow cylinder**[Poster]

Author(s): Rui-Xin Wu, *Nanjing University, China;* Jiang Zhu, *Nanjing University, China*

Abstract: We demonstrate that a hollow cylinder made of gyromagnetic anisotropy left-handed material directs the radiation of a line-source within the cylinder. It is found that the direction of the directive radiation is controlled by degree of anisotropy of the permeability. Varying the degree of magnetic anisotropy, which can be tuned by applied magnetic field, the maximum radiation can scan in a range of angles about the optical axis

12 - **Polarization degeneracy of Bragg reflection at magnetization**[Poster]

Author(s): Alexander Merzlikin, *Institution of the Russian Academy of Sciences Institute for theoretical and applied electromagnetics RAS (ITAE RAS), Russia;* Alexey Vinogradov, *Institution of the Russian Academy of Sciences Institute for theoretical and applied electromagnetics RAS (ITAE RAS), Russia;* Miguel Levy, *Department of Physics, Michigan Technological University, USA;* Sergey Tarapov, *Institute of Radiophysics and Electronics, National Academy of Science of Ukraine, Ukraine*

Abstract: The role of anisotropy in formation of band gaps in one dimensional magneto-photonic crystal is studied. It is shown that magnetization of the structure in a direction normal to the plane of the layers may cause the formation of an additional band gap of a new type. The main feature of such band gaps is polarization degeneracy of Bragg reflection.

13 - **Transient response of wideband cloaking structures made of Isotropic cylindrical layers**[Poster]

Author(s): Gi-Ho Park, *Institute of High Performance Computing, Singapore;*
Haoyuan She, *Institute of High Performance Computing, Singapore;* Er Ping Li,
Institute of High Performance Computing, Singapore; Wolfgang Hoefer, *University of Victoria, Canada*

Abstract: Transient numerical studies of wideband cloaking structures have been carried out. Simulation results show that good cloaking performance can be achieved over more than an octave of transient bandwidth.

14 - **Imaging property of negative index waveguide structures in the optical regime**[Poster]

Author(s): Takeshi Baba, *Department of Physics, Tohoku University, Japan;*
Seigo Ohno, *Department of Physics, Tohoku University, Japan;*
Teruya Ishihara, *Department of Physics, Tohoku University, Japan*

Abstract: We investigate imaging property of a Veselago lens consisting of a slab waveguide imbedded with periodic metallic dots on a ground plane. Angle resolved reflection spectrum of the top surface shows a characteristic feature of negative index. For a point light source, image is focused on the other side.

15 - **Electromagnetic and other properties of MnTiO3 – TiO2 self - organized microstructure**[Poster]

Author(s): Katarzyna Kolodziejak, *Institute of Electronic Materals Technology, Poland;* Dorota Pawlak, *Institute of Electronic Materals Technology, Poland;* Maria Kafesaki , *Institute of Electronic Structure and Laser, Foundation for Research and Technology Hellas, Greece;* Stavroula Foteinopoulou, *Institute of Electronic Structure and Laser, Foundation for Research and Technology Hellas , Greece;* George Kenankis, *Institute of Electronic Structure and Laser, Foundation for Research and Technology Hellas , Greece;* Nikos Katsarakis, *Institute of Electronic Structure and Laser, Foundation for Research and Technology Hellas , Greece*

Abstract: An self-organized eutectic with a 3D fishnet-like microstructure is presented. The 3 D network is made of TiO2 elipsoidal particles interconnected with TiO2 planes and all this is embedded in a mnTiO3 matrix. The results of the etching of the structure and filling the empty spaces with metal as well as the results on reflection measurements of the samples grown with different pulling rates will be presented.

16 - **X-band linear to circular polarisation conversion using a doubly periodic EBG structure**[Poster]

Author(s): Matthias Euler, *ECIT, United Kingdom;* Vincent Fusco, *ECIT, UK; Robert Cahill, ECIT, UK*

Abstract: This study investigates the properties of a new type of freestanding sub-mm wavelength FSS Linear to Circular Polarisation Converter. The polarisation converter was designed to operate at normal incidence at a centre frequency of 10 GHz. CST Microwave Studio was used to generate the dimensions of the structure and optimise their axial ratio performance. Predicted performance was validated experimentally at X-band.

17 - **Multiple scattering and speckle instability in Kerr random media**[Poster]

Author(s): Patrick Sebbah, *CNRS -UMR6622, France;* Umberto Bortolozzo, *CNRS -UMR6618, France;*
Stefania Residori, *CNRS -UMR6618, France*

Abstract: We consider the transverse diffusion of a light beam multiply reflected between the dielectric walls of a scattering liquid crystal light-valve. We demonstrate speckle instability in the regime of a slow nonlinearity. The existence of a threshold intensity confirms earlier theoretical predictions.

18 - **Using RCWA to analyse gratings and negative index structures**[Poster]

Author(s): Michael Bergmair, *CD-Labor für oberflächenoptische Methoden, Institut für Halbleiter- und Festkörperphysik, Johannes Kepler Universität Linz, Austria;* Babak Dastmalchi, *CD-Labor für oberflächenoptische Methoden, Institut für Halbleiter- und Festkörperphysik, Johannes Kepler Universität Linz, Austria;* Iris Bergmair, *Profactor GmbH, Austria; Kurt Hingerl, Zentrum für Oberflächen- und Nanoanalytik, Johannes Kepler Universität Linz, Austria*

Abstract: We use the rigorous coupled wave analysis to simulate the reflectivities for various polarisations. From these data we calculate the reflection and transmission coefficients and the ellipsometric angles and compare them with the experimentally measured data for the given samples which were produced by nanoimprint lithography on large areas. With this technique we are able to check the quality of the grating and negative index structures respectively their geometry and periodicity. For gratings with a metallic cover we are able to see the quality and homogeneity of the metallic film.

19 - **Design of compact RF superconducting metamaterials**[Poster]

Author(s): Cihan Kurter, *University of Maryland, USA;* Steven M. Anlage, *University of Maryland, USA*

Abstract: We report development of a tunable, low-loss RF superconducting metamaterial fabricated out of Nb thin films on sapphire substrates. This compact device is designed in the form of a unique planar spiral resonator array operating at frequencies below 100 MHz, where normal metal metamaterials are generally quite lossy. The goal is to investigate the RF response of this metamaterial by placing it in a superconducting wave guide, at temperatures below and above the superconducting transition temperature Tc of Nb. Numerical simulations mimicking the exact experimental design are done with HFSS software, and transmission data are examined in the light of those calculations. We discuss the novel aspects of using superconductors in constructing metamaterials, such as the ability to miniaturize the designs, adding kinetic inductance, strong magnetic field/temperature tunability and nonlinearity.

Plenary Session IV

(Great Hall)

Session chairperson(s): Ari Sihvola

11:40 - **Gradient index and transformation optical metamaterials**[Plenary]
Author(s): David R. Smith, Duke University, USA

12:40 – Lunch (The Hive – Catering Building)

Bio: Since 2004, Dr. David R. Smith has held the position of Associate Professor and Augustine Scholar in the Electrical and Computer Engineering Department at Duke University. Dr. Smith is also an Adjunct Associate Professor in the Physics Department at the University of California, San Diego (UCSD), and is a Visiting Professor in the Physics Department at Imperial College, London. Dr. Smith's research has been focused on advanced electromagnetic materials and composites, including photonic crystals and metamaterials. In 2000, Dr. Smith and colleagues at UCSD demonstrated the first metamaterial with a negative index-of-refraction. Dr. Smith was selected as a member of The Electromagnetics Academy in 2001; was a co-recipient of the Descartes Research Prize awarded by the European Union in 2004; received the Stansell Research Award from the Pratt School of Engineering in 2005; and was selected to be one of Scientific American's “Top 50” researchers and policy makers in 2006. His work has twice been selected as one of the top ten scientific breakthroughs of the year by Science Magazine (2003, 2006).

Special Session 10 - Metamaterial-based directive antennas

(Skeel Theatre)

Organizer(s): Alexandros Feresidis
Session chairperson(s): Alexandros Feresidis, Ian Youngs

14:00 - **A novel miniature wideband stacked-patch antenna design using matched Impedance magneto-dielectric substrates**[Invited]
Author(s): Douglas Werner, *Penn State University, USA;* Zikri Bayraktar, *Penn State University, USA;* Frank Namin, *Penn State University, USA;* Tom Spence, *Penn State University, USA;* Micah Gregory, *Penn State University, USA;* Pingjuan Werner, *Penn State University, USA;* Elena Semouchkina, *Penn State University, USA*

Abstract: In this paper, we will introduce a novel miniaturized broadband stacked-patch antenna design methodology that utilizes matched magneto-dielectric layers (εr = μr) and employs a genetic algorithm for optimization. In addition, two potential approaches will be explored for realizing the matched magneto-dielectric materials. One approach is based on thin ferromagnetic film composites, while the other method employs metamaterial concepts.

14:20 - **Directive antennas based on zeroth-order resonant CRLH metamaterials implemented in multilayer-technology**[Invited]
Author(s): Andre Rennings, *University of Duisburg-Essen, Germany;* Thorsten Liebig, *University of Duisburg-Essen, Germany;* Simon Otto, *IMST GmbH, Germany;* Christophe Caloz, *Ecole Polytechnique de Montreal, Canada;* Daniel Erni, *University of Duisburg-Essen, Germany*

Abstract: Series and shunt mode directive composite right/left-handed (CRLH) zeroth-order resonant antennas (ZORAs) implemented in multilayer-technology (low temperature cofired ceramics, short LTCC) are demonstrated experimentally.

14:40 - **Highly directive Fabry-Pérot cavity antennas: a review and our developments**[Invited]
Author(s): Filippo Capolino, *University of California, USA; D. R. Jackson, Dept. of Electrical and Comp. Engineering, University of Houston, Houston, TX, 77204-4005, USA;* P. Burghignoli, *Dept. of Electronic Engineering, "La Sapienza" University of Rome, 00184 Roma, Italy;* G. Lovat, *Dept. of Electrical Engineering, "La Sapienza" University of Rome, 00184 Roma, Italy;* M. Albani, *Dept. of Information Engineering, University of Siena, 53100 Siena, Italy;* A. Vallecchi, *Dept. of Electrical Engineering and Computer Science, University of California, Irvine, USA;* S. A. Hosseini, *Dept. of Electrical Engineering and Computer Science, University of California, Irvine, USA;* F. De Flavii, *Dept. of Electrical Engineering and Computer Science, University of California, Irvine, USA*

Abstract: We review the history of Fabry-Pérot Cavity (FPC) antennas (which may be particular cases of EBG or leaky-wave antennas), and present and discuss our developments compared to those made by other research groups. An FPC antenna is a highly directive radiator consisting of a cavity and a surface, that allows power to be leaked in free space and that forms a large radiating area. The usual drawback is the small pattern bandwidth.

15:00 - **Analysis and design of 1D and 2D high-gain leaky-wave antennas using metallodielectric FSS and AMC**[Invited]
Author(s): Maria García-Vigueras, *UPCT, Spain;* Carolina Mateo-Segura, *Heriot-Watt University, United Kingdom;* Jose Gómez-Tornero, *UPCT, Spain;* George Goussetis, *Heriot-Watt University, United Kingdom;* Alexandros Feresidis, *Loughborough University, UK*

Abstract: We present simple and accurate analysis techniques to simulate and design high-gain Fabry-Perot resonant Leaky-Wave Antennas in one dimensional and two dimensional configurations. To control the radiation properties of these antennas, two metallodielectric periodic structures are used, one acting as a PRS and a second one acting as an AMC. The analysis procedures are based on simple Transverse Equivalent Networks, from which the leaky-mode complex propagation constant is obtained, and full-wave method of moments (MoM) for the calculation of the radiation patterns.

15:20 - **Partially reflective surfaces for wide-band EBG resonator antennas**[Invited]
Author(s): Yuehe Ge, *Dept of Physics and Electronic Engineering, Macquarie University, Australia;* Karu Esselle, *Dept of Physics and Electronic Engineering, Macquarie University, Australia;* Trevor Bird, *ICT Centre, CSIRO, Australia*

Abstract: A partially reflective surface (PRS), with reflection phase that increases with frequency, is presented for use in wideband, low-profile electromagnetic band-gap (EBG) resonator antennas. The partially reflective surface is made up of a dielectric slab. Each surface of the slab has a periodic resonant slot array. The first PRS design is then refined to improve its reflection magnitude. The resulting antenna has the potential to provide a gain greater than 15dBi over a Gigahertz bandwidth (10.8 to 11.8 GHz or ~ 9%.)

15:40 – Coffee break (Octagon Room)

Regular Session 10A - Terahertz metamaterials: New devices

(People's Palace 1)

Session chairperson(s): Willie Padilla, Ekmel Ozbay

14:00 - **Asymmetric split ring resonators for infrared optical sensing of organic materials**[Invited]

Author(s): Nigel P. Johnson, *Department of Electronics and Electrical Engineering, University of Glasgow, United Kingdom;*
Basudev Lahiri, *Department of Electronics and Electrical Engineering, University of Glasgow, United Kingdom;*
Ali Z. Khokhar, *Department of Electronics and Electrical Engineering, University of Glasgow, United Kingdom;*
Richard M. De La Rue, *Department of Electronics and Electrical Engineering, University of Glasgow, United Kingdom;*
Scott G. McMeekin, *School of Computing and Engineering, Glasgow Caledonian University, United Kingdom*

Abstract: Asymmetric Split Ring Resonators, consisting of two arcs of a circular metal structure of unequal length, can exhibit resonant modes where the optical electric field is strongest near the ends of their arms. The concentration of optical electric field can increase the sensitivity of spectral techniques such as surface enhanced Raman scattering (SERS). The asymmetry in the two arms of the ring produce distinct plasmonic resonances related to their lengths – but are also modified by the presence of the other arm. The arrangement leads to a steepening of the slope of the reflection spectrum between the resonances that increases the sensitivity of the resonant behaviour to the addition of different molecular species. To demonstrate this action we have used thin films of PMMA with different thicknesses, resulting in characteristic shifts from the original resonance. By adjusting the overall size of the rings we demonstrate matching of asymmetric split ring resonators to a molecular resonance of PMMA in the infra red region of the spectrum.

14:20 - **FSS-filters and metasurfaces for subterahertz and terahertz frequencies**[Regular oral]

Author(s): Sergey Kuznetsov, *Budker Institute of Nuclear Physics SB RAS & Novosibirsk State University , Russia;*
Andrey Arzhannikov, *Budker Institute of Nuclear Physics SB RAS & Novosibirsk State University , Russia;*
Vitaly Kubarev, *Budker Institute of Nuclear Physics SB RAS, Russia;* Mario Sorolla, *Millimeter and Terahertz Wave Laboratory, Universidad Pública de Navarra, Spain;* Miguel Beruete, *Millimeter and Terahertz Wave Laboratory, Universidad Pública de Navarra, Spain;* Miguel Navarro-Cía, *Millimeter and Terahertz Wave Laboratory, Universidad Pública de Navarra, Spain;* Mariam Aznabet, *Millimeter and Terahertz Wave Laboratory, Universidad Pública de Navarra, Spain;* Igor Campillo, *CIC nanoGUNE Consolider, Spain;* Alexander Gelfand, *Institute of Semiconductor Physics SB RAS, Novosibirsk Branch "TDIAM", Russia;* Nina Fedorinina, *Institute of Semiconductor Physics SB RAS, Novosibirsk Branch "TDIAM", Russia*

Abstract: In this report we will review our recent results on experimental development of different frequency selective surfaces operating at frequencies from a few tens GHz up to ten THz. FSS are represented both by substrate-free and polymeric-film-backed structures realized mainly in single- and double-layered configurations designed for the following applied and fundamental research tasks: 1) frequency filtering of (sub)THz-radiation in experiments at free electron laser and plasma facilities of the Novosibirsk research centre; 2) implementation of the electromagnetic metamaterials using topologies of SRR, CSRR, EOT-hole-arrays and some others. Technological aspects of FSS fabrication by the photolithographic techniques will be described with emphasis on the case of employed low-loss FSS-supporting substrates based on polypropylene (or partly polyimide) films as the most promising for multilayered configurations.

14:40 - **Subterahertz metasurfaces with extra-densely packed cells comprised by convoluted tripole elements**[Regular oral]

Author(s): Sergey Kuznetsov, *Budker Institute of Nuclear Physics SB RAS & Novosibirsk State University , Russia;*
Miguel Navarro-Cía, *Millimeter and Terahertz Wave Laboratory, Universidad Pública de Navarra, Spain;*
Miguel Beruete, *Millimeter and Terahertz Wave Laboratory, Universidad Pública de Navarra, Spain;*
Mario Sorolla, *Millimeter and Terahertz Wave Laboratory, Universidad Pública de Navarra, Spain;*
Andrey Arzhannikov, *Budker Institute of Nuclear Physics SB RAS & Novosibirsk State University , Russia;*
Alexander Gelfand, *Institute of Semiconductor Physics SB RAS, Novosibirsk Branch "TDIAM", Russia;*
Nina Fedorinina, *Institute of Semiconductor Physics SB RAS, Novosibirsk Branch "TDIAM", Russia*

Abstract: In this report we will present investigation results for novel types of frequency selective surfaces (FSS) de-signed for experimental implementation in the millimetre-submillimetre wave band. FSS are represented by polypropylene-substrate backed inductive 2D-arrays of convoluted tripole elements maximally packed on a triangular lattice. For single- and double-layer configurations it is demonstrated up to 27-times increase of the fundamental resonance wavelength relative to the effective lattice constant that surpasses the case of FSS with complementary SRR topology and makes the designed FSS to be promising for metamaterials applications. A detailed analysis of possibility for electroinductive wave excitation and left-handed propagation in multistack configurations of proposed FSS will be also considered.

15:00 - **Terahertz spoof surface plasmon polaritons on wires, channels and wedges**[Regular oral]

Author(s): Antonio I. Fernandez-Dominguez, *Departamento de Física Teórica de la Materia Condensada, Universidad Autonoma de Madrid, Spain;* Esteban Moreno, *Departamento de Física Teórica de la Materia Condensada, Universidad Autónoma de Madrid, Spain;* Luis Martin-Moreno, *Instituto de Ciencia de Materiales de Aragón (ICMA) and Departamento de Fisica de la Materia Condensada, CSIC-Universidad de Zaragoza, Spain;* Francisco J. Garcia-Vidal, *Departamento de Física Teórica de la Materia Condensada, Universidad Autonoma de Madrid, Spain*

Abstract: We propose a feasible way of guiding terahertz waves along wires, channels and wedges. Plasmonic metamaterials are built by periodically corrugating these structures in such a way that the system supports the propagation of electromagnetic modes with characteristics mimicking those of surface plasmon polaritons in the optical regime. These geometrically-induced guided modes present long propragation lengths and low bending losses, making them excellent candidates for routing terahertz waves.

15:20 - **Single and multi-pixel modulators for infrared beams using active metamaterials**[Regular oral]

Author(s): Igal Brener, *Sandia National Laboratories, USA;* Xomalin Peralta, *UT San Antonio, USA;*
William Chan, *Rice University, USA;* Dan Mittleman, *Rice University, USA;*
Michael Cich, *Sandia National Laboratories, USA;* Michael Wanke, *Sandia National Laboratories, USA;*
John Reno, *Sandia National Laboratories, USA;* Hou-Tong Chen, *Los Alamos National Laboratory, USA;*
John O'Hara, *Los Alamos National Laboratory, USA;* Antoniette Taylor, *Los Alamos National Laboratory, USA;*
Jeremy Wright, *Sandia National Laboratories, USA;* Charles Fuller, *Sandia National Laboratories, USA*

Abstract: We have designed, fabricated and measured single and multi-pixel optical modulators for terahertz beams using electrically-driven active metamaterials. We will present our recent results on external modulators for terahertz quantum cascade lasers and a 4x4 pixel spatial light modulator.

15:40 – Coffee break (Octagon Room)

Regular Session 10B - Cloaking

(People's Palace 2)

Session chairperson(s): Arthur Yaghjian, David R. Smith

14:00 - **Resonant cloaking and local density of states**[Invited]

Author(s): Ross McPhedran, *CUDOS/School of Physics, University of Sydney, Australia;* Nicolae Nicorovici, *CUDOS/University of Sydney, Australia;* Lindsay Botten, *CUDOS/University of Technology Sydney, Australia*

Abstract: We discuss aspects of resonant cloaking at finite wavelengths. We extend previous discussions to include the association between cloaking and local density of states (LDOS). We show that the LDOS can diverge at the boundary of a double-negative cylinder, but be finite at the boundary of a single-negative cylinder.

14:20 - **Wide-band electromagnetic cloaking with a simple volumetric structure composed of metal plates**[Regular oral]

Author(s): Pekka Alitalo, *TKK Helsinki University of Technology, Finland;*
Olli Luukkonen, *TKK Helsinki University of Technology, Finland;*
Sergei Tretyakov, *TKK Helsinki University of Technology, Finland*

Abstract: We present numerical simulations of a simple metallic structure that is shown to be capable of wide-band cloaking in the microwave regime. The cloak consists of periodically stacked cone-shaped metallic plates. The cloak structure is very simple as compared to most other cloaking methods proposed in the literature.

14:40 - **Is it possible to overcome basic dispersion constraints and achieve broadband cloaking?**[Invited]

Author(s): Silvio Hrabar, *Faculty of Electrical Engineering and Computing, University of Zagreb, Croatia;*
Igor Krois, *Faculty of Electrical Engineering and Computing, University of Zagreb, Croatia;*
Marijan Matvijev, *Faculty of Electrical Engineering and Computing, University of Zagreb, Croatia*

Abstract: It is shown both theoretically and experimentally that basic dispersion constraints of any passive medium might be overcome by use of the active transmission-line-based metamaterials. These types of metamaterials appear promising for the design of broadband cloaking devices.

15:00 - **Design of plasmonic covers to cloak arbitrarily-shaped objects**[Regular oral]

Author(s): Simone Tricarico, *University of Roma Tre, Italy;* Filiberto Bilotti, *University of Roma Tre, Italy;*
Andrea Alù, *University of Texas at Austin, U.S.A;* Lucio Vegni, *University of Roma Tre, Italy*

Abstract: In this contribution, we investigate the possibility of applying the plasmonic cloaking technique, based on the use of homogenous plasmonic covers, to arbitrarily shaped objects. The scattering cancellation approach, applied so far to canonical geometries, is extended here to more complex configurations.

15:20 - **A scattering cancellation approach for acoustic waves**[Regular oral]

Author(s): Matt D. Guild, *University of Texas at Austin, USA;* Andrea Alù, *University of Texas at Austin, USA;*
Michael R. Haberman, *University of Texas at Austin, USA*

Abstract: This paper explores the possibility of applying the non-resonant scattering-cancellation cloaking technique to acoustic waves, proposing the use of homogeneous isotropic acoustic cloaks. It is shown that the cloaking layer may be effective in drastically reducing the scattering from acoustic objects at relatively low frequencies.

15:40 – Coffee break (Octagon Room)

Regular Session 11A - New terahertz metamaterials

(People's Palace 1)

Session chairperson(s): Maria Kafesaki

16:00 - **Resonant coupling to a dipole absorber inside a metamaterial: anti-crossing of the negative index response** Regular oral

Author(s): Igal Brener, *Sandia National Laboratories, USA;* Slava Smolev, *University of New Mexico, USA;* Zayhun Ku, *University of New Mexico, USA;* Steve Brueck, *University of New Mexico, USA;* Michael Sinclair, *Sandia National Laboratories, USA;* Greg Ten-Eyck, *Sandia National Laboratories, USA;* William Langston, *Sandia National Laboratories, USA;* Lorena Basilio, *Sandia National Laboratories, USA*

Abstract: We demonstrate a resonant coupling between the structural resonance in the permeability of a fishnet and a material resonance in the dielectric spacer layer. The resonances in the permeability and the negative index response exhibit anti-crossing behavior. We simulate this using a simple analytic model, as well as rigorous coupled wave analysis (RCWA). Experimental verification is underway.

16:20 - **Circuit approach for terahertz left-handed sub-wavelength holes arrayed stacks** Regular oral

Author(s): Didier Lippens, *IEMN/USTL, France;* Jorge Carbonell, *ITEAM/UPV, Spain;* Charles Croënne, *IEMN/USTL, France;* Frédéric Garet, *IMEP/LAHC, France;* Eric. Lheurette, *IEMN/USTL, France;* Jean Louis Coutaz, *IMEP/LAHC, France*

Abstract: In this communication, we start from the experimental demonstration of a left-handed dispersion branch we recently performed by the time domain spectroscopy of a Terahertz sub-wavelength holes arrayed stack, to show that the full-wave electromagnetic features can have a lumped element circuit description

16:40 - **Variable effective refractive index of a gap layer between two cut-through metal slit array metamaterial slabs** Regular oral

Author(s): Koichi Akiyama, *Advanced Technology R&D Center, Mitsubishi Electric Corporation , Japan;* Kyoji Shibuya, *Institute of Laser Engineering, Osaka University, Japan;* Keisuke Takano, *Institute of Laser Engineering, Osaka University, Japan;* Yuji Abe, *Advanced Technology R&D Center, Mitsubishi Electric Corporation, Japan;* Yasunori Tokuda, *Advanced Technology R&D Center, Mitsubishi Electric Corporation, Japan;* Masanori Hangyo, *Institute of Laser Engineering, Osaka University, Japan*

Abstract: Transmission spectra of a system composed of two cut-through metal slit array metamaterial slabs with a gap layer in between are investigated by the modal expansion method. It is shown theoretically and experimentally that the system can be regarded as a system with three dielectric layers with variable refractive index.

17:00 - **Fabrication of free-standing matrix-free electromagnetic metamaterials with THz resonances** Regular oral

Author(s): Linke Jian, *National University of Singapore/SSLS, Singapore;* Herbert Moser, *National University of Singapore/SSLS, Singapore*

Abstract: Electromagnetic metamaterials (EM) exhibit simultaneously negative permittivity ε and permeability μ within a resonance frequency band called left-handed pass-band. The common embedding of the metal particles in plastic matrices and/or deposition on substrates within a small area severely limits the usefulness of the materials. In the present work, we use microfabrication to build comparably large areas and quantities of the first freely-suspended matrix-free THz metamaterials in which the metallic structures are string-like. Experimental characterization and simulation prove the left-handed passbands around 2.2 THz.

Regular Session 11B - Anisotropic metamaterials

(People's Palace 2)

Session chairperson(s): Raj Mittra, Richard Langley

16:00 - **Transport of an arbitrary near-field component with an array of tilted wires** Regular oral

Author(s): Tiago Morgado, *Departamento de Engenharia Electrotécnica e Computadores da Universidade de Coimbra, Portugal;* Mário Silveirinha, *Departamento de Engenharia Electrotécnica e Computadores da Universidade de Coimbra, Portugal*

Abstract: In this work, we study the electromagnetic properties of an array of tilted metallic wires. It is shown that the proposed configuration may enable the restoration of the electric field component parallel to the wires at the image plane, even when there is no electric field normal to interface.

16:20 - **Additional boundary conditions for nonconnected wire media** Regular oral

Author(s): Mário Silveirinha, *Universidade de Coimbra - Instituto de Telecomunicações, Portugal*

Abstract: We formulate new additional boundary conditions for nonconnected wire media. It is shown that in general the number of boundary conditions at an interface is equal to the number of metallic wires in a unit cell. It is proven that in the lossless case the proposed additional boundary conditions ensure the conservation of the power flow through a metamaterial slab.

16:40 - **Effective properties of periodic, partially disordered, and amorphous metamaterials** Regular oral

Author(s): Christian Helgert, *ZIK ultra-optics, Institute of Applied Physics, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany;* Carsten Rockstuhl, *Institute of Condensed Matter Theory and Solid State Optics, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany;* Christoph Etrich, *ZIK ultra-optics, Institute of Applied Physics, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany;* Ernst-Bernhard Kley, *ZIK ultra-optics, Institute of Applied Physics, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany;* Andreas Tünnermann, *ZIK ultra-optics, Institute of Applied Physics, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany;* Falk Lederer, *Institute of Condensed Matter Theory and Solid State Optics, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany;* Thomas Pertsch, *ZIK ultra-optics, Institute of Applied Physics, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany*

Abstract: We consider the impact of positional disorder of the metamaterial unit cells on its spectral properties. We reveal that electric and magnetic resonances posses a different sensitivity, correlate this finding to the excited eigenmodes and retrieve the effective MM properties along its transition from a crystalline to an amorphous structure.

17:00 - **Design of polarizers at optical frequencies** Regular oral

Author(s): Alessandro Toscano, *University "Roma Tre", Italy;* Lucio Vegni, *University "Roma Tre", Italy*

Abstract: Starting from the concept of "form birefringence", we present here a new schema to design a polarizing module operating at optical frequencies, using alternating layers of two different homogeneous and isotropic media. A complete analysis through design formulas and numerical examples of nanoscale polarizing components at optical frequencies is presented and discussed.

Regular Session 11 - Nonlinear and active metamaterials

(Skeel Theatre)

Session chairperson(s): George Palikaras

16:00 - **Superheterodyne amplification for high-frequency active metamaterials** Regular oral

Author(s): Allan Boardman, *University of Salford, United Kingdom;* Vladimir Grimalsky, *Autonomous University of Morelos, Mexico*; Svetlana Koshevaya, *University of Salford, United Kingdom;* Yuriy Rapoport, *University of Salford, United Kingdom*

Abstract: Superheterodyne amplification is investigated and involves parametric coupling between relatively low-frequency space-charge waves in a suitable semiconductor and high frequency electromagnetic waves. This is applied to the control of a high frequency active metamaterial and it is shown that the technique avoids absolute instability in linear materials.

16:20 - **Multipole induced nonlinearity of metamaterials** Regular oral

Author(s): Joerg Petschulat, *Friedrich-Schiller-Universitaet Jena, Germany;* Arkadi Chipouline, *Friedrich-Schiller-Universitaet Jena, Germany;* Carsten Rockstuhl, *Friedrich-Schiller-Universitaet Jena, Germany;* Andreas Tuennermann, *Friedrich-Schiller-Universitaet Jena, Germany;* Falk Lederer, *Friedrich-Schiller-Universitaet Jena, Germany;* Thomas Pertsch, *Friedrich-Schiller-Universitaet Jena, Germany*

Abstract: We present a self-consistent physical approach to treat the complex optical response of metamaterials. Therefore we develop the complex near field dynamics into multipole contributions beyond the electric dipole moment. We show that especially 2nd order moments, i.e. the electric quadrupole induces also a nonlinear material response which we refer to as multipole nonlinearity.

16:40 - **Surface second harmonic generation in metamaterials of nanowires made of centro-symmetric media** Regular oral

Author(s): Claudiu Biris, *University College London - Department of Electronic and Electrical Engineering, United Kingdom;* Nicolae Panoiu, *University College London - Department of Electronic and Electrical Engineering, United Kingdom*

Abstract: A numerical method for computing both linear and non-linear optical effects in metamaterials based on nanowires made of centro-symmetric materials (metals) has been developed and used to study the scattering of light by a collection of metallic nanowires and the surface second harmonic generated in the scattering process.

17:00 - **Amplification of the evanescent modes and connection with the guided modes for 1-D, multi-layered structures** Regular oral

Author(s): Concita Sibilia, *Universita' di Roma La Sapienza, Italy;* Mario Bertolotti, *Universita' di Roma La Sapienza, Italy;* Antonio Mandatori, *Universita' di Roma La Sapienza, Italy;* Nadia Mattiucci, *Dept. of the Army. Charles M.Bowden Facility, Research Development and Engineering Command, Redstone Arsenal, USA;* Giuseppe D'Aguanno, *Dept. of the Army. Charles M.Bowden Facility, Research Development and Engineering Command, Redstone Arsenal, USA*

Abstract: We analytically demonstrate that for a generic multi-layered structure the amplification of the evanescent modes along the propagation direction can be directly linked to the guided modes supported by the same structure in the transverse direction. We also briefly discuss how to enlarge the transmission band of the evanescent modes in the framework of the guided mode theory of leaky-waveguides.

Closing Ceremony

17:20 (Great Hall)

Session chairperson(s): Alex Schuchinsky

Session Matrix

Monday	31 August 2009	**08:30-17:00**				
		Pre-registration & General Setup for Exhibitors [Octagon Room]				
Tuesday	1 September 2009		**09:00-10:40**	**10:40-11:40**	**11:40-12:40**	
		08:30-09:00 Set-up [Octagon Room]	Registration Coffee/Tea Exhibition [Octagon Room]	**10:20-10:40** Opening Ceremony [Great Hall]	Plenary 1 John Pendry [Great Hall]	Poster Session 1: Theory [Octagon Room] Exhibition [Octagon Room] COMSOL - Free Workshop [Computer Centre - ITL]	**12:40-14:00** LUNCH [The Hive- Catering building]
Wednesday	2 September 2009		**09:00-10:40**	**10:40-11:40**	**11:40-12:40**	
		08:30-09:00 Registration Coffee/Tea/Exhibition [Octagon Room]	Special Session 3 [Skeel Theatre]: Optical Meta-devices Session 3A [PP1]: Microwave Applications of Metamaterials Session 3B [PP2]: New Concepts	Poster Session 2: Experimental [Octagon Room] Coffee/Tea/ Exhibition [Octagon Room]	Plenary 2 Xiang Zhang [Great Hall]	**12:40-14:00** LUNCH [The Hive- Catering building]
Thursday	3 September 2009		**09:00-10:40**	**10:40-11:40**	**11:40-12:40**	
		08:30-09:00 Registration Coffee/Tea/Exhibition [Octagon Room]	Special Session 6 [Skeel Theatre]: Optical Metamaterials Session 6A [PP1]: Metamaterial Transmission Lines and Waveguides Session 6B [PP2]: Theoretical Aspects: Defining Boundaries	Poster Session 3: Modelling and Simulations [Octagon Room] Coffee/Tea/ Exhibition [Octagon Room]	Plenary 3 Harald Giessen [Great Hall]	**12:40-14:00** LUNCH [The Hive - Catering building]
			CST - Free Workshop AM Session [Computer Centre - ITL]			
Friday	4 September 2009		**09:00-10:40**	**10:40-11:40**	**11:40-12:40**	
		08:30-09:00 Registration Coffee/Tea/Exhibition [Octagon Room]	Special Session 9 [Skeel Theatre]: Cloaking and Coordinate-Transformation Applications Session 9A [PP1]: Metasurfaces Session 9B [PP2]: State-of-the-Art Overviews	Poster Session 4: General Topics and Student Paper Competition [Octagon Room] Coffee/Tea/ Exhibition [Octagon Room]	Plenary 4 David Smith [Great Hall]	**12:40-14:00** LUNCH [The Hive- Catering building]

08:30-17:00	17:00-19:40
Pre-registration & General Setup for Exhibitors [Octagon Room]	Pre-registration Reception with Finger Buffet and Wine & Exhibition [Octagon Room]

14:00-15:40		16:00-17:40	17:40-19:40
Special Session 1 [Skeel Theatre]: Theoretical modelling of metasurfaces	1540-1600 Coffee/Tea/Exhibition [Octagon Room]	Special Session 2 [Skeel Theatre]: Metamaterial Antennas	Welcome Reception with Finger Buffet and Wine [Octagon Room]
Session 1A[PP1]: Tunable and Active Metamaterials		Session 2A[PP1]: Terahertz Metamaterials: New Phenomena	Poster Session 1: Theory [Octagon Room]
Session 1B [PP2]: Periodical Structures		Session 2B [PP2]: Extraordinary Transmission	Exhibition [Octagon Room]
COMSOL - Free Workshop [Computer Centre - ITL]			

14:00-15:40		16:00-17:40	17:40-19:40
Special Session 4 [Skeel Theatre]: Applications to Magnetic Resonance Imaging	1540-1600 Coffee/Tea/Exhibition [Octagon Room]	Special Session 5 [Skeel Theatre]: Extreme-Parameter Metamaterials	Evening Reception with Finger Buffet and Wine [Octagon Room]
Session 4A [PP1]: Applications of Metasurfaces		Session 5A [PP1]: Applications of Tunable Metamaterials	Poster Session 2: Experimental [Octagon Room]
Session 4B [PP2]: Plasmonics I		Session 5B [PP2]: Plasmonics II	Exhibition [Octagon Room]

14:00-15:40		16:00-17:40	17:40-19:00	19:00-22:00
Special Session 7 [Skeel Theatre]: Progress of ECONAM Project	1540-1600 Coffee/Tea/Exhibition [Octagon Room]	Special Session 8 [Skeel Theatre]: Nonlinear Metamaterials	Social Tour by Classic Buses around London Tower Bridge and the Tower of London [Bancroft Rd]	Conference Banquet Medieval Themed with Entertainment [St Katherine's Dock]
Session 7A [PP1]: New Metamaterial Particles		Session 8A [PP1]: Homogenization and Bulk Metamaterials		
Session 7B [PP2]: Transformational Electromagnetics		Session 8B [PP2]: Fabrication of Artificial Materials		
CST - Free Workshop PM Session [Computer Centre - ITL]				

14:00-15:40		16:00-17:20	
Special Session 10 [Skeel Theatre]: Metamaterial-Based Directive Antennas	1540-1600 Coffee/Tea/Exhibition [Octagon Room]	Session 11 [Skeel Theatre]: Nonlinear and Active Metamaterials	17:20-17:40 Closing Ceremony [Great Hall]
Session 10A [PP1]: Terahertz Metamaterials: New Devices		Session 11A [PP1]: New Terahertz Metamaterials	
Session 10B [PP2]: Cloaking		Session 11B [PP2]: Anisotropic Metamaterials	

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This Publication has been produced by
the Publications and Web Office for
the School of Electronic Engineering
and Computer Science – Pub4432

For further information contact:
George Palikaras (Editor)
School of Electronic Engineering and Computer Science
Queen Mary, University of London
Mile End Road
London E1 4NS
Tel: +44 (0)20 7882 5459
Fax: +44 (0)20 7882 7997
email: george.palikaras@elec.qmul.ac.uk
www.eecs.qmul.ac.uk

ISBN 978-0-9551179-6-1