Metamaterials'2007

First International Congress on Advanced Electromagnetic Materials in Microwaves and Optics, Rome, Italy, October 22-26, 2007

Congress Sponsors

Congress is supported by

Metamaterials 2007

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Program of the Conference

22-24 October 2007

The conference is organized by the Virtual Institute for Artificial Electromagnetic Materials and Metamaterials "Metamorphose VI"
www.metamorphose-vi.org

The conference is hosted by the University "Roma Tre"

Edited by Filiberto Bilotti and Lucio Vegni
University "Roma Tre"
Rome – October 2007

Foreword

It is our great pleasure to welcome you to the First International Congress on Advanced Electromagnetic Materials in Microwaves and Optics (*Metamaterials 2007*), initiated by the European Network of Excellence *Metamorphose* and organized by the Virtual Institute for Artificial Electromagnetic Materials and Metamaterials (*Metamorphose VI*).

The Congress programme covers a wide area of research, related to metamaterials, artificial electromagnetic materials and surfaces for microwave and optical ranges, and encompasses various aspects of their general theory, modelling, design, applications, fabrication and measurements.

This new event 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 Rome International Workshops on Metamaterials had three editions with rapidly growing international participation. Now as we witness fast advancements and promising developments in the newly conceptualized area of *metamaterials*, time has come to establish a wider forum for researchers and engineers working in the interdisciplinary field of artificial electromagnetic materials and applications of their novel and exotic properties to practical devices.

We would like to thank all colleagues who have helped with the organization of this event and offered their scientific and technical contributions. 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.

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Conference venue

The Congress is hosted by the University of Roma Tre. The *opening ceremony* and the *plenary session* on Monday 22 (morning) will be held at the *Aula Magna* of the university, via Ostiense 159.
The *regular sessions* (from Monday 22, afternoon) will be held in the *buildings of the Faculty of Engineering* at via della Vasca Navale, 109.

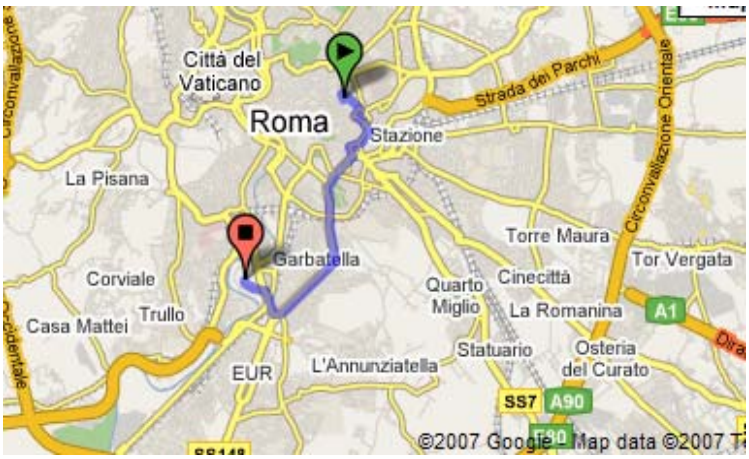
Travel directions

If you arrive ***by plane*** you can land either in *Fiumicino*, which is the main Roman airport, or in *Ciampino*, which is the second Roman airport.
From Fiumicino airport you can reach the centre of the city either by taxi (regular fares are around 40-60 Euros) or by train. There are two different trains. The first one is a direct train to Termini (11 Euros, it takes 30 min and departs every 30 min). In order to reach the conference venue from Termini, please, follow the information in the next page. The second train from Fiumicino is the one to Stazione Tiburtina, which has several stops throughout the city (around 5.5 Euros, it takes around 30 min and departs every 30 min). The most convenient stop to the conference venue is *Ostiense*. In front of Ostiense Station in Piazzale Ostiense take bus n°23 (direction Pincherle). In order to reach the plenary session venue, get off at the stop *San Paolo*. If you want to reach the regular session venue, just get off at the last stop (see the next page for more information). The price of the bus ticket is 1 Euro each.
From Ciampino airport you can reach the city centre either by taxi (regular fares are around 30-60 Euros) or by bus. The bus Terravision will bring you from Ciampino airport to Termini railways station (one way 8 Euros, round-trip 14 Euros). Details on how to reach the conference venue from Termini are given in the next page.

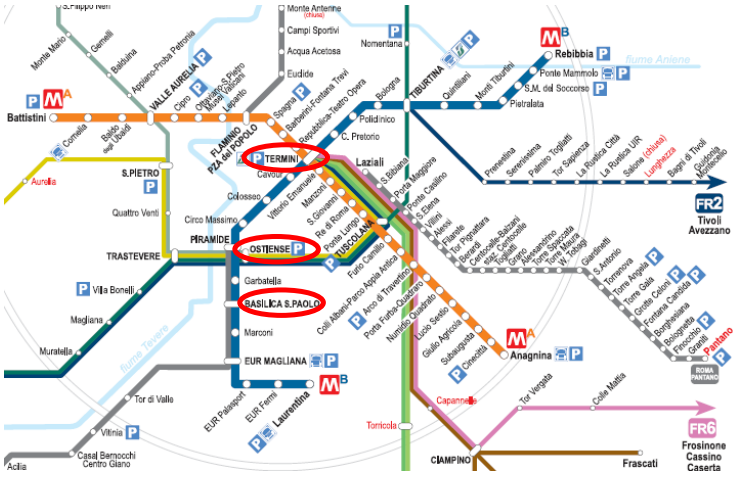
If you arrive ***by train***, check if you can get off at *Ostiense railways station*. If so, just follow the above information from Ostiense. If you arrive at *Termini railways station*, please, follow the information on the next page. If you arrive at *Tiburtina railways station*, just take a train to Ostiense and then follow the above information from Ostiense.

If you arrive ***by car*** both from the North and from the South, take the highway ring around Rome, which is called *Grande Raccordo Anulare* (GRA) and take the exit n°28 towards the city centre. You are already in via Ostiense.

The places where the conference will be held (*via Ostiense 159* for the plenary session on Monday 22 – morning – and *via della Vasca Navale 109* for the regular sessions from Monday 22 afternoon) are located in the South-West part of the city, close to San Paolo Basilica.
In the map you can see where the conference places (red marker) are located with respect to Stazione Termini (green marker), which is the main railways station of Rome. The distance between Termini and San Paolo Basilica is about 10 km and it can take even more than one hour by car during the rush hours.



The best way to reach the conference venues is by *Metro*. Here you find a complete map of the railways transportation in the city.



If your hotel is close to any of the metro stations (either *Metro Line A*, or *Metro Line B*), it is very easy to reach the conference place.

- If the closest metro station belongs to the *red line* (orange in the map), which is *Metro Line A*, just take the metro to Termini, which is the only metro station where you can switch between the two Metro lines. Then, take *Metro Line B*, the blue one, (direction *Laurentina*) and get off at *Basilica San Paolo*.
- If the closest metro station belongs to the *blue line*, which is *Metro Line B*, just take the metro (direction *Laurentina*) and get off at *Basilica San Paolo*.

Tickets for the metro and for the buses costs 1 Euro each and can be purchased at any metro station, in some kiosks selling newspapers, or in some Tabacchi shops.

The conference will be held in two different buildings of the University "Roma Tre". They can be both reached easily from the metro station *Basilica San Paolo*.

The opening ceremony and the plenary session venue (Aula Magna of the University "Roma Tre", via Ostiense 159) is very close to the metro station *Basilica San Paolo*: it is just 5 min walking distance along via Ostiense (direction Piramide). The place is marked in the map with "1".

The regular session venue (via della Vasca Navale, 109) is 15-20 min. walking distance from the metro station *Basilica San Paolo*. The place is marked with "2" in the map. You can either go on walking or take the bus n°23 (direction *Pincherle*) in via Baldelli, next to the metro station (see green box in the map). Get off at the last stop (via Salvatore Pincherle), which is marked again with a green box in the map. Bus number 23 is officially scheduled to pass every 20 min.

Registration

The registration desk for pre-registered attendees is open at

Via della Vasca Navale 84
Sunday 21 – 17:00 – 19:00

Via della Vasca Navale 109
Monday 22 – 13:00 – 17:00
Tuesday 23 – 8:00 – 17:00
Wednesday 24 – 8:00 – 12:00

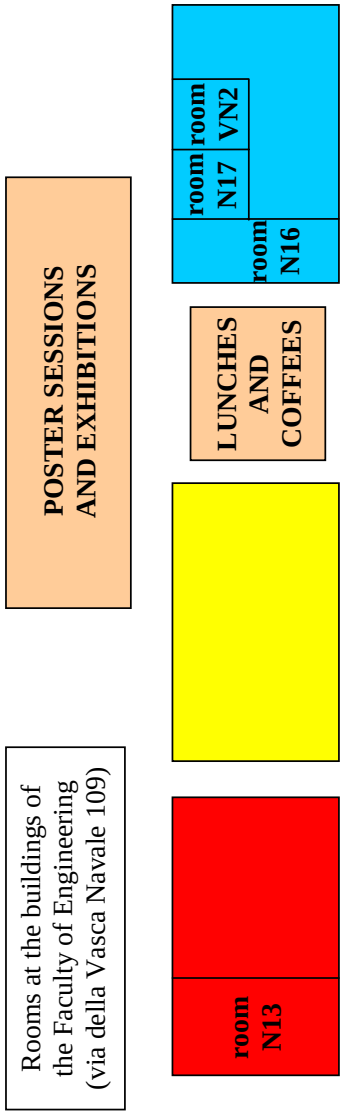
Via Ostiense 159
Monday 22 – 8:00 – 11:00

During the opening hours of the registration desk it is on-site registration is also available. The registration fee can be paid either in cash or by credit card and the on-site registration fees are:

Full registration	Euro 550
Student registration	Euro 300

Tickets for the social dinner can be also purchased at the price of Euro 50 each.

Map of the rooms at via della Vasca Navale 109



Session Matrix

	Monday – October 22				
08:30 – 09:30	*Opening Session*				Aula Magna Via Ostiense 159
09:30 – 10:30	*Plenary Session (I)*				
10:30 – 11:00	*Coffee break*				
11:00 – 12:00	*Plenary Session (II)*				
12:00 – 12:30	*Transfer to the buildings of the Faculty of Engineering*				
12:30 – 13:30	*Lunch*				Buildings of the Faculty of Engineering Via della Vasca Navale 109
13:30 – 16:00	*Session 1 – Optical and microwave sensing, imaging, photolithography*	*Session 2 – Localization and channelling of light and microwave radiation*	*Session 3 – Tunable and active metamaterials and surfaces*	*Session 4 – Fabrication and processing of metamaterials and artificial electromagnetic surfaces*	
16:00 – 16:30	*Coffee break*				
17:00 – 18:30	*Session 5 – Microwave devices*	*Session 6 – Optical properties of metamaterials*	*Session 7 – Plasmonics (I)*	*Session 8 – EBG and photonic crystals (I)*	
	Room N13	Room N16	Room N17	Room VN2	

	Tuesday – October 23				
08:30 – 10:30	Session 9 – Quasicrystals (I)	Session 10 – Electromagnetic theory	Session 11 – Metamaterials and antennas (I)	Session 12 – Plasmonics (II)	Buildings of the Faculty of Engineering Via della Vasca Navale 109
10:30 – 11:00	Coffee break				
11:00 – 12:30	Session 13 – Quasicrystals (II)	Session 14 – Chirality and handedness	Session 15 – Metamaterials and antennas (II)	Session 16 – Negative material parameters	
12:30 – 14:00	Lunch				
14:00 – 15:00	Poster session (I)				
15:00 – 16:30	Session 17 – Quasycristals (III)	Session 18 – Cloaking and field transformation (I)	Session 19 – Metamaterials and antennas (III)	Session 20 – NI metamaterials in optics	
16:30 – 17:00	Coffee break				
17:00 – 19:00	Session 21 – Homogenization of metamaterials	Session 22 – Subwavelength imaging	Session 23 – Enhanced transmission	Session 24 – FSS and guiding structures	
	Room N13	Room N16	Room N17	Room VN2	

	Wednesday – October 24				
08:30 – 10:30	Session 25 – Metasurfaces, metaboundaries and enhanced transmission (I)	Session 26 – Effective material parameters and role of disorder in metamaterials (I)	Session 27 – Nonlinear metamaterials (I)	Session 28 – Cloaking and field transformation (II)	Via della Vasca Navale 109
10:30 – 11:00	Coffee break				
11:00 – 12:30	Session 29 – Metasurfaces, metaboundaries and enhanced transmission (II)	Session 30 – Effective material parameters and role of disorder in metamaterials (II)	Session 31 – Nonlinear metamaterials (II)	Session 32 – EBG and photonic crystals (II)	
12:30 – 14:00	Lunch				
14:00 – 15:00	Poster session (I)				
15:00 – 16:30	Session 33 – Modelling, fabrication and characterisation techniques for plasmonics and metamaterials (I)	Session 34 – Analysis and synthesis of metamaterials using numerical modelling (I)	Session 35 – High impedance surfaces and thin layers	Session 36 – Magnetic materials	
16:30 – 17:00	Coffee break				
17:00 – 18:30	Session 37 – Modelling, fabrication and characterisation techniques for plasmonics and metamaterials (II)	Session 38 – Analysis and synthesis of metamaterials using numerical modelling (II)	Session 39 – Modelling, extraction and measurements	Session 40 – Educational aspects of metamaterials	
18:30 – 19:00	Closing Ceremony				
	Room N13	Room N16	Room N17	Room VN2	

Monday 22 October

Aula Magna of the University "Roma Tre"
via Ostiense 159

08:30 Opening session
Chair: F. Bilotti

08:30 *Welcome by "Roma Tre" Authorities*

Welcome by the General Chair
S. Tretyakov

Welcome by the Local Chairs
L. Vegni and A. Toscano

08:55 *European Commission - Material research in the metamaterial field*
A. de Baas

09:05 *Metamaterial Roadmap - Metamorphose vision for the future advancements*
E. Ozbay

09:30 Plenary session
Chairs: S. Tretyakov, A. Schuchinsky

09:30 Plenary talk
Microwave metamaterials and applications: current status of the experimental and theoretical developments

George Eleftheriades
Univ. of Toronto
Canada

George V. Eleftheriades earned his Ph.D. and M.S.E.E. degrees in Electrical Engineering from the University of Michigan, Ann Arbor, in 1993 and 1989 respectively, and a diploma in Electrical Engineering from the National Technical University of Athens, Greece in 1988. In the period 1994-1997 he was with the Swiss Federal Institute of Technology in Lausanne. Presently he is a full Professor and the Canada Research Chair/Velma M. Rogers Graham Chair in the Department of Electrical and Computer Engineering at the University of Toronto. Dr. Eleftheriades received the Ontario Premier's Research Excellence Award in 2001. In 2004 he received an E.W.R. Steacie Fellowship from the Natural Sciences and Engineering Research Council of Canada. Prof. Eleftheriades is a Fellow of the IEEE and serves as a Distinguished Lecturer for the IEEE Antennas and Propagation Society. His present research interests include negative-refraction metamaterials for microwave and optical applications, antennas and components for wireless communications, novel antenna beam-steering techniques, low-loss silicon micromachined components, plasmonic nano-structures, and electromagnetic design for high-speed digital circuits.

10:30 Coffee

11:00 Plenary talk

Optical metamaterials and applications: current status of the experimental and theoretical developments

Vladimir Shalaev

Purdue University U.S.A.

Vladimir M. Shalaev, the Robert and Anne Burnett Professor of Electrical and Computer Engineering and Professor of Biomedical Engineering at Purdue University, specializes in nano-photonics, nano-plasmonics, and optical metamaterials. Dr. Shalaev has several awards for his research in the field of nano-photonics and metamaterials. He is a Fellow of the American Physical Society (APS), Fellow of The International Society for Optical Engineering (SPIE), a Fellow of the Optical Society of America (OSA). Dr. Shalaev is editor/co-editor for a number of journals and book series in the area of nanoscale optics. He authored and edited 7 books, published 20 invited book chapters, and over 200 research papers.

12:00 Transfer to *via della Vasca Navale, 109*

12:30 Lunch

13:30 – 16:00 Session 1 – Room N13

Optical and microwave sensing, imaging and photolithography (focused session organized by A. Zayats)

Chair: A. Zayats

13:30 *Negative refraction, subwavelength focusing and beam formation using photonic crystals (invited)*

E. Ozbay

Abstract: Photonic crystals are three dimensional periodic structures having the property of reflecting the electromagnetic (EM) waves in all dimensions, for a certain range of frequencies. We report our experimental and theoretical investigation of negative refraction and subwavelength focusing of electromagnetic waves in a 2D PC.

14:00 *Diffraction and dispersion management in active nanoplasmonic metamaterials (invited)*

V.A. Podolskiy, A.A. Govyadinov

Abstract: We show that anisotropy-based systems support confined optical modes even when the waveguide size is subwavelength. Modal indices in these nm-thick structures are inversely proportional to waveguide sizes, and can be either positive or negative. In active metamaterials, interplay between waveguide-

and material- dispersions yields versatile manipulation of group velocity.

14:30 *Subwavelength imaging in the visible using a pair of arrays of metal nanoparticles (invited)*
P. Alitalo, C.R. Simovski, L. Jylha, A.J. Viitanen, S.A. Tretyakov
Abstract: The concept of using two coupled material sheets possessing surface mode resonances for evanescent field enhancement suggested earlier for the microwave range is developed in this presentation for the optical region. The operation of the super-lens based on the resonant sheets can be realized with the use of metallic nanoparticles located in the dielectric matrix. We present a design of such structures and study the electric field distributions in the image plane for the case of two closely positioned point sources.

15:00 *Infrared-to-THz spectroscopic near-field imaging of materials and metamaterials (invited)*
F. Keilmann
Abstract: Microscopy with a truely sub-micrometer resolution potential has been demonstrated for mid-infrared, THz and microwave operation. In this, a sub-wavelength focusing occurs through the lightning-rod effect at a sharp probing tip. Local contrast is obtained according to either a material's complex dielectric value or to a metamaterial's local electric or magnetic field.

15:30 *Uniaxial metallo-dielectric metamaterials with isotropic positive permeability*
J. Schilling
Abstract: The indefinite dielectric tensor of a uniaxial metallo-dielectric metamaterial is sufficient to create a hyperbolic dispersion relation, which can cause partly counterpropagating wave vectors and negative refraction. As an example a metallo-dielectric multilayer stack is investigated applying an effective medium model and analytical exact Bloch wave calculation. The extraordinary waves in these structures are identified as multilayer plamons and implications for possible subwavelength imaging are discussed.

15:45 *Imaging process in superlens-based mid-infrared near-field microscopy*
T. Taubner, M. Brongersma, C. Fietz, Y. Urzhumov, D. Korobkin, G. Shvets, R. Hillenbrand
Abstract: Here we combine a SiC superlens with a near-field optical microscope to create a mid-infrared imaging system with resolution far below the illumination wavelength and analyze the imaging process of this combination. By varying the illumination

wavelength we examine image quality and phase effects when the superlensing condition is not exactly fulfilled.

13:30 – 16:00 Session 2 – Room N16
Localization and channelling of light and microwave radiation (focused session organized by M. Stockman)
Chair: M. Stockman

13:30 *Plasmonics throughout the spectrum: sub-wavelength energy confinement for waveguiding, spectroscopy and sensing (invited)*
S.A. Maier
Abstract: The confinement of electromagnetic energy to volumes below the diffraction limit leads to a concomitant field enhancement, enabling a wealth of opportunities for sensing and spectroscopy. One of the challenges is to create such confinement in a controlled manner, and to channel electromagnetic energy from conventional, wavelength-scale devices such as planar waveguides and optical fibres down to the nanoscale. The field of plasmonics holds the promise of achieving this via the excitation of electromagnetic surface modes at the interface between a conductor and a dielectric. Depending on the exact geometry and the frequency of the electromagnetic radiation, a deep sub-wavelength mode size is possible.

14:00 *Light confinement at interfaces and Talbot effects in surface modes of various systems (invited)*
F.J.G. de Abajo, R. Sainidou, T.V. Teperik, M. Dennis, N.I. Zheludev
Abstract: Light confinement to surfaces is at the heart of many recent advances in nanophotonics, for instance in the field of plasmonics, which relies upon plasmon polaritons at metallic surfaces. Various ways of confining light to an interface will be reviewed and new ones demonstrated in this talk. A common description of such modes will be offered, which leads to a global understanding of their interference at interface features. In particular, the interference of surface plasmons emanating from a row of holes in a metal film will be shown to lead to complex plasmonic structures that present self-reconstruction of the hole array at distances up to tens of wavelengths away from the holes. This is the plasmonic version of the optical Talbot effect. Interestingly, subwavelength hot plasmonic spots are observed at those distances, suggesting the possibility of using them for far-field patterning and for long-distance plasmon-based interconnects in

plasmonic circuits. Some examples of such applications will be also presented.

14:30 *Localization, diffusion, and time reversal in anisotropic structures*

G. Samelsohn

Abstract: In this work we study the relation between a number of phenomena, namely, localization, diffusion, and time reversal of wave fields, in (mainly two-dimensional) systems with anisotropic disorder. It is shown, in particular, that in the long-wavelength limit the radiation is always localized, and the localization length is independent of the direction of propagation, the latter in contrast to the predictions based on an anisotropic tight-binding model. For shorter wavelengths that are comparable to the correlation scales of the disorder, the transport properties of disordered media are essentially different in the directions along and across the correlation ellipse. There exists a frequency-dependent critical value of the aspect ratio, below which waves are localized at all angles of propagation. Above this critical value, the radiation is localized only within some angular sectors centered at the short axis of the correlation ellipse and is extended in other directions. Analytical results concerning anisotropic time-domain diffusion in both localized and extended regimes have been also obtained. Extensive numerical time reversal experiments aimed at studying the resolution in both space focusing and time compression of wideband signals have been performed. The resolution obtained is shown to depend essentially on the aspect ratio of the structure. The analysis can be generalized to 3D anisotropic media.

14:45 *Experimental demonstration of surface wave excitation between a truncated photonic crystal and a metal (invited)*

Z.M. Zhang, B.J. Lee, Y.-B. Chen

Abstract: This work describes the experimental observation of surface wave excitation at the edge of truncated photonic crystal adjacent a metallic film by near-infrared reflectance spectrometry. We first obtain the dispersion relation of surface waves for the one-dimensional photonic crystal (1DPC) using the supercell method. A Fourier-transform infrared spectrometer meas-ured the spectral reflectance at several fixed incidence angles; while a laser scatterometer measured the specular reflectance at the wavelength of 891 nm for various incidence angles. The measurements compare well with the dispersion relation, and demonstrated both temporal coherence and spatial coherence of the fabricated multilayer structures. This work provides strong experimental evidence of the excitation of surface waves between a truncated 1DPC and a metal. The results also sug-gest that planar

structures can be made for thermal emission control and for the construction of coherent thermal-emission sources.

15:15 *Nanoplasmonics: generation and control of nanoscale optical fields (invited)*
M. Stockman
Abstract: Nanoplasmonic phenomena are based on resonant excitation of surface plasmons causing highly enhanced and localized optical fields on nanoscale. These nanoscale fields induce a multitude of enhanced optical effects, in particular, surface enhanced Raman scattering (SERS) including single-molecule SERS, enhanced second- and third-harmonic generations, enhanced two-photon electron emission from nanostructured surfaces, and others. Special emphasis of the talk is on ultrafast and active nanoplasmonics. There are many existing and prospective applications of nanoplasmonics in nanoprobing, ultrasensitive detection, biomedical monitoring, etc. The talk will include a broad introduction to the topic and also certain forefront, focus areas based partially on original contributions, including ultrafast, coherent, nonlinear, and stimulated phenomena. Spaser will be one of the focus points of the talk.

15:45 *FDTD study of resonance phenomena at electromagnetic wave localization in 3D dielectric fractal and modified structures*
E. Semouchkina, Y. Miyamoto, G. Semouchkin, S. Kirihara, M. Lanagan
Abstract: Wave propagation through 3D dielectric fractals of Menger sponge type and PBG-like cubic structures, obtained by transformation of these fractals, have been investigated, in order to get deeper insight into the nature of resonance formation and electromagnetic (EM) wave localization in fractal structures. It is demonstrated that in fractals, localization occurs at wave penetration into the central cavity, which, in turn, is governed by interplay between the resonances in different elements of the structure. Another type of localization related to formation of integrated resonance mode in a dielectric cube with spatially averaged permittivity, has been observed in PBG-like structures.

13:30 – 16:00 Session 3 – Room N17
Tunable and active metamaterials and surfaces
Chairs: I. Vendik, I. Nefedov

13:30 *1D and 2D tuneable metamaterials based on ferroelectric varactors (invited)*
S. Gevorgian, D. Kuylenstierna, A. Vorobiev

Abstract: The tuneable technologies useful for applications in tuneable metamaterials are reviewed briefly. The possibilities and potentials of the integrated tuneable 1D and 2D metamaterials based on ferroelectric varactors are and demonstrated experimentally. The reported devices are fabricated on high resistivity silicon substrates making them potentially useful for the development of tuneable metamaterial based microwave circuits in the form of multichip modules.

14:00 *Parametrically amplified magneto-inductive ring resonators*
R.R.A. Syms, L. Solymar, I.R. Young
Abstract: MI waveguide rings have been constructed and their resonances measured. The resonance can be tuned by inserting varactors into each element, and the non-linear resonant elements thus obtained also allow parametric amplification. Selective amplification of the individual resonances of a 16-element MI wave ring resonator is demonstrated.

14:15 *Tunability of ferroelectric-polymer composite*
L. Jylha, A. Sihvola
Abstract: A novel method to calculate the electric tunability of a composite consisting of tunable electroceramic inclusions in nontunable dielectric background is introduced. Such composites can be used to create tunable materials with reduced permittivity or to modify mechanical properties of the tunable material.

14:30 *Voltage-controlled composite metamaterials via the loaded transmission line approach*
G. Houzet, A. Marteau, G. Velu, E. Lheurette, L. Burgnies, J.C. Carru, D. Lippens
Abstract: The tuning of composite left-right handed transmission line is demonstrated in a balance mode at Ku and K/Ka bands. To this aim, Coplanar Waveguides loaded by series interdigitated capacitances and shunt stub-like inductances were patterned and metal evaporated onto a Barium Strontium Titanate ($Ba_{0.5}Sr_{0.5}TiO_3$) 0.3-µm thick film deposited by a sol-gel technique on a Sapphire substrate.

14:45 *Design and measurements of active RF metamaterials*
S.A. Cummer, B.-I. Popa, T.H. Hand
Abstract: We report the theoretical design and experimental validation of a general approach to create active metamaterial particles. This active particle uses a field sensing element to generate a voltage proportional to some electromagnetic field component. This element could be a loop for a magnetic particle or a short wire for an electric particle. The sensed voltage is amplified

by an amplifier, which in turn drives a second element that produces an electric or magnetic dipole moment proportional to the sensed field. This architecture could also be used to create active cross-polarizing elements by rotating the driven loop relative to the sensing loop, and also magnetoelectric elements by mixing electric sensing loops and magnetic driven loops or vice versa.

15:00 *Tunable metamaterial transmission lines based on complementary split rings resonators (CSRRs)*

A. Velez, J. Bonache, F. Martin

Abstract: In this work, tuning in metamaterial transmission lines based on complementary split rings resonators (CSRRs) is considered for the first time. The unit cell of these artificial lines consists on a microstrip configuration with CSRRs etched in the ground plane and a variable capacitance series connected to the line, above the positions of the CSRRs. By varying the capacitance, the transmission characteristics of the line are tailored. Specifically, the typical transmission zero present below the left handed band, as well as the limits of this band, are modified. It is even possible to balance the line by properly tuning the structure. These results are interpreted to the light of the equivalent circuit model of the unit cell. Experimental data has been obtained by using different series capacitances, and also by using a variable capacitance (varactor diode) controlled by a polarization voltage. This work opens the door to the design of reconfigurable microwave components based on CSSR-loaded lines.

15:15 *Nanoparticles in microcavities as all-optical tunable systems*

R. Sainidou, F.J.G. de Abajo

Abstract: An all-optical tunable system is proposed consisting of metallic nanoparticles within open metallic cavities. Resonant nanoparticle-cavity interaction is observed through both electromagnetic forces, intended to move the nanoparticle, and light absorption of the combined system.

15:30 *Tunable split ring resonators at microwave frequencies*

K. Aydin, E. Ozbay

Abstract: We discuss the possibility of achieving tunable split ring resonators at microwave frequencies. One method is to use varying capacitance values to tune the magnetic resonance frequency. As another method ferroelectric thin films can be employed to obtain active response from the split ring resonators.

15:45 *Analytic theory for active circuit metamaterials and applications in evanescent-wave amplification*

D. Huang, R. Liu, N.N. Wan, T.J. Cui, D.R. Smith

Abstract: We present a transmission-line model for active/lossy metamaterials by inserting negative/positive resistance. Analytic formulations have been derived for the effective permittivity and permeability of active metamaterials. As a specific application, a bilayer of active electric-magnetic plasmas is used to amplify evanescent waves. Analytic derivations show that negative and positive resistances must appear simultaneously to enhance the evanescent-wave amplification, which results in a transmission coefficient larger than one.

13:30 – 16:00 Session 4 – Room VN2

Fabrication and processing of metamaterials and artificial electromagnetic surfaces

Chairs: R. Ziolkowski

13:30 *Monolithic fabrication of multi-material artificial electromagnetic surfaces and devices (invited)*

K.W. Whites, T. Amert, K. Kirschenmann, S.M. Woessner

Abstract: The purpose of this paper is to demonstrate the capabilities of direct-write technology for the fabrication of certain types of multilayer, multi-material electromagnetic surfaces and devices. This work builds on new capabilities in direct-write fabrication we have recently developed that allow low-loss dielectric materials and high conductivity metals to be deposited onto very low temperature substrates.

14:00 *Novel nanolithography for large area photonic gratings and metamaterials (invited)*

Y. Chen, B.-R. Lu, S.-Q. Xie, Y. Sun, X.-P. Qu, R. Liu

Abstract: This paper demonstrates our recent progress in the technical development of fast speed EBL for the fabrication of large area NIL templates using highly sensitive e-beam resists, chemically amplified resists (CARs). Particularly, the NEB-22 resist supplied by Sumitomo Chemical plc with high resolution and high resistance to plasma is used for the EBL process for large area patterning. Based on this success, nanoimprint/hot embossing has been carried out to fabricate dielectric and metallic metamaterials in special plastics such as SU-8. Self-aligned techniques for multiple layer of planar chiral structures by EBL as well as NIL technique are discussed.

14:30 *Stacking of split-ring resonator metamaterials in the optical regime*

N. Liu, H. Guo, L. Fu, H. Schweizer, H. Giessen

Abstract: We develop a practical approach to stacking two- dimensional (2D) metamaterial structures at optical frequencies. Split -ring resonators (SRRs), which are the promising element for constructing three- dimensio nal (3D) negative index materials (NIMs), are selected as the building block for the stacking demonstration. Experimental design and procedures of the stacking process are presented. In particular, the crucial steps in the stacking process, such as the planarization of the spacer and the alignment of the different layers are described in detail. The optical properties of single- and three-layer SRR structures are compared and investigated experimentally and numerically.

14:45 *Metamaterials and photonic crystals – potential applications for self-organized eutectic micro- and nanostructures*

D.A. Pawlak, K. Kolodziejak, S. Turczynski, K. Rozniatowski, J. Kisielewski, B. Andrzejewski, T. Klimczuk

Abstract: In recent years, two different types of materials are being developed in the area of photonics: photonic bandgap materials (photonic crystals) and metamaterials. In photonic crystals, the wavelength of the light has to be comparable to the periodicity of the structure, in order to exhibit a photonic bandgap effect. In metamaterials, on the other hand, the wavelength should be much bigger than the structuring of the matter, since only the effective properties such as effective permittivity and permeability are important.

15:00 *Strong broadband near-IR resonances observed from nano-lithographically fabricated metallic metamaterials*

M.C. Martin, Z. Hao, B. Harteneck, A. Liddle, S. Cabrini, W. Padilla

Abstract: We report in this talk strong broadband absorption resonances mid- and near-infrared frequencies from our nanometer size metamaterial resonators. We report systematic studies of these resonances with different dimensions of the resonators and their spacing, combined with theoretical simulations. We have used FTIR microscopy, employing a synchrotron source when needed for high brightness. We will present our experimentally measured reflection at different incidence angles, and transmission of those resonators with different feature sizes and different lattice spacings which control the coupling between neighbouring units. We found distinctively strong and broadband resonance in the spectrum of the resonators. We will discuss results from various split ring type resonators as well as plasmonic responses from ring resonators. We will discuss how

our results can be used to introduce strong electric and magnetic responses and could provide a route to broadband negative refraction.

15:15 *Fabrication of metamaterials on the basis of precise micro- and nanoshells*
E.V. Naumova, V.Ya. Prinz, V.A. Seleznev, S.V. Golod, R.A. Soots, V.V. Kubarev, B.A. Knyazev, G.N. Kulipanov, N.A. Vinokurov
Abstract: ecently developed method of precise 3D nanostructuring was applied to fabrication of metamaterials. 2D arrays of hybrid micro- and nanoshells were fabricated. 2D array of metal-semiconductor microhelices demonstrated high optical activity in THz range. Potential applications of created structures and advantages of used approach to fabrication of metamaterials are discussed.

15:30 *Properties of multilayer plasmonic metamaterials fabricated by ion-beam mixing and conformal deposition*
V. Ovchinnikov
Abstract: A novel nanofabrication procedure for preparation of multilayer plasmonic metamaterials by using an ion beam mixing (IBM) and conformal deposition of dielectric was developed. Interactions between Ag nanoparticles in adjacent layers were characterized by studying the spectral position of the extinction bands corresponding to surface plasmon resonance.

15:45 *Ultrafast laser micromachining of silicon surfaces*
D.P. Korfiatis, K.-A. Th. Thoma, J.C. Vardaxoglou
Abstract: The use of femtosecond pulsed lasers in hole drilling offers the advantage of high accuracy together with minimal heat affected zone during the preceding ablation. In this work parameters determining the accuracy of femtosecond laser hole drilling on silicon surface are defined and calculated as functions of incident fluence and pulse duration.

16:00 Coffee

16:30 – 18:30 Session 5 – Room N13
Microwave devices
Chairs: F. Martin, D. Werner

16:30 *Design of miniature microwave devices based on a combination of natural right handed and metamaterial left handed transmission lines (invited)*

I. Vendik, O. Vendik, D. Kholodnyak, P. Kapitanova

Abstract: The general approach to a design of miniature microwave devices based on a combination of sections of transmission lines with positive and negative dispersion is considered. Such lines, which are also known as right- and left-handed trans-mission lines, exhibit different dispersion characteristics. Using combination of these lines gives additional degrees of free-dom for improving microwave device performance. At the same time, there is a possibility to drastically decrease dimensions of the devices. The following passive devices are under consideration: broadband digital phase shifters, microwave direc-tional couplers, resonators and filters with suppressed spurious responses.

17:00 *Design of directional couplers using full-integrated left-handed transmission lines*

D. Kholodnyak, P. Kapitanova, I. Vendik

Abstract: Using a combination of right-handed and left-handed transmission line sections to design of directional couplers with improved performance is considered. Design of a dual-band 3-dB directional coupler and a miniaturized rat-race ring, which were implemented as fully-integrated multilayer structures on low-temperature cofired ceramic boards without using any surface-mount devices, is presented.

17:15 *Novel left-handed unit cells for filter applications*

B. Jokanovic, L. Trifunovic, V. Crnojevic-Bengin

Abstract: In this paper, novel super-compact left-handed unit cells based on grounded spirals are proposed. The cells consist of two and four rectangular grounded spirals, which are both mutually coupled and end-coupled to the microstrip line. Simulated and measured results show lower resonant frequencies and improved values of the Q-factor in comparison with the recently proposed unit cell called ‘ForeS’. The overall dimensions of novel unit cells are: (λ_g/16 x λ_g /32), (λ_g /16 x λ_g /15) and (λ_g /19 x λ_g /16) which is considerable size reduction in comparison to ForeS (λ_g /13 by λ_g /13).

17:30 *Guided wave properties in Lorentz type resonant layer structures*

A.J. Viitanen, I.S. Nefedov

Abstract: Guided waves in layers of Lorentz type resonant materials are considered. Eigenvalue equations and dispersion curves are evaluated for one and two slab systems. The results show that we can obtain quite flat dispersion curves applicable for perfect lens imaging choosing the material parameters properly. Also the backward wave propagation in such

structures is possible with proper permittivity values and geometry.

17:45 *Periodically LC loaded lines for RFID backscatter applications*
M. Schuessler, C. Damm, R. Jakoby
Abstract: The operation principle of a passive RFID tag on the basis of periodically LC loaded delay lines is discussed. It turns out, that especially the dispersion properties of these lines significantly influence the performance limits. An expression relat-ing the maximal number of usable bits for the tag impulse response to system parameters like bandwidth, center frequency etc. is given. A proof of the concept is realized with a 40 cell three bit backscatter tag.

18:00 *Coplanar waveguide incorporating complementary split ring resonators*
I.A. Ibraheem, M. Koch
Abstract: This paper proposes a new coplanar waveguide stopband metasurface based on the duality principle. The resulting layout is a compact structure with complementary split ring resonators, which exhibits a high rejection stopband. The complementary rings provide a frequency band with an effective negative dielectric permittivity. Moreover, slots nearby the rings are introduced to modify the rejected bandwidth.

18:15 *Archimedean spiral resonators for super compact metamaterial filter design*
O. Isik, K.P. Esselle, Y. Ge
Abstract: Recently proposed Archimedean spiral resonators are further studied. Electric and magnetic field excitation conditions are investigated. A monofilar spiral with a super compact size of 0.05 lg is presented. The operating principles of connected-arm and disconnected-arm multifilar spirals are explained by analyzing fictitious magnetic surface current distributions.

16:30 – 18:30 Session 6 – Room N16
Optical properties of metamaterials
Chairs: J. Garcia de Abajo, S. Maier

16:30 *Mapping electron excitations in the visible-UV range using sub-nm resolved STEM-EELS spectrum imaging (invited)*
M. Kociak, J. Nelayah, O. Stephan, M. Couillard, R.A. de la Concha, M. Tence, D. Taverna, L. Henrard, F.J.G. de Abajo, C. Colliex

Abstract: For decades, the electron energy loss spectroscopy (EELS) in a transmission electron microscope has been used to explore electronic and electromagnetic excitations of solids. In particular, the low-loss energy domain (from few eV to 50 eV) has been exploited for studying dielectric properties of materials. However, so far, only excitations in the UV range and above were investigated due to severe limitations in the detection of lower energy spectral features hidden by the strong contribution of the transmitted beam to the measured spectrum.

17:00 *Reflectance measurements of self-organized microstructure of $Tb_3Sc_2Al_3O_{12}$-$TbScO_3$ eutectic (invited)*

N.P. Johnson, B. Lahiri, D.A. Pawlak, S. Turczynski, K. Kolodziejak

Abstract: The$Tb_3Sc_2Al_3O_{12}$-$TbScO_3$ eutectic grows with a rod-like microstructure, with $TbScO_3$ perovskite forming the microrods embedded in the matrix of $Tb_3Sc_2Al_3O_{12}$. The growth of the structures has been realized by the micro-pulling method. The eutectic rods were grown with several different pulling rates of: 0.15, 0.3, 0.45, 1 and 4 mm/min. The pulling rate gives control over the dimensions of the microstructure. At higher pulling rates smaller sized microstructures are obtained and at smaller pulling rates the microstructures exhibit larger distances between the microrods. The rod-like eutectic microstructure is a possible candidate for self organised two-dimensional photonic crystals. In this work the reflectance measurements of the eutectic grown with different pulling rates will be presented in comparison of the reflectance of the pure single crystalline phases.

17:30 *Experimental observation of negative magnetic response in the visible spectral range*

W. Cai, U.K. Chettiar, H.-K. Yuan, V.P. Drachev, A.V. Kildishev, V.M. Shalaev, A. Boltasseva

Abstract: A negative magnetic response in a system of coupled thin silver strips is experimentally demonstrated in the visible spectral range. For two different samples, the real part of permeability of μ_r=1 at a wavelength of 770 and μ_r=1.7 at 725 nm is obtained, and the effect of the silver surface roughness on negative permeability is evaluated. Moreover, coupled strips with varying dimensions were shown to exhibit optical magnetic responses across the whole visible spectrum, from red to blue, implying that such structures can be used as building blocks for producing controllable optical magnetism for various applications.

17:45 *Experimental investigation of magnetic and electric resonances of single nano structures in the optical domain*
P. Banzer, S. Quabis, G. Leuchs, U. Peschel
Abstract: We focus on the investigation of the scattering properties of individual nano structures. By using highly focused beams with tailored polarization structure we selectively test the dielectric and magnetic response of single metallic spheres and other nano structures.

18:00 *Anderson localization in the presence of metamaterials*
A.A. Asatryan, L.C. Botten, M.A. Byrne, V.D. Freilikher, S.A. Gredeskul, R.C. McPhedran, I.V. Shadrivov, Y.S. Kivshar
Abstract: The localization properties of one-dimensional stacks composed of alternating layers of normal and metamaterials have been studied both numerically and analytically. It is shown that the localization length in mixed stacks in the long wavelength limit is much longer than that in homogeneous samples containing layers of only one type. The absence of transmission resonances in mixed stacks for long wavelengths is also established. We attribute these results to the inability of waves to accumulate phase in the mixed structures.

18:15 *Circuit model for optical metamaterials: studies at the border between electronics and optics*
T.P. Meyrath, T. Zentgraf, H. Giessen
Abstract: In this contribution, we explore the connection between optics and high frequency electronics by considering equivalent circuit calculations for split-ring resonators in the optical frequency range. Our calculations are not quasi-static and include interactions between sites. For a variety of samples, we calculate the resonance positions and quality factors which agree well with simulations and experiments.

16:30 – 18:30 Session 7 – Room N17
Plasmonics (I)
Chairs: V. Shalaev, M. Brongersma

16:30 *Metamaterials for information systems (invited)*
Y. Fainman
Abstract: Optical technology plays an increasingly important role in numerous information system applications, including optical communications, storage, signal processing, biology, medicine, and sensing. However, with these rapid technological advances,

there is a growing need in establishing novel integration methods to enable reliable, scalable, power efficient and cost effective integration methods for miniaturization of future information systems. These include the development of passive and active optical components that can be integrated into functional optical circuits and systems, including filters, electrically or optically controlled switching fabrics, optical sources, detectors, amplifiers, etc.

17:00 *Towards sub-wavelength resolution using transparent metal-dielectric stacks (invited)*
H. Jiang, J. Zhang, B. Gralak, M. Cathelinaud, G. Tayeb, M. Lequime, S. Enoch
Abstract: We report a theoretical and experimental study of negative refraction and sub-wavelength resolution using metal-dielectric stacks. A theoretical analysis of the behavior of optical waves in the structure is presented and used to ground its optimization. Experimental results in relation with a demonstration of negative refraction are reported and discussed.

17:30 *Tunable terahertz absorption bands in a scaled plasmonic crystal*
T.V. Teperik, F.J.G. de Abajo, V.V. Popov, M.S. Shur
Abstract: We show the existence of total-absorption bands in scaled plasmonic crystals composed of periodic arrangements of spherically-shaped two-dimensional free-electron-like open shells at terahetz frequencies. These absorption bands appear as a result of the coupling between plasmon modes of different shells in the crystal and can be tuned by varying the structure parameters throughout the entire terahetz frequency domain.

17:45 *Plasmons in coupled voids*
I. Romero, T. Teperik, F.J.G. de Abajo
Abstract: Coupled voids buried in metal are shown to exhibit colourful optical behaviour, that will depend strongly on the degree of overlap between voids, while void arrays display transmission bands of buried plasmons for signal transmission and processing.

16:30 – 18:30 Session 8 – Room VN2
EBG and Photonic crystals (I)
Chairs: F. Chiadini, C. Craeye

16:30 *Peculiar feature of photonic crystals containing anisotropic and gyrotropic ingredients (invited)*

A.P. Vinogradov, M. A. Merzlikin, A. V. Dorofeenko, M. Inoue, A. A. Lisyansky

Abstract: In this presentation we consider the consequences of application of anisotropic and gyrotropic materials in photonic crystal design. The consideration is focused on the distinctive features of 1D PCs because any devices made on the base of 1D PC are more robust for losses than those employing 2D or 3D PC. To make better off the properties of comparative simple 1D geometry we suggest the usage of anisotropic and gyrotropic materials. Firstly, such PCs exhibit new physical phenomena, namely, formation of the Yeh band gaps, magnetooptical and birefringence effects. Secondly, since the anisotropy and gyrotropy are easy caused by the external electric and magnetic fields the new properties of the PCs are tunable. The functioning of switchable filter, magnetic super-lens and other devices are considered.

17:00 *FCC magnetic photonic crystals: symmetry analysis*

V. Dmitriev

Abstract: We discuss in this paper some general properties of magnetic photonic crystals with face-centered cubic (FCC) lattice. Using the theory of magnetic groups, we consider the problem of changing symmetry of photonic crystals with face-centered cubic lattice by a dc magnetic field, classification of eigenmodes in magnetic lattices and qualitative characteristics of their eigenwaves.

17:15 *Threadlike small filling factor 2D photonic structures*

M.Yu. Barabanenkov, Yu.N. Barabanenkov

Abstract: A theoretical study is presented of transmission spectra of 2D photonic crystals composed of fine dielectric thread-like rods. Opaque bands in the transmission spectra of PC are not destroyed even when filling fraction of volume occupied by threads as small as under half a percent, i.e if photonic structures are made practically from “nothing”.

17:30 *Novel properties of six-fold symmetric photonic quasi-crystal fibers*

C.-S. Kee, S. Kim, J. Lee, J.-E. Kim, H.Y. Park

Abstract: We propose new optical fibers having six-fold symmetric quasiperiodic arrays of air holes in cladding, six-fold symmetric photonic quasicrystal fibers. We found that the photonic quasicrystal fiber can exhibit almost zero ultra-flattened chromatic dispersion, 0 ± 0.05 ps nm^{-1} km^{-1}, in the range of wavelength from 1490 to 1680 nm.

17:45 *Optical properties of zero-average refractive index photonic crystal heterostructure*

V. Mocella, S. Cabrini, D. Olynick, B. Harteneck, S. Dhuey, P. Dardano, L. Moretti, I. Rendina

Abstract: In this work we present the project design together with the fabrication of a photonic device based on the negative refraction properties of Photonic Crystals (PhCs) in combination with positive index region. This zero average refractive index metamaterial has unconventional properties potentially extremely attractive for integrated photonic applications.

18:00 *Secondary emission of globular photonic crystals*

V.S. Gorelik

Abstract: The results of secondary emission observation in globular photonic crystals as a result of ultraviolet and visible light illumination are presented. Spectra of such type emission corresponded to forbidden gap of photonic crystal spectral position and changed its shape with the changing of exciting light wave length.

18:15 *Photonic crystals and hetero-crystals of mixed dimensionality from Langmuir-Blodgett colloidal multilayers*

S.G. Romanov, M. Bardosova, I.M. Povey, M. Pemble, C.M. Sotomayor Torres

Abstract: Langmuir-Blodgett technique has been used to prepare 3-dimensional colloidal crystals, topology of which differs from face-centered cubic symmetry of conventional opals. Comparative study of optical properties Langmuir-Blodgett crystals and opals has been performed. As a result, the realization of photonic bandgap structure of reduced (2+1)-dimensionality has been demonstrated. Non-reciprocity of light propagation in heterogeneous photonic crystals with interfaces between frequency-matched photonic bandgaps of different dimensionality has been studied.

Tuesday 23 October

Buildings of the Faculty of Engineering
via della Vasca Navale, 109

08:30 – 10:30 Session 9 – Room N13
Quasicrystals (I) (special session organized by S. Enoch, V. Galdi, and F. Capolino)
Chairs: S. Enoch, V. Galdi, F. Capolino

08:30 *A parametric study of negative refraction and superlensing in 12-fold symmetric photonic quasicrystals (invited)*
E. Di Gennaro, C. Miletto, S. Savo, A. Andreone, D. Morello, G. Castaldi, V. Galdi, V. Pierro
Abstract: We present a study of the refraction and focusing properties of a two-dimensional 12-fold symmetric square-triangle photonic quasicrystal generated by a recursive algorithm. The work is carried out via both numerical simulations and microwave measurements on alumina rods inserted in a parallel plate waveguide. Our study reveals that the expected higher degree of isotropy, by comparison with periodic structures, seems not verified, since negative refraction and superlensing phenomena turn out to be critically associated to local symmetry centers that are present in the quasicrystal.

09:00 *Quasi-crystal-like electromagnetic structures (invited)*
C.T. Chan
Abstract: We show that electromagnetic quasi-crystalline structures have some interesting properties. We will discuss the photonic band gap properties of photonic quasicrystals and the unusual properties of planar metamaterials employing quasicrystalline tiling. We will also show that electromagnetic quasicrystalline structures can be made in a rather straightforward way by holographic lithography and if we use light to organize matter, quasicrystals are not more difficult to make than crystalline structures.

09:30 *Properties of octagonal quasi-crystals and their photonic applications (invited)*
D.N. Chigrin, A.V. Lavrinenko
Abstract: We present a numerical study of optical properties of a quasi-crystal made from dielectric rods arranged in a two-dimensional octagonal lattice. Positions of band gaps are obtained by applying the plane wave expansion and the finite-difference time-

domain methods. We analyse resonances and light confinement in the bulk quasicrystals and in quasi-crystals with point-like or line-like defects and make comparison with the same properties of photonic crystals. The pros and cons of quasi-crystals applications in photonics are discussed.

10:00 *Analysis of modal propagation in slabs of photonic quasicrystals with Penrose-type lattice*
A. Della Villa, F. Capolino, V. Galdi, S. Enoch, V. Pierro, G. Tayeb
Abstract: Guided modes are investigated in defect-free photonic quasicrystal (PQC) slabs via a Fourier transform analysis of the electric field at the air-slab interface. Since a unit-cell cannot be defined in PQCs, the presence of modes is inferred by observing peaks of the Fourier transform of the field along an observation scan.

08:30 – 10:30 Session 10 – Room N16
Electromagnetic theory
Chairs: A. Sihvola, F. Olyslager

08:30 *100 years of backward wave (invited)*
L. Solymar
Abstract: The emergence of the concept of backward waves as well as their subsequent development in electronic devices, antennas and metamaterials is reviewed

09:00 *Light pressure in negative refraction materials (invited)*
V.G. Veselago
Abstract: Not available.

09:30 *Class of self-dual media (invited)*
I.V. Lindell
Abstract: Applying four-dimensional differential-form formalism, a class of electromagnetic media labeled as that of self-dual media is defined as consisting of media which are invariant in some duality transformation. Another way to define the medium class is to require that the medium dyadic defining the relation between the two electromagnetic two-forms satisfy an algebraic equation of the second order. Corresponding relations for the three-dimensional (’Gibbsian) medium dyadics are derived. Properties of fields in such a medium are analyzed in the full paper.

10:00 *Covariance, negative refraction and dispersion*
M.W. McCall

Abstract: We show that material dispersion, known to be a pre-requisite for negative refraction, actually enters explicitly into the criterion for its occurrence. This results from consideration of a covariant formulation of the criterion for negative refraction. Other consequences include an appraisal of the occurrence of negative refraction induced by changing fields and constitutive parameters to a frame in which the medium is in relative motion, and connections to light propagation in generalized metric spaces.

10:15 *An equivalence principle for electrodynamics using geometric algebra*
M.A. Ribeiro, C.R. Paiva
Abstract: Using the universal language of geometric algebra an equivalence principle for electromagnetism is here presented. Only recently this principle, already known in the literature of general relativity, has been applied to metamaterials and electrical engineering, namely in invisibility problems and through tensor methods. Several problems can be easily handled with this equivalence principle using geometric algebra. One should stress that, in contrast to tensors and differential forms, geometric algebra is a natural extension of the familiar vector analy-sis originally developed by Gibbs from Hamilton's quaternions.

08:30 – 10:30 Session 11 – Room N17
Metamaterials and antennas (I)
Chairs: F. Bilotti, I. Huynen

08:30 *Reconfigurable metamaterial peano antenna (invited)*
D.H. Lee, A. Chauraya, J.A Flint, W.S. Park, J.C. Vardaxoglou
Abstract: In this paper, we propose a simple compact reconfigurable metamaterial (MM) antenna. This unique smart antenna has been designed, fabricated and measured for low frequency communications systems.

09:00 *Modeling and measurements of a planar meta-surface based on grids of short dipoles and wires*
E. Saenz, R. Gonzalo, I. Ederra, P. Ikonen, S. Tretyakov, P. de Maagt
Abstract: In this paper the transmission and reflection properties of meta-surface based on parallel short dipoles and continuous wires is presented. An electrodynamic model based on the local field approach has been developed and validated by comparison with full wave simulations. In order to corroborate both numerical results, measurements of the configuration

under normal incident plane wave excitation are presented.

09:15 *Active variable phase metamaterial cavity for directive antenna*
A. Ourir, S.N. Burokur, A. de Lustrac
Abstract: In this paper, we present the modeling and the characterization of an optimized resonant cavity for an active reconfigurable directive antenna near 8 GHz using a variable phase metamaterial. The cavity is composed of a Perfect Electrical Conductor (PEC) surface and an active Partially Reflective Surface (PRS). The considered PRS is composed of a electronically phase varying metamaterial by the insertion of an active electronic compo-nents on a composite metamaterial based surface. An adjustable resonance frequency between 7.9 and 8.2 GHz is obtained and a drastic enhancement in the directivity of the antenna is also observed for a cavity thickness as small as λ/75.

09:30 *Dual band antennas on an EBG substrate*
S. Zhu, R. Langley
Abstract: A dual band coplanar patch antenna integrated with an electromagnetic band gap substrate is reported. The antenna structure is made from common clothing fabrics and operates at the 2.45 GHz and 5.1-5.8 GHz wireless bands. The band gap array consists of just 3x3 elements but reduces radiation into the body by over 10 dB and improves the antenna gain by 3 dB.

09:45 *Some considerations on radiation properties of antennas embedded into low-permittivity metamaterial*
D. Bonefacic, S. Hrabar, D. Kvakan
Abstract: Gain increase and radiation properties of a quarter wavelength monopole, an open rectangular waveguide and a rectangular horn antenna embedded into a low-permittivity wire-based metamaterial are studied. Measurement results confirm that metamaterial used for embedding of the antennas contributes to the increase of the antenna gain. Lower the antenna gain, the gain improvement achieved by the metamaterial slab is larger. The influence of dimensions and thickness of the metamaterial slab on the gain improvement and radiation patterns is investigated. The results show that for thin slabs the gain improvement weakly depends on the slab cross section area, while for thick slabs larger cross section allows significantly better focusing of the radiated waves.

10:00 *Ultra wide band pass filter with frequency notch characteristic*
A. Ali, Z. Hu

Abstract: An ultra-wide band (UWB) filter with frequency band notch is presented. Complementary split ring resonators (CSRR) are utilised for frequency band notch characteristic and are integrated into the design to reject the HiPerLAN frequency range. A novel method using open circuit stubs to improve the matching between the CSRR and microstrip line is presented.

10:15 *Numerical modelling of non-homogeneous dielectrics with very different permittivity of components*
R. Cret, E. Simion, M. Plesa, D.D. Micu
Abstract: For mixtures with very different permittivities of the components, there are no known analytic formulas for computing the dielectric constant, leading to results well verified by measurements. This paper emphasizes the results of numerical modelling of such statistical and matrix mixtures. The computation of the average permittivity of the mixture is done using FEM based software (Maxwell 2,3D by ANSOFT). Our study presents the influence of the spatial distribution, shape and concentration of inclusions in the mixture. The numerical results are compared with those obtained with analytic formulas by various researchers.

08:30 – 10:30 Session 12 – Room VN2
Plasmonics (II)
Chairs: N. Engheta, V. Podolskiy

08:30 *Plasmonics – the missing link between nanoelectronics and microphotonics (invited)*
M.L. Brongersma, E. Bernard, A. Chandran, P. van Dorpe, Y. Chul, Jun, J. Liu, R. Pala, J.A. Schuller, J. White, T. Taubner, R. Zia
Abstract: Plasmonics is an exciting new device technology that has recently emerged. It exploits the unique optical properties of metallic nanostructures to enable routing and manipulation of light at the nanoscale. A tremendous synergy can be attained by integrating plasmonic, electronic, and conventional dielectric photonic devices on the same chip and taking advantage of the strengths of each technology. We will provide a perspective on future directions and possibilities for integrating plasmonic devices on a chip.

09:00 *Active plasmonic structures and metamaterials (invited)*
H.A. Atwater, H.J. Lezec, J.A. Dionne, C.E. Ross, L.A. Sweatlock, D. Pacifici, K. Diest, M. Dicken, V. Ferry
Abstract: We describe recent advances in plasmon dispersion control and actively modulated devices

enabled by new plasmonic components formed from metal-insulator-metal plasmon waveguides that facilitate dispersion control to enable very high positive as well as negative refractive index in the visible and near infrared electro-optic modulation of metal-insulator-metal resonator transmission.

09:30 *Three-dimensional Hilbert structures as compact resonant plasmonic elements in laterally confined transmission lines at micro-wave frequencies (invited)*
J. McVay, N. Engheta, A. Hoorfar
Abstract: In this paper we discuss the possible applications for the utilization of the mathematical concept of space-filling curves, such as the 3-dimensional Hilbert curve, in the design of novel, electrically small guiding structures.

10:00 *Numerical simulation of electron energy loss in complex metallic nanoparticles*
V. Myroshnychenko, F.J.G. de Abajo
Abstract: The energy loss suffered by fast electrons passing near systems of metallic nanoparticles is calculated using the boundary element method based upon rigorous solution of Maxwell's equations. Plasmon modes in metallic nanoparticles, including particle dimers are observed. These modes are characterized by spectrally selective absorption and electromagnetic field enhancements. It is shown that fast electrons can efficiently excite dark modes that are not visible by external light illumination.

10:15 *Optical properties of bowtie slot antenna metamaterials*
H. Guo, N. Liu, T. Zentgraf, T. Meyrath, L. Fu, H. Schweizer, H. Giessen
Abstract: In this contribution, we present work on the optical properties of bowtie slot antenna arrays in thin gold films. These structures exhibit transmission resonances at a wavelength much larger than the period of the arrays. Numerical simulations based on a Finite Integration Time Domain (FITD) algorithm reveal that enhanced light confinement can be achieved when the polarization of the light is perpendicular to the gap. The influences of structural periods on the optical properties of the bowtie slot antenna arrays will be discussed.

10:30 Coffee

11:00 – 12:30 Session 13 – Room N13
Quasicrystals (II) (special session organized by S. Enoch, V. Galdi, and F. Capolino)
Chairs: S. Enoch, V. Galdi, F. Capolino

11:00 *Photonic quasicrystal distributed feedback lasers: lasing action due to quasiperiodicity (invited)*
M. Notomi, H. Suzuki, T. Tamamura, K. Edagawa
Abstract: We have fabricated photonic quasicrystal lasers with Penrose lattice that does not posses translational symmetry but has long-range order, and observed coherent lasing action due to the optical feedback from quasiperiodicity, exhibiting a variety of 10-fold-symmetric lasing spot patterns. The lattice constant dependence of lasing frequencies and spot patterns show complicated features very different from photonic crystal/random lasers, and we have quantitatively explained them by considering their reciprocal lattice. Unique diversity of their reciprocal lattice opens up new possibilities for the form of lasers.

11:30 *Negative refraction and focusing of wave through high-symmetry quasicrystals (invited)*
X. Zhang, Z. Feng, Y.-Q. Wang, Z. Li, B. Cheng, D.-Z. Zhang
Abstract: We report some theoretical and experimental investigations on the electromagnetic wave and the acoustic wave transport in high symmetry quasicrystals (QCs). It is shown that the "local" negative refraction and the universal non-near-field focus can be realized by 8-fold, 10-fold and 12-fold high-symmetry QCs.

12:00 *Far-field subwavelength focusing and extraordinary transmission of light by a quasi-periodic array of nanoholes (invited)*
F.M. Huang, A. Schwaneke, P. Papasimakis, Y. Chen, F.J.G. de Abajo, N.I. Zheludev
Abstract: We report that the Talbot effect on a quasi-crystal arrays of nano-holes may be used to achieve subwavelength localizations of optical fields and simultaneously study extraordinary transmission of light through the quasi-crystal structure.

11:00 – 12:30 Session 14 – Room N16
Chirality and handedness
Chairs: I. Lindell, A. Hoorfar

11:00 *Possibilities for chiral nihility to achieve negative-index materials (invited)*
C.W. Qiu, S. Zouhdi, S. Tretyakov, L.-W. Li
Abstract: Chiral nihility, a special case of chiral composites, is studied. Nihility physical constraints and associated conditions are discussed in different formalisms not only for conventional chiral media but

also for non reciprocal chiral media and gyrotropic chiral media.

11:30 *Balanced right/left-handed mixtures of quasi-planar chiral inclusions*
R. Marques, F. Mesa, L. Jelinek, J.D. Baena
Abstract: Some novel quasi-planar chiral inclusions, feasible from standard photo-etching techniques, are proposed. It is shown that such inclusions can be designed in order to present balanced electric, magnetic and magneto-electric polarizabilities. Using these inclusions, random and periodic bi-isotropic artificial metamaterials exhibiting a balanced positive/negative refractive index can be build up. These metamaterials would exhibit reasonable bandwidths and excellent matching to free space.

11:45 *Chiral metamaterial with unit negative refraction index*
I.V. Semchenko, S.A. Khakhomov, S.A. Tretyakov
Abstract: In this presentation we introduce helical inclusions of a certain shape (called the “optimal shape”), such that the electric, magnetic, and magneto-electric polarizabilities are equal, and discuss unusual refractive and absorptive properties of artificial chiral materials based on such inclusions. We propose a new method of analytical calculation of resonant susceptibility of non canonical, but real spirals. This method takes into account spiral trajectories and effective concentration of conduction electrons.

12:00 *Strong optical activity in metal screw arrays*
K. Takano, T. Fujii, T. Nagashima, M. Tani, M. Hangyo, H. Miyazaki
Abstract: We have measured the polarization characteristics of terahertz waves transmitted through the metal screw hole arrays and metal male screw arrays. It is shown that the origin of the optical activity in these structures is possibly associated with the screw pitch.

12:15 *Bloch waves with negative phase velocity in multilayered structures containing uniaxial chiral media*
J.R. Canto, C.R. Paiva, A.M. Barbosa
Abstract: A matrix formulation that describes reflection and transmission of plane waves in a multilayered structure containing uniaxial chiral media is derived. Analytical expressions for the reflectance and transmittance of the structure are then obtained. Furthermore, the periodic condition that allows a Bloch wave analysis is also found. For a multilayered structure containing uniaxial chiral media numerical

results were obtained. A single resonance dispersion model, which takes losses into account, is used to describe the properties of the uniaxial chiral layers. By including losses it is possible to select the proper Bloch wave solutions for the structure and to obtain a more realistic form for the forbidden bands. It is shown that forward propagating Bloch waves with negative phase velocity do exist in this structure, regardless of the sign of the constitutive parameters of the uniaxial chiral layers.

11:00 – 12:30 Session 15 – Room N17
Metamaterials and antennas (II)
Chairs: Y. Vardaxoglou, D. Jackson

11:00 *Modelling and design of a sub-wavelength metamaterial resonant cavity antennas*
J.R. Kelly, T. Kokkinos, A.P. Feresidis
Abstract: This paper presents techniques for the full-wave modelling and design of sub-wavelength highly-directive resonant cavity antennas. The antenna is comprised from a square aperture PRS located above an AMC ground plane. The latter is formed from an array of square patches. The objective of the paper is to present a range of different techniques for modelling this type of structure and report recent antenna designs at wireless LAN frequencies.

11:15 *Optimisation of EBG Antennas with a Combined PRS*
T.-H. Vu, K. Mahdjoubi, A.-C. Tarot, S. Collardey
Abstract: A new structure based on a combination of two PRS (Partially Reflective Surface) is introduced to improve the bandwidth of the EBG antennas. An optimisation procedure is developed to design the suitable PRS, allowing to enlarge the bandwidth of these antennas.

11:30 *Metamaterial-inspired efficient electrically-small antennas: designs and experiments of 2D and 3D electric and magnetic versions*
A. Erentok, R.W. Ziolkowski
Abstract: The details of the design, fabrication, and testing of several 2D and 3D metamaterial-inspired electric- and magnetic-based electrically-small antennas are presented. It is demonstrated that these antenna systems are naturally matched to a source and have very high overall efficiencies.

11:45 *Millimeter wave dual-band microstrip antennas with metamaterial substrates using the LTCC process*
I.-K. Kim, V.V. Varadan
Abstract: Millimeter wave dual-band microstrip antennas are designed and simulated using a metamaterial substrate. The design has been optimized for fabrication by the LTCC (Low-temperature Cofired Ceramics) technique. The dual-band microstrip antenna is designed using two kinds of SRRs which have different scales.

12:00 *Prediction of the input impedance of primary sources placed inside FP and EBG antennas*
T.-H. Vu, K. Mahdjoubi, S. Collardey, A.-C. Tarot
Abstract: In several previous works, we developed an original method to evaluate the input impedance of the EBG antennas excited by line or point sources. The method is based on the generalisation of the plane wave expansion of the antenna internal fields to cylindrical or spherical wave expansions. In this paper, the procedure is generalised further to treat primary sources of arbitrary form and nature. The successive reflections (of the plane, cylindrical or spherical waves) are replaced by the successive images of the arbitrary primary source.

11:00 – 12:30 Session 16 – Room VN2
Negative material parameters
Chairs: A. Viitanen, M. Silveirinha

11:00 *Left-handed metamaterial designs in microwave and infrared frequencies (invited)*
M. Kafesaki, E.N. Economou, N. Katsarakis, I. Tsiapa, S. Foteinopoulou, C.M. Soukoulis, T. Koschny
Abstract: The novel and unique properties of left-handed metamaterials, entailing unique capabilities in the manipulation of EM waves, have led in recent years to very strong efforts for the study and understanding of the behavior of those materials. Here we will present the attempts of our group to realize and analyze various designs (existing and novel) appropriate for the achievement of left-handed materials operating in both microwave and infrared frequencies. Such designs are SRRs, short-wire pairs, and continuous wires, in various combinations and shapes. Particular attention will be given to the understanding of the behavior of those materials going to the infrared and optical range and to the capacity of those materials to be empowered with switching or tuning capabilities.

11:30 *Electrostatic resonances of negative-permittivity interfaces, spheres and wedges*
H. Wallen, H. Kettunen, A. Sihvola
Abstract: A surface plasmon or electrostatic resonance mode is possible at an interface between two materials with permittivity of opposite signs. We present a brief review of the possible electrostatic resonance modes in three canonical geometries, and also some numerical results highlighting the importance of these resonances for metamaterial modeling.

11:45 *Tailoring transparency of negative-index metamaterials with parametric amplification*
A.K. Popov, S.A. Myslivets, T.F. George, V.M. Shalaev
Abstract: The possibility of compensating losses in negative-index metatamterials doped by resonant four-level centers is shown based on quantum interference and extraordinary properties of parametric amplification of counter-propagating electromagnetic waves.

12:00 *Influence of spatial dispersion on properties of waveguide filled with wire media – an experimental investigation*
S. Hrabar, A. Vuckovic, M. Vidalina, M. Masic
Abstract: The wire media is very attractive as the basic building structure for metamaterial-based devices due to its low losses associated with inherent non-resonant behavior. Early studies suggested description of a wire-media by simple Drude model. However, recent theoretical investigations showed that one should take the spatial dispersion into account if the wave vector contains components parallel to the wires. This paper reports the experimental investigation of spatial dispersion in waveguide environment. Several different configurations were studied experimentally in 10 GHz band: the rectangular waveguide filled with 2D array of thin wires and excited in TE_{10} or TE_{11} mode and rectangular waveguide filled with 2D array of crossed non-connected wires excited in TM_{11} mode. Experimental results revealed that spatial dispersion indeed exists in the cases with modes that contain wave vectors components parallel to the wires (TE_{11} and TM_{11} modes). However, in some cases (a waveguide with crossed not-connected wires excited in TM_{11} mode) it was found that qualitative behavior of transmission coefficient (S_{21}) is similar to that predicted by with simple Drude models (the existence of both the forward-wave propagation and the backward-wave propagation), with apparently shifted plasma frequency. Thus, it seems that apparent shift of plasma frequency, which was in previous experimental studies attributed to manufacturing errors, is actually a consequence of spatial dispersion.

12:15 *Negative refraction and negative phase velocity through cutwire/wire based metamaterial*

K. Guven, A.O. Cakmak, M.D. Caliskan, E. Ozbay

Abstract: We investigate the left-handed transmission properties of a planar composite metamaterial (CMM) consisting of paired cutmetallic wire and wire arrays on dielectric substrates. The incident electromagnetic wave is normal to the metamaterial planes, thus allowing the use of a single fabricated layer. The left-handed transmission band of the metamaterial is demonstrated experimentally. The negative refraction of electromagnetic waves through the metamaterial slab is demonstrated. By using metamaterials with different number of layers (i.e. thicknesses), we confirm that the phase velocity within the left-handed transmission band is negative.

12:30 Lunch

14:00 Poster Session (I)

Chairs: J. Machac, A. Alù

1 - G.A.Kraftmakher, V.S. Butylkin - *Appearance and increase of resonant nonreciprocal microwave response of waveguiding chiro-ferrite-metastructures*

2 - V.S. Butylkin, G.A. Kraftmakher - *Left- and right-handed pass-bands of bianisotropic and waveguide - bianisotropic metamaterials with gratings of double split rings*

3 - L. Akhoondzadeh-Asl, P.S. Hall - *Element shape effect on the behaviour of artificial magnetic conductors*

4 - A. Rumberg, M. Berroth - *Negative refractive index in stacked conventional structured printed circuit board material*

5 - P.Y. Chen, S.C. Wu, Y.C. Chen - *Periodic porous-nanostructured left-handed material slab at optical frequencies*

6 - S.E. Bankov, M.D. Duplenkova - *Waveguide components on the base of two-dimensional EBG structure*

7 - D.C. Skigin, R.A. Depine - *Resonant and dynamical properties of compound gratings with metamaterials*

8 - J. Hao, Y. Yuan, L. Ran, T. Jiang, J.A. Kong, L. Zhou, C.T. Chan - *Manipulating photon polarizations by anisotropic metamaterials*

9 - L.H. Moustafa, B. Jecko - *Design of a broadband EBG resonator antenna using dual-resonant FSS*

10 - H. Mosallaei, A. Ahmadi - *Electric and magnetic dipole moments of dielectric resonators: an all-dielectric metamaterial design*

11 - R. Brazis, V. Kazakevicius, R. Narkovic - *Single split-ring resonators and metamaterials*

12 - Q. Wu, H.-L. Wang, J. Wu, L.-W. Li - *Investigation on the electric line source illumination of a lossless metamaterial covered dielectric cylinder*

13 - R. Kushal - *Effect of variable MgO and Fe_2O_3 doping on structural, electrical and thermal properties of PZT ($PbZr_{0.7}Ti_{0.3}O_3$) nano-ceramics derived by Sol-Gel technology*

14 - S.A. Nikitov, Yu.K. Chamorovskii, E.A. Nekrashevich, M.V. Ryabko, V.A. Isaev - *Polarization mode dispersion in holey fibers with two side holes*

15 - Z. Wang, Z. Zhang, X. Wang, S. Qin - *Wave-absorbing property of an absorber with LHM and RHM structure*

16 - J. Shi, Z. Wang, Z. Zhang, X. Wang, S. Qin - *Theoretical research on a LHM & RHM composed wave-absorber*

17 - A. Martinez, R. Ortuno, J. Marti - *Subwavelength imaging by a negative-index photonic-crystal slab: role of the thickness and surface cut*

18 - J. Herrmann, I. Babushkin, A. Husakou - *Supercontinuum generation in a nanowaveguide with slow nonlinearity*

19 - Yu.S. Dadoenkova, I.L. Lyubchanskii, Y.P. Lee, A. Lakhtakia - *Brewster and pseudo-Brewster angles for bigyrotropic negative magnetic materials*

20 - G. Goussetis - *Generalized scattering matrix of discontinuities embedded in electromagnetic band gap transmission lines*

21 - M.L. Shendeleva - *Imaging through a negative-index slab with the use of ray tracing*

22 - C.M.J. Wijers, O. Voskobyonikov - *Magneto-optical properties of layers of quantum dot molecules*

23 - M.-S. Wu, S.-G. Mao - *Dispersion characteristics of compact composite right/left-handed and electromagnetic bandgap coplanar waveguide stubs*

24 - A.N. Gruzintsev, A.N. Redkin, Z.I. Makovey, E.E. Yakimov, C. Barthou, G.A. Emelchenko - *Fabrication of the ZnO vertical nanorod arrays and their random lasing.*

25 - G.A. Emelchenko, V.M.Masalov, M. Romanelli, A. Maître, C. Barthou, P. Benalloul, A.N. Gruzintsev, E.E. Yakimov - *Angle-resolved self-activated luminescence of 3D photonic crystals -opals*

26 - A. Alden, P. Bouliane, M. Zhang - *A controllable resistance sheet using rectifying diodes*

27 - A.E. Serebryannikov, T. Magath - *Applying fast coupled-integral equations technique to photonic crystals and metamaterial gratings*

28 - F. Frezza, L. Pajewski, C. Ponti, G. Schettini - *Band properties and directivity enhancement in 3D electromagnetic crystals for antenna applications*

29 - D. Draskovic, D. Budimir - C*omposite right/left handed coupler and its application to WiMAX power amplifiers*

30 - O.N. Kozina, L.A. Melnikov - *Axial and off-axial laser effect in 1D photonic crystal with active layers.*

31 - A.V. Ivanov, A.N. Shalygin, V.Yu. Galkin, A.V. Vedyayev, V.A. Ivanov - *Optical Magnus effect in tunable metamaterials fabricated from amorphous ferromagnetic microwires*

32 - S. Simion, G. Sajin, R. Marcelli, G. Bartolucci, F. Craciunoiu - *Silicon CPW composite right/left-handed coupled lines directional coupler*

33 - S. Simion, G. Sajin, R. Marcelli, F. Craciunoiu - *CPW composite right/left-handed zeroth-order resonance antenna on silicon substrate*

34 - M.V. Golovkina - *Two-layered waveguide containing a negative index material slab with resistive film*

35 - E.J. Sartori, H.E. Hernandez-Figueroa, J.E. Bertuzzo - *Metamaterial behaviour of low cost PVC dielectric grids*

36 - A. Sanada - *Negative refractive index media of infinite metallic wire array*

37 - A.A. Bulgakov, O.V. Shramkova - *Three-wave interaction of electromagnetic and plasma waves in the layered semiconductor structures*

38 - S.A. Matos, C.R. Paiva, A.M. Barbosa - *A coordinate-free approach to a pseudochiral omega medium*

39 - O. Takayama, L.-C. Crasovan, D. Artigas, S.K. Johansen, D. Mihalache, L. Torner - *Excitation of Dyakonov surface wave in the Kretschmann configuration*

40 - T. Sengor - *Possibilities creating higher chirality with a new metamaterial element*

41 - O. Karabasoglu, G. Kiziltas - *Design optimization of artificial magneto-dielectrics for RF applications*

42 - M. Iwanaga - *Effective magnetic response at visible frequency in stratified metal-dielelctric metamaterials*

43 - K. Sakoda - *Study on scaling law of the Menger sponge by LCAO approximation*

44 - S.K. Ghosh, A. Ghosh - *Study and development of diamagnetic ferrite substrate as magnetic super conducting substrate & core element at room temperature in an inhomogeneous magnetic field*

45 - G. Monti, L. Tarricone - *Dispersion analysis of a metamaterial-loaded waveguide*

46 - C. Sibilia, A. Mandatori, V. Violante, E. Castagna, M. Bertolotti - *Electromagnetic field behaviour at electrochemical interface of metallic electrodes*

47 - L. Crocco, F. Cuomo, T. Isernia - *An effective generalized scattering matrix method for the characterization of 2D photonic crystals*

48 - F. Aznar, J. Garcia-Garcia, M. Gil, J. Bonache, F. Martin - *Considerations for the miniaturization of electromagnetic resonators for metamaterial and LHM design*

49 - A. Anan'ev, A. Lipovskii, L. Maksimov, V. Polukhin, D. Tagantsev, B. Tatarintsev - *Solid band gap photonic crystal fibers: design, materials, technology*

50 - G.C. Vietti Colome, L. Matekovits, M. Orefice - *The effect of transverse periodicity in a modulated microstrip line*

51 - R. Karimzadeh Baee, G. Dadashzadeh, F. Geran Kharakhili - *An equivalent circuit model for CSRR and using of its in size reduction of microstrip antenna*

52 - M.A. Abdalla, Z. Hu - *A nonreciprocal left handed coplanar waveguide on ferrite substrate with only shunt inductive load*

53 - F.J. Herraiz-Martinez, V. Gonzalez-Posadas, D. Segovia-Vargas - *Compact dual-mode and triple-frequency circular patch antenna based on metamaterial structures*

54 - M. Plesa, R. Cret, L. Cret, D. Duma - *Numerical calculus of binary dielectric mixtures permittivities with Inclusions of different geometrical shapes and sizes*

55 - A.F. Konstantinova, K.K. Konstantinov, V.V. Filippov, E.A. Evdishchenko, K.B. Imangazieva - *Propagation of electromagnetic waves in layered anisotropic media*

56 - P.V. Dolganov, V.M. Masalov, E.N. Samarov, V.K. Dolganov, G.A. Emelchenko - *Optical properties and band structure of opal and blue phase photonic crystals*

57 - C. Du, J. Ma, X. Luo - *Surface plasmon modes from a hybrid metallic nanostructure array*

58 - X. Luo, J. Ma, C. Du - *Light diffraction from grating like surfaces*

59 - N. Medvedeva, O. Vendik, S. Zubko - *Modelling and characterization of structures containing spherical or ellipsoidal ferroelectric inclusions*

60 - S. Arslanagic, R.W. Ziolkowski, O. Breinbjerg - *Radiation properties of concentric metamaterial spheres excited by an electric Hertzian dipole*

61 - I.A. Ibraheem, J. Schoebel, M. Koch - *Group delay in coplanar waveguide left-handed media*

62 - M.C. Larciprete, A. Belardini, M. Centini, E. Fazio, C. Sibilia, M. Cappeddu, D. de Ceglia, M. Scalora, M. Bloemer - *Second harmonic generation from metallo-dielectric multilayer structures*

63 - A. Gopinath, N.-N. Feng, M.L. Brongersma, L. Dal Negro - *Collective plasmon resonances and field enhancement in two-dimensional aperiodic arrays of metal nanoparticles*

64 - A.V. Akimov, A.A. Meluchev, D.A. Kurdyukov, A.V. Scherbakov, A. Holst, V.G. Golubev - *Optical reflection and diffraction in opal-metal composites*

65 - A.A. Bulgakov, V.K. Kononenko, O.V. Kostylyova – *The internal fields influence on the properties of the waveguide between two periodic layered structures*

15:00 – 16:30 Session 17 – Room N13

Quasicrystals (III) (special session organized by S. Enoch, V. Galdi, and F. Capolino)

Chairs: S. Enoch, V. Galdi, F. Capolino

15:00 *Disordered and quasicrystalline metallic photonic crystals (invited)*
H. Giessen, Ch. Bauer, D. Nau

Abstract: We investigate quantitatively the influence of different disorder types on the optical properties of metallic photonic crystals. The two positional disorder types, frozen phonon disorder and long-range disorder, are characterized by different two-particle correlation functions. We present a method based on neutron scattering techniques which allows to predict the optical spectra and the photonic bandstructures to a great accuracy, even for large disorder amounts. This method works as well for quasicrystalline structures, which are characterized by short-range disorder and long-range order.

15:30 *Resonant terahertz transmission through Penrose metal hole arrays (invited)*

M. Hangyo, K. Takano, F. Miyamaru, H. Miyazaki

Abstract: The transmission properties of metal hole arrays with a quasiperiodic Penrose type have been investigated in the terahertz (THz) region. The transmission spectra show characteristic resonant peaks corresponding to the Fourier transform of a Penrose tile. The intensities of the resonant transmission peaks for finite arrays normalized by the fraction of the hole area increase with the number of holes N and saturate at N ~ 150 indicating that about 150 holes are needed to excite surface plasmon polariton in this system.

16:00 *Theory of extraordinary optical transmission through quasi-periodic arrays of subwavelength holes (invited)*

F.J. Garcia-Vidal, J. Bravo-Abad, A.I. Fernandez-Dominguez, L. Martin-Moreno

Abstract: Very recently, several experimental studies have reported the appearance of the phenomenon of extraordinary optical transmission (EOT) through quasi-periodic arrays of subwavelength holes. The phenomenon was firstly described in 1998 for periodic arrays of holes. Therefore, it is clear that the key ingredient to observe EOT phenomenon is the long-range order present in both periodic and quasi-periodic arrays of holes. In this paper, we demonstrate that the physics behind EOT in quasi-periodic arrays is based on the excitation of surface electromagnetic modes, much in the same way as it happens in periodic arrays

15:00 – 16:30 Session 18 – Room N16

Cloaking and field transformations (I)

Chairs: V. Veselago, P. Uslenghi

15:00 *Field-transforming metamaterials (invited)*

S.A. Tretyakov, I.S. Nefedov

Abstract: Here we introduce a concept of field-transforming metamaterials. These artificial media change the fields in a prescribed fashion in the volume occupied by the medium. We show what electromagnetic properties of transforming medium are required if the transformed fields are arbitrary linear functions of the original fields. The coefficients of these linear functions can be arbitrary functions of position and frequency, which opens a possibility to realize various unusual devices, such as, for instance, absorbers, antennas, and cloaks.

15:30 *General relativity in electrical engineering (invited)*

U. Leonhardt, T.G. Philbin

Abstract: The recent breakthroughs in invisibility devices are a result of advances in theoretical optics and in material science. On the theoretical side, invisibility devices are an example of transformation media - media that, as far as electromagnetism is concerned, perform active coordinate transformations. General relativity provides the theoretical tools for calculating the material properties required to achieve a given transformation. The development of electromagnetic metamaterials allows electrical engineers to implement the design recipes of transformation media.

16:00 *Dispersion characteristics of metamaterial cloaking structures*
A. Alù, N. Engheta
Abstract: Here we discuss the dispersion features of cloaking structures formed by plasmonic materials and metamaterials. Following our recent proposal for realizing a cloaking metamaterial shell capable of drastically suppressing the total scattering of moderately-sized objects, here we investigate the frequency response and dispersion behavior of this anomalous phenomenon. Insights into the scattering reduction and possibility of multi-frequency response will be discussed in details, considering disper-sion constraints on passive materials.

16:15 *Invisible metamaterial trenches*
P.L.E. Uslenghi
Abstract: Two-dimensional trenches, or channels, in a metal plane that are partially filled with double-negative (DNG) material are considered. It is shown that for certain directions of incidence and polarization of the primary plane wave, the trenches are invisible at all frequencies.

15:00 – 16:30 Session 19 – Room N17
Metamaterials and antennas (III)
Chairs: R. Gonzalo, V. Podlozny

15:00 *Full-wave dispersion analysis and broadside optimization for the microstrip CRLH leaky-wave antenna*
S. Paulotto, P. Baccarelli, F. Frezza, D. R. Jackson
Abstract: In this paper we present a complete dispersion analysis of a planar microstrip Composite Right/Left-Handed Leaky-Wave Antenna. This analysis is performed through a numerical approach that enables a systematic investigation of bound modes, surface-leaky modes, and space-leaky modes. By means of a parametric study based on the dispersion

behavior of the Composite Right/Left-Handed microstrip structure, the geometry of the unit cell has been optimized to eliminate open-stopband effects and to achieve an almost constant radiation efficiency while the beam is scanned through broadside.

15:15 *Design of metamaterial based patch antennas with reduced back-radiation for radio navigation systems*

F. Bilotti, C. Vegni

Abstract: In this paper, we propose the design of patch antennas with reduced back-radiation levels through the employment of proper magnetic inclusions (Split-Ring Resonators, Multiple Split-Ring Resonators, Spiral Resonators). Such inclusions are designed in order to resonate at the operating frequency of the antenna, leading, thus, to the suppression of the surface wave contribution. A few antenna layouts to be employed in the receivers of radio navigation systems are also presented. Finally, some full-wave numerical simulations are presented, showing the effectiveness of the proposed design in terms of back-lobe reduction.

15:30 *Tuneable active EBGs*

H.J. Lee, R.J. Langley, K.L. Ford

Abstract: This paper summarises the measured and simulated performance of a wideband printed monopole antenna over a tunable electromagnetic band gap substrate (EBG). The EBG consists of square elements loaded with varactor diodes and is tunable from 800MHz to 2000 MHz. The complete antenna is tunable for 900 MHz to 1650 MHz.

15:45 *Directive radiation from grounded wire-medium slabs covered with metal strip gratings*

G. Lovat, P. Burghignoli, F. Capolino, D.R. Jackson, D.R. Wilton

Abstract: A study of directive radiation from a horizontal electric dipole embedded in a grounded wire-medium slab covered with a partially reflecting surface in the form of a metal strip grating is presented. The combined effect of the volumetric metamaterial and the partially reflective surface allows for very directive beams. The performance is compared with antennas made from a wire medium slab alone and from an air substrate covered with a metal strip grating. In all cases omnidirectional beams are obtained.

16:00 *A design formulation of a periodic high-impedance surface for a miniaturised antenna array*

M. Schuhler, R. Wansch, M.A. Hein

Abstract: The focus of our work is the miniaturisation of a dipole antenna array by two complementary means. On the one hand, we want to place the antennas close above a high-impedance surface. On the other hand, we want to reduce the coupling between the antennas so that the elements can be placed at separations less than λ/2. We derive a formulation to design analytically a high-impedance surface consisting of a periodic structure, which displays a surface wave band gap for a range of wavelengths much larger than the periodicity of the structure. For frequencies below the band gap, the structure supports backward waves, above the band gap forward waves are supported. Our considerations are verified by measurements.

16:15 *Band-notched UWB monopole planar antenna with split-ring resonator*
P.Y. Chen, S.C. Wu, J.H. Tsai
Abstract: We have proposed complimentary a split-ring resonator (CSRR) used as band-rejection filter for ultra-wide band (UWB) planar monopole antenna. The simulated results show that the preoccupied band within the UWB region has been successfully notched. The band-notched characteristics can be attributed to the narrow forbidden band when magnetic resonance occurs.

15:00 – 16:30 Session 20 – Room VN2
NI Metamaterials in optics
Chairs: N. Zheludev, C. Soukoulis

15:00 *Photonic metamaterials: artificial magnetism, negative refraction, and circular dichroism at optical frequencies (invited)*
S. Linden, G. Dolling, N. Feth, M. Decker, C.M. Soukoulis, M. Wegener
Abstract: We present some of our recent experimental results and numerical calculations on photonic metamaterials. In particular, we demonstrate artificial magnetism, negative refraction, and circular dichroism at optical frequencies.

15:30 *Low-loss single-layer metamaterial with negative index of refraction at visible frequencies*
C. Garcia-Meca, R. Ortuno, R. Salvador, A. Martinez, J. Marti
Abstract: We present a structure exhibiting a negative refractive index at visible frequencies using a single metal layer. The metamaterial is numerically analysed and it is shown that the dimensions can be engineered to shift the negative index band within a region ranging from telecommunication wavelengths down to blue light.

15:45 *Efficient slow light in adiabatically tapered left-handed waveguides*
K.L. Tsakmakidis, O. Hess
Abstract: We introduce a new means of realizing ultraslow and stopped light, which is based on wave propagation along an adiabatically tapered waveguide with a core of negative refractive index (NRI) material. We analytically demonstrate that this scheme can allow for arbitrary large normalized time delays, delay-bandwidth products, as well as for efficient in-/out-coupling from/to conventional optical waveguides. The salient features of wave propagation in such structures, as well as a novel ray-tracing analysis that confirms the halt of light, are concisely discussed.

16:00 *Photo-induced voltage in perforated metal-dielectric-metal layered structures*
Y.-G. Roh, Y. Segawa, S.G. Tikhodeev, T. Ishihara
Abstract: Photo-induced voltage due to the photon drag effect was investigated on a metamaterial. Reversal of the sign of photo-induced voltage indicates opposite sign of the group velocity of the lowest mode, which corresponds to the reversal energy transfer to the electron.

16:15 *Superconductor-based optically isotropic negative refraction index metamaterial at visible frequencies*
A.-G. Kussow, A. Akyurtlu, A. Semichaevsky, N. Angkawisittpan
Abstract: We report a novel principally optically isotropic metamaterial in a visible regime. It consists of the matrix (polycrystalline magnesium diboride in a normal state, at room temperature), with randomly (or regularly) embedded spherical nanoparticles of a polaritonic crystal, SiC. Both the effective medium theories (Maxwell-Garnett and Lewin's) and FDTD calculations demonstrate explicitly, that the metamaterial exhibits negative refraction index behavior with extremely low losses. This result, due to carefully adjusted parameters, in the long wavelength limit, stands for both random and regular distribution of SiC nanoparticles inside the matrix.

16:30 Coffee

17:00 – 19:00 Session 21 – Room N13
Homogenization of metamaterials
Chairs: S. Zouhdi, L. Vegni

17:00 *Numerical methods for analysing periodic metamaterials (invited)*
F. Capolino, D.R. Wilton, D.R. Jackson, J. Chen, C. Craeye, W.A. Johnson, L. Basilio
Abstract: We present a variety of numerical techniques to model metamaterial geometries involving periodic structures of infinite or finite size. Accelerated method of moments and FDTD techniques are used to model metamaterials with infinite extent in one or more dimensions that are excited by either periodic excitations or by a localized (non-periodic) source. Fast solvers like GIFFT (Green's function Interpolation and FFT) and as well as techniques such as the use of macro basis functions are used to model metamaterials having a large finite size.

17:30 *Six-dimensional view of dielectric mixtures as metamaterials (invited)*
A. Sihvola
Abstract: In this presentation a holistic view is taken to homogenization theories that connect effective properties of mixtures with its microstructure. The analysis helps in interpreting predictions of classical mixing rules into the domain of negative-permittivity metamaterials.

18:00 *Frequency-dependent homogenization: application to metamaterials (invited)*
A. Bossavit
Abstract: A new approach to homogenization of spatially periodic composite materials is proposed, in which the frequency of the excitation is an essential parameter. An analysis of the "cell problem", by which effective homogeneous parameters ε_{eff} and μ_{eff} are obtained, show they can have negative real part, which is one of the interesting emergent properties of some (so-called "left-handed") metamaterials. The method can be used to design such materials, by numerical shape-optimization.

18:30 *Investigation of coupling effects in SNG metamaterial based on spiral particles (invited)*
I. Huynen, X.Radu, S.Massaoudi, F. Capolino, C. Craeye
Abstract: In this paper we investigate in the frequency range [110-150 MHz] the interaction between electromagnetic waves and spiral resonators designed to behave as Single Negative Metamaterial. In a first part, we analyze the transmission and the permeability of a spiral metamaterial in the infinite-array case and we show the influence of the number of layers and of the unit cell size on the resonant frequency. In a second

part, an equivalent circuit is presented to explain the emergence of multiple resonances.

17:00 – 19:00 Session 22 – Room N16
Subwavelength imaging
Chairs: G. Eleftheriades, P. Belov

17:00 *Magnetoinductive lenses: basic principles and future trends (invited)*
R. Marques, M.J. Freire
Abstract: In this contribution the basic concepts underlying the physics of magnetoinductive (MI) lenses are devel-oped and the main practical limitations to their performances are analyzed. Strategies to overcome such limita-tions are proposed. Possible applications of MI lenses in magnetic resonance imaging (MRI) are discussed.

17:30 *Near field imaging with metamaterials (invited)*
E. Shamonina
Abstract: An overview of recent developments in the field of near field imaging with metamaterials and an analysis of the validity of proposed models based on experimental data is provided.

18:00 *Amplification of evanescent spatial harmonics and subwavelength imaging inside of a wire medium slab*
Y. Zhao, P.A. Belov, Y. Hao
Abstract: The amplification of evanescent spatial harmonics has been observed inside of a wire medium slab with half-wavelength thickness. The physics of the phenomenon are drastically different as compared to the amplification observed for the slabs of left-handed media. The slab of wire medium has been modeled using spatially dispersive finite-difference time-domain method. The opportunity of subwavelength imaging was revealed. It is shown that the near field produced by an object placed at the distance less than λ/10 from the front interface of the device can be detected inside of the wire medium slab with resolution about λ/20. The resolved subwavelength details of the source absent at the front interface of the wire medium due to rapid decay of evanescent spatial harmonics the free space, but they happens to be resolved inside of the wire medium slab. The reported effect may be used for sub-surface imaging and creation of subwavelength imaging devices of new generation.

18:15 *Subwavelength imaging at infrared frequencies using an array of metallic nanorods*
M.G. Silveirinha, P.A. Belov, C. Simovsky

Abstract: In this work, we present our recent theoretical findings that suggest the possibility of using an array of metallic nanorods to transport an image with subwavelength resolution at infrared frequencies over a significant distance (comparable with the free-space wavelength). We develop an analytical formalism that can describe with good accuracy the imaging properties of the proposed imaging device. Full wave numerical simulations (taking into account the effect of realistic losses) suggest that an array of silver rods at 30THz may enable imaging with resolution λ_0 /10 .

18:30 *Broadband super-resolution and energy transport in a metallo-dielectric lens*
G. D'Aguanno, M.J. Bloemer, N. Mattiucci, M. Scalora, D. de Ceglia, N. Akozbek
Abstract: We analyze a super-resolving lens for TM-polarized waves based on Ag/GaP multilayers. The lens maintains a normal incidence transmittance of ~60% for propagating waves over the super-resolving wavelength range of 500-650 nm. We also study the energy transport and in particular we put into evidence the role played respec-tively by the evanescent and propagating modes on the ohmic losses and on the power transported through the lens. The energy transport is characterized by strong energy circulation outside the lens.

17:00 – 19:00 Session 23 – Room N17
Enhanced transmission
Chairs: M. Sorolla, M. Notomi

17:00 *Optical properties of subwavelength holes in metal films: finite size effects (invited)*
L. Martin-Moreno
Abstract: In this presentation we will study the dependence with the number of holes of the extraordinary optical transmission through optically thick metal films, perforated with subwavelength holes. We will also discuss other effects appearing in the optical properties of these systems which are related to the presence of edges hole arrays. A comparison will be made with the related system of a finite array of 1D holes (slits).

17:30 *Eigenmodes of metal-dielectric structures and transmission through subwavelength slits*
M. Gorkunov, B. Sturman, E. Podivilov
Abstract: We show that the wide-spread concept of optical eigenmodes in lossless waveguide systems, which assumes the separation into propagating and evanescent modes, fails in the case of metal-dielectric structures, including photonic crystals. In addition, there

exists a sequence of new eigen-states with complex values of the propagation constant and non-anishing circulating energy flow. The new anomalous modes are essential for the modeling of extraordinary light transmission through subwavelength holes.

17:45 *Control of extraordinary transmission of light through nanohole arrays in metal films*
Y.M. Strelniker, D.J. Bergman, D.G. Stroud
Abstract: We have studied analytically (in the quasistatic limit) and numerically the extraordinary transmission through perforated metal films with elliptical holes. We propose to use a static magnetic field B_0 or a static electric field E_0 in order to control the extraordinary light transmission.

18:00 *Squeezing obliquely-incident electromagnetic waves through subwavelength regions or openings using epsilon-near-zero (ENZ) materials*
M.G. Silveirinha, N. Engheta
Abstract: In this work we investigate the possibility of squeezing a complex electromagnetic field distribution through a narrow and/or partially obstructed region without losing the fine details of the wave front. To this end, we propose a two step procedure in which the incoming wave is first sampled “pixel by pixel” using an array of microstructured metallic waveguides, and then the signal corresponding to each individual pixel is squeezed through a very narrow channel filled with an ε-near zero material. Full wave results obtained with an electromagnetic simulator demonstrate the possibility of compressing the incoming wave by several folds. This result promises an unprecedented compression of electromagnetic waves through subwavelength regions or openings.

18:15 *Low-loss and miniaturized extraordinary transmission metamaterial*
M. Beruete, M. Navarro-Cia, M. Sorolla
Abstract: A structure based on stacked perforated metallic plates with simultaneously Left-Handed behaviour, Extraordinary Transmission and Electromagnetic Band Gap phenomenon has been recently reported. In this paper, a further study of this low-loss and miniaturized doubly periodicity subwavelength hole array sandwiched in dielectric is presented. It is shown the advantage of a symmetric configuration instead of an asymmetric one.

18:30 *Enhanced resonance transmission of light through a dense layer of large noble-metal nanoparticles*
S.M. Kachan, A.N. Ponyavina

Abstract: We establish the existence of enhanced resonant transmission of light through 2D random close-packed arrays of noble-metal nanospheres with the diameter of the order of hundreds nanometers. This effect resembles enhanced resonant transmission of light through an optically thick metal film with the subwavelength aperture array. We detect that the corresponding resonance wavelength is extremely sensitive to the environmental changes making such structures very attractive for sensing applications.

18:45 *Plasmonic leaky-wave propagation and radiation on periodic silver films at optical frequencies*
D.R. Jackson, A.A. Oliner, J. Chen, F. Capolino, R. Qiang, G. Lovat, P. Burghignoli, D.R. Wilton
Abstract: Enhanced transmission through a subwavelength aperture in a silver film surrounded by a periodic structure, as well as the directive beaming of light from an aperture on the surface of a silver film surrounded by a periodic structure are explained in terms of leaky-mode propagation and radiation.

17:00 – 19:00 Session 24 – Room VN2
FSS and guiding structures
Chairs: L. Solymar, S. Hrabar

17:00 *Design of ENG loaded coupled microstriplines with very high and very low coupling values (invited)*
F. Bilotti, S.E. Lauro, A. Toscano, L. Vegni
Abstract: In this paper, we propose the design of coupled microstriplines with anomalous coupling values by employing ENG slabs properly placed in the substrate between two metallic strips. The effect of the ENG slab is firstly explained by using an heuristic physical interpretation. Then, the expected behavior of the coupled lines has been predicted through a quasi-static model based on the conformal mapping technique. The application of this model leads to very simple design formulas, that can be used to quickly design the ENG slabs. Finally, both the heuristic and the analytical models are veri fied through proper full-wave numerical simulations.

17:30 *Subwavelength guiding of electromagnetic energy in structures based on anisotropic SNG metamaterials (invited)*
S. Hrabar, D. Zaluski
Abstract: In the last few years there have been several experimental studies showing that a waveguide, transversal dimension of which is arbitrarily smaller than

half of a wavelength supports the propagating modes if it is filled with an anisotropic single-negative (SNG) metamaterial. So far, only the simplified transmission-line explanation of this counter-intuitive phenomenon has been developed, while the clear physical explanation of the wave propagation and field distribution inside the waveguide has not been available. In this paper, it is attempted to explain the guiding of the electromagnetic energy in the structures with subwavelength transversal dimensions, which are based on anisotropic SNG metamaterial. Analytical, numerical, and experimental investigation revealed that a key issue of the counter-intuitive physics of subwavelength propagation deals with the existence of inhomogeneous plane waves within the anisotropic filling material. An alternative, equally valid, explanation on the microscopic ('in-cell') level is the excitation of the surface backward waves that are confined to the inclusions of anisotropic SNG filling.

18:00 *Applications of frequency selective surfaces in the design of metamaterials (invited)*
D.H. Werner
Abstract: This talk will provide an overview of research in the area of FSS-based metamaterials, with an emphasis on work being done at the Pennsylvania State University Computational Electromagnetics and Antennas Research Lab (PSU CEARL) http://labs.ee.psu.edu/labs/dwernergroup/. Other types of novel metamaterials under development by the PSU CEARL group will also be discussed. An emphasis will be placed on the computational modeling tools developed specifically for the analysis and design optimization of electromagnetic metamaterial performance.

18:30 *Hybrid FSS for resonant narrow band IR emission: A new generation of infrared sources and spectroscopic sensors*
I. Puscasu, A. Shah, A. Greenwald, E. Johnson, W. Schaich
Abstract: We propose a new class of IR gas sensors, where the enabling technology is a spectrally tuned hybrid frequency selective surface (FSS). Building both the emitting and sensing capabilities on to a single discrete element, Ion Optics' infrared sensorchip brings together a new sensor paradigm to vital commercial applications, incorporating for the first time plasmonic photonic crystals into a commercial product.

18:45 *Slow light tunneling of X waves through a stopband*
A. Di Falco, C. Conti, S. Trillo
Abstract: We show that a new type of non-spreading wavepackets, X-shaped envelopes of Bloch waves, can

lead to slow light tunneling at frequencies close to the edge of a stopband characterized by a negative curvature of the linear dispersion relation.

Wednesday 24 October

Buildings of the Faculty of Engineering
via della Vasca Navale, 109

08:30 – 10:30 Session 25 – Room N16
Metasurfaces, metaboundaries and enhanced transmission (I) (focused session organized by G. Shvets)
Chairs: G. Shvets

08:30 *Surface waves in a magnetized ferrite slab filled with wire media (invited)*
I.S. Nefedov
Abstract: In this presentation we discuss surface waves propagating in a tangentially magnetized ferrite slab, filled with a single wire media, arranged transversely to the plane of slab.

09:00 *Left-handed propagation and beaming in stacked subwavelength hole arrays (invited)*
M. Sorolla, M. Beruete, M. Navarro, I. Campillo
Abstract: Our recent experimental demonstration of Left-Handed propagation properties in stacked subwavelength hole arrays operating at millimeter wavelengths (subterahertz) has opened the question of the beaming properties of such structures. In this work, we present an initial step towards the full characterization of these properties that could be interesting for some applications in antennas and frequency selective surfaces.

09:30 *Planar and layered chiral meta-surfaces (invited)*
V.A. Fedotov , E. Plum, A.S. Schwanecke, Y. Chen, V.V. Khardikov, S.L. Prosvirnin, N.I. Zheludev
Abstract: We report first results on the development of planar and layered microwave and photonic 2D and 3D meta-surfaces and to the study of their unusual and intriguing properties including giant rotatory power of the 3D layered structures and asymmetric transmission through the 2D chiral metasurfaces.

10:00 *Extraordinary transmission and absorption in hole arrays mediated by surface phonon polaritons (invited)*
G. Shvets, D. Korobkin, Y.A. Urzhumov, B. Neuner III

Abstract: Measurements of mid-IR light transmission through optically thin SiC membranes suspended in air and perforated by an array of sub-wavelength holes reveal extraordinary transmission/absorption. These effects are explained in terms of the effective permittivity ε_{eff} (ω) of the perforated film. Multiple resonances of ε_{eff} (ω) correspond to the excitation of surface phonon polaritons (SPPs). Because the film is suspended in air (no high-index substrate) and the spacing between the holes is sub-wavelength, transmission/absorption anomalies are clearly associated with SPPs and not with diffractive effects.

08:30 – 10:30 Session 26 – Room N17

Effective material parameters and role of disorder in metamaterials (I) (focused session organized by H. Giessen and K. Whites)

Chairs: H. Giessen, K. Whites

08:30 *Exact full-wave simulation of finite pieces of metamaterials and extraction of effective material parameters (invited)*

I. Bogaert, F. Olyslager

Abstract: A stable plane wave multilevel fast multipole method (SPWMLFMA) is presented for the simulation of the scattering at a very large number of scatterers using the T-matrix method. The method is used to accurately simulate the interaction of an incident field with a piece of metamaterial consisting of a large number of particles embedded in a host medium. From the scattering data it is possible to derive effective material parameters of the piece of metamaterial. We will show two examples. The first one consists of a metamaterial Luneburg lens and illustrates the interaction of the incident field with a large number of scatterers and the second one is a chiral medium composed from a large number of metal spiral like objects and illustrates the extraction of effective parameters.

09:00 *Mesoscopic ``effective material parameters'' for single and double grids of loaded wires describing*

P. Ikonen, E. Saenz, R. Gonzalo, C. Simovski, S. Tretyakov

Abstract: We consider single and double grids of periodically arranged wires loaded with distributed reactive impedances as examples of thin metamaterial layers. Currents induced to the wires by a normally incident plane wave are rigorously calculated, and the corresponding dipole moment densities are determined. Using this data and the averaged fields we assign mesoscopic ``effective material parameters'' for thin grid structures that measure the averaged induced

polarizations. The physical meaning of such effective parameters is clarified, and the important differences compared to the results obtained using other methods are discussed. Several illustrative examples are provided.

09:15 *Volumetric single negative metamaterials (invited)*
J. Zehentner, J. Machac
Abstract: This paper presents the results of a study of bulk single negative isotropic metamaterials. Magnetic and electric metamaterials are treated separately. The same approach was used for developing anisotropic particles with magnetic or electric responses. A volumetric isotropic medium was made up consecutively from unit cells with cubic symmetry of the particles, and in parallel by random or quasi-periodic location of particles in the host medium. The consequences of periodic and random distributions of the unit cells in the host medium are given. The experiments confirmed the rightness of the concepts selected here, and have provided media for microwave applications that can be manufactured using inexpensive, currently-available technology.

09:45 *Engineering R-card surface resistivity with printed metallic patterns*
B. Glover , K. Kirschenmann, K.W. Whites
Abstract: Precisely engineered sheet resistivities, especially with spatial variation, have important applications .We experimentally study the effect of inkjet printing arrays of metallic square patches on 370 Ohm/sq carbon loaded poly-imide (Kapton® XC). X-band measurements are presented and results for a 50 Ohm, resistively tapered bowtie antenna are also presented.

10:00 *Effective epsilon and mu from the general scattering matrix of a metamaterial slab (invited)*
S.G. Tikhodeev
Abstract: The retrieval of the effective electric permittivity ε and magnetic permeability μ of metamaterials is discussed, based on the general scattering matrix of a photonic crystal slab in the long wavelength (zero diffraction) case. It is shown that the possibility to describe the electromagnetic response of metamaterial slabs in the near-infrared and optical range by local ε and μ is very limited, and a more general nonlocal description is needed.

08:30 – 10:30 Session 27 – Room VN2
Nonlinear metamaterials (I)

Chairs: M. Scalora

08:30 *Dispersion and nonlinearity engineered metamaterial devices (invited)*
C. Caloz, S. Gupta
Abstract: Several novel prospective ideas for dispersion-based and nonlinearity-based phase engineering in metamaterials are discussed, including pulse delay systems, Talbot generators, real-time Fourier transformers, shock-wave and soliton pulse shaping networks.

09:00 *Static and dynamic control of metamaterials by ferroelectrics and active devices (invited)*
D. Lippens
Abstract: We report on the possibility to tune the dispersion characteristics of metamaterial-based devices taking benefit of the recent advances in ferroelectrics films technology and monolithic integration of varactor-type diodes.

09:30 *Nonlinear pulse propagation in metamaterials: solitons, gap solitons, and the influence of phase matching on pulsed second and third harmonic generation (invited)*
M. Scalora
Abstract: I will talk about nonlinear pulse propagation effects in negative index and metallo-dielectric metamaterials. I will discuss a generalized nonlinear Schrödinger equation describing the propagation of ultra-short pulses in bulk media exhibiting frequency dependent dielectric susceptibility and magnetic permeability. I will also discuss bright and dark gap solitons in a nonlinear, quadratic Fabry-Perot negative index cavity, and the influence of phase matching and competing nonlinearities on second and third harmonic generation in semi-infinite ordinary and negative index materials. Finally, I will address the concept of broad-band optical limiting, and explore salient features of competing nonlinearities, and harmonic generation in metallo-dielectric photonic band gap structures.

10:00 *Parametric amplification of magnetoinductive waves under rotational resonance*
O. Sydoruk, V. Kalinin, E. Shamonina, L. Solymar
Abstract: Parametric amplification of magnetoinductive waves in ring resonators comprising metamaterial elements is studied theoretically under the condition of rotational resonance. The dispersion of magnetoinductive waves is shown to be able to satisfy phase-matching conditions. The achieved amplification gain is estimated. Potential amplification in Magnetic Resonance Imaging is discussed.

10:15 *Non linear frequency and space selective metamaterials*
J. Carbonell, G. Houzet, C. Croenne, E. Lheurette, V. Boria, D. Lippens
Abstract: The advantages afforded by the symmetrical C-V characteristics of Heterostructure Barrier Varactor diodes for the fabrication of active metamaterials are investigated. The studies are conducted by means of full-wave numerical modeling along with large signal circuit simulations. It is believed that the HBV technologies can replace the conventional Schottky diode not only in up and down frequency conversion Left-Handed devices, but also by bringing new functionality in terms of space filtering for unbiased devices.

08:30 – 10:30 Session 28 – Room N13
Cloaking and field transformations (II)
Chairs: U. Leonhardt

08:30 *External cloaking through plasmonic resonance (invited)*
R.C. McPhedran, G.W. Milton, N.A. Nicorovici, L.C. Botten
Abstract: There is much current interest in electromagnetic cloaking of objects, by exploiting structured materials. One approach has been pioneered by J.B. Pendry and U. Leonhardt , and exploits metamaterials to create electromagnetic guiding around the region to be shielded (internal cloaking). A second approach uses electromagnetic resonances in a coated cylinder, designed to have a resonant interaction between its coating and the surrounding material, to quench polarization responses in dipoles within an analytically-determined cloaking region surrounding the cylinder (external cloaking). We have extended the treatment to include interacting systems of polarizable dipoles or quadrupoles, and present animations illustrating that resonant cloaking still works for complicated assemblies of dipoles, or for higher order multipoles, and that the cloaking region does not depend on the details of the entity to be cloaked.

09:00 *Metamaterial plasmonics for optical nanocircuits, cloaking, squeezing energy, and supermicroscopy (invited)*
N. Engheta, A. Alù, M. Silveirinha, J. Li, A. Salandrino, B. Edwards
Abstract: We have been exploring, analytically and with full-wave numerical simulations, the electromagnetic and optical wave interaction with metamaterials and plasmonic media that offer exciting potential

applications for develop-ment of the concept of optical lumped nanocircuit elements, far-field sub-diffraction optical microscopy (FSOM), electromagnetic cloaking, optical nanoantennas, and squeezing light through narrow channels and tight bends. In this talk, an overview of some of our results will be given, and some future research directions in this area will be forecasted.

09:30 *Study of cloakings on cylindrical scatterers: rotation effects, resonant scattering, and resonance shifts (invited)*
C. W. Qiu, L.-W. Li, S. Zouhdi
Abstract: Electromagnetic wave properties in the presence of cloaking on a thin or thick wire medium are investigated. Present theorem can take into account the rotation of core and cloaking, and also arbitrary dielectrics. The present results are thus useful due to the generality especially in studying specific cases such as rotating/stationary and left-handed/right-handed core-cloaking combinations. In particular, the optical resonances due to the plasmons and morphology-dependent resonances (MDR) are examined. Due to the rotation, the resonances are found to shift and the effects of velocity on such phenomena are investigated.

10:00 *Invisibility cloaking and inverse problems*
M. Lassas
Abstract: The recent studies on metamaterials to create invisibility (or “cloaking”) from observations by electromagnetic waves have a close connection to inverse problems. The inverse problems mean the task of finding the unknown parameter functions of a partial differential equation using external measurements. As cloaked objects appear similar to the empty space in measurements, the cloaking can be viewed as creating counter examples for the uniqueness of inverse problems.

10:30 Coffee

11:00 – 12:30 Session 29 – Room N13
Metasurfaces, metaboundaries and enhanced transmission (II) (focused session organized by G. Shvets)
Chairs: G. Shvets

11:00 *Bandgaps and cloaks using soft and hard surfaces (invited)*
P.-S. Kildal
Abstract: The paper explains the similarity between the anisotropic soft surface, and the artificial magnetic conductor and the so-called bandgap surface. It also

explains how the hard surface can be used to make cylindrical objects invisible. This was experimentally proven ten years before the promised theoretical metamaterial cloak published last year.

11:30 *Structured surfaces as optical metamaterials (invited)*
T.A. Leskova, A.A. Maradudin, E.R. Mendez
Abstract: We describe the design of two-dimensional randomly rough surfaces that produce fields scattered from them with specified optical properties that naturally occuring surfaces cannot produce. Examples are presented of surfaces that produce scattered fields with prescribed angular or coherence properties.

12:00 *Holographic metasurfaces realized by curvilinear strip gratings (invited)*
F. Caminita, M. Nannetti, S. Maci
Abstract: The optical concept of holography can been extended to the microwave frequencies offering new potential for antenna applications. The attention to these applications has been recently renewed by the possibility to realize modulated impedances on the basis of artificial magnetic surfaces (metasurfaces), as suggested by Sievenpiper.

11:00 – 12:30 Session 30 – Room N16
Effective material parameters and role of disorder in metamaterials (II) (focused session organized by H. Giessen and K. Whites)
Chairs: H. Giessen, K. Whites

11:00 *Metamaterials - from thin film to bulk*
C. Rockstuhl, T. Zentgraf, T.P. Meyrath, H. Giessen, T. Pertsch, F. Lederer
Abstract: We present investigations of the optical properties of metamaterials in transition from thin-film to layered bulk media. We show that the effective material parameters can be dramatically affected and attribute these changes to the excitation of higher order Bloch modes in the bulk medium.

11:15 *Near perfect absorption by the use of metamaterials (invited)*
A. Lagarkov, V. Kisel
Abstract: The problem regarding top possible (hopefully, total) field suppression of a filamentary source placed above nonuniform impedance plane is discussed. New designs of the electromagnetic field absorbers and resonators are suggested which may be engineered with the use of metamaterials.

11:45 *Mechanical tuning and superlattice structures in metamaterials*
D.A. Powell, I.V. Shadrivov, S.K. Morrison, G.N. Milford, Y.S. Kivshar
Abstract: We study experimentally both transmission and reflection of microwave radiation scattered by metamaterial lattices created by layers of periodically arranged wires and split-ring resonators. We measure the dependance of the metamaterial resonance on the spatial period of the lattice, and demonstrate resonance broadening and splitting for metamaterial superlattice structures.

12:00 *The physics and applications of random lasers (invited)*
D.S. Wiersma
Abstract: In this seminar we will give an overview of the recent developments in this rapidly growing field of research. In particular, we will discuss the possibility of observing coherent effects from random laser sources and make the connection between interference effects, like Anderson localization, and random lasing. Also we will discuss possible applications of random laser materials obtained by infiltrating a liquid crystal – laser dye solution into porous random systems and by synthesis of optically active polymer dispersed liquid crystals. In the latter case we observe that, due to extremely anisotropic light transport, a fascinating anomalous transport regime can be reached for light waves.

11:00 – 12:30 Session 31 – Room N17
Nonlinear metamaterials (II)
Chairs: M. Lapine, A. Boardman

11:00 *Nonlinear plasmonic metamaterials (invited)*
A.V. Zayats
Abstract: Hybridisation of metallic nanostructures capable of supporting surface plasmon excitations with molecular species exhibiting nonlinear optical response allows the development of novel nonlinear metamaterials with enhanced functionalities. In this talk we will discuss various realisations of such metamaterials, including hybridised surface plasmon polaritonic crystals.

11:30 *Towards gain control and diffraction-managed solitons in metamaterials (invited)*
A.D. Boardman, N. King, Yu. Rapoport
Abstract: A discussion of gain control applicable to the THz frequency range is presented together with a brief study of diffraction-managed solitons in metamaterials.

Dynamical simulations illustrate the principles being evolved.

12:00 *The role of local field asymmetry in second-harmonic generation from T-shaped gold nanodimers*
M. Kauranen, B.K. Canfield, H. Husu, J. Laukkanen, B. Bai, M. Kuittinen, J. Turunen
Abstract: Asymmetry in the local fundamental field distribution plays a more important role in second-harmonic generation from T-shaped gold nanodimers with nanogaps than field enhancement due to nanogap size. Strong response arises from the interaction of an asymmetric field distribution with the surface susceptibility of a nanodimer even though the field is not concentrated in the nanogap.

12:15 *Highly nonlinear, bistable transmission of light through a metal-dielectric nanostructure*
J. Herrmann, A. Husakou
Abstract: We numerically study light propagation through a nonlinear metal-dielectric multilayer structure, and predict all-optical bistable switching due to change of the effective dielectric constant from negative (low-transmission state) to positive (high-transmission state) values.

11:00 – 12:30 Session 32 – Room VN2
EBG and Photonic crystals (II)
Chairs: D.A. Pawlak, A. Toscano

11:00 *Filtering properties of periodic and fractal 1-D EBG multilayers (invited)*
F. Chiadini, V. Fiumara, I. Gallina, I.M. Pinto, A. Scaglione
Abstract: Filtering properties of 1-D EBG dielectric structures are investigated. Perturbed periodic and fractal Cantor dielectric multilayers are both shown to be able to work as tunable narrow band filters. Comparison between the filtering features of these multilayer morphologies is also performed, pointing out that fractal structures exhibit filtering properties significantly better than the periodic ones.

11:30 *Characterization of new compact filter based on EBG resonators*
L. Inclan-Sanchez, J.-L. Vazquez-Roy, E. Rajo-Iglesias
Abstract: In this paper a band-stop compact filter based on electromagnetic bandgap (EBG) resonators in a modified version of mushroom type is investigated. The new resonator is obtained by changing the position of

the metallic via of the mushroom from its center to its edge. In this case the forbidden frequency band moves towards lower frequencies. This modified resonator achieves a size reduction in comparison with conventional EBG mushroom shape with centered vias. A numerical characterization of the new resonator and its stop band behavior will be described in the paper. Finally a experimental validation of the proposed compact resonator and measured results of a three-cell filter are presented.

11:45 *Magnetostatic bandgap structures based on periodic arrays of slots and strips*
S.A. Nikitov, S.E. Bankov
Abstract: Theoretical study of two-dimensional magnonic crystal is provided. Magnon band-gap structure for propagating magnetostatic wave was discovered. It is shown that two-dimensional array may be effectively used for control of magnetostatic waves parameters including stop-band forming.

12:00 *Controllable spherical radome in X band using electromagnetic band gap material*
S. Hache, S.N. Burokur, F. Gadot, A. de Lustrac, P. Cailleu, G.-P. Piau
Abstract: We present a spherical Electromagnetic Band Gap (EBG) structure used as a radome with a commutation of the transmitted signal at around 10 GHz. The final goal is to design an electronically active radome, which allows the commutation from an allowed transmitting state to a forbidden one. The structure will consist of metallic parallel wires including active elements (PIN diodes for example). These active elements allow the commutation between an electric state of continuous wires and a state of discontinuous ones according if they are biased or not. We have tested also a commutation between two states of discontinuous wires with different periods of discontinuity. In this study, we consider the EBG radome in a passive mode. Then we have realized and characterized several structures with continuous and discontinuous wires and we have observed a very well agreement between the measurement results and the calculated ones..

12:15 *Wave reflection by a periodic layered metamaterial*
L.M. Lytvynenko, S.L. Prosvirnin
Abstract: We demonstrate a technique involved a reflection matrix of a semi-infinite discrete layered periodic structure to analyzes of electromagnetic properties of a metamaterial.

12:30 Lunch

14:00 Poster Session (II)

Chairs: M. Kafesaki, O. Vendik

66 - N.-H. Shen, M. Kang, T. Lan, J. Chen, H.-T. Wang - *Giant LS near the critical angle in a quasi waveguide structure with a metamaterial embedding*

67 - O. Zhuromskyy, E. Shamonina, L. Solymar - *Dipole waves on nanoparticles and magnetoinductive waves on capacitively loaded loops: driven solutions*

68 - C. Croënne, J.M. Lerat, M.N. Mallejac, O. Acher, D. Lippens - *Retrieval technique by field summation: application to double negative media*

69 - I. Vendik, I. Kolmakova - *Design of stepped-impedance resonators based on a combination of right handed and left handed transmission lines*

70 - I.V. Semchenko, S.A. Khakhomov, A.P. Balmakov - *Electromagnetic model of DNA: observation of polarization selectivity of radiation*

71 - A.M. Lerer, M.I. Mazuritsky, V.V. Makhno, P.V. *Makhno - Theoretical investigation of propagation and emission of CuKa radiation from planar X-ray waveguide's aperture*

72 - B. Sauviac, S. Nemer, B. Bayard, T. Rouiller - *S-Spirals particles for metamaterials applications*

73 - A.-G. Kussow, A. Akyurtlu - *Negative index of refraction metamaterial in the optical regime with randomly distributed nanoparticles*

74 - G. Ruvio, M.J. Ammann - *Radial EBG mushroom-like structures for enhancing axial-ratio performance of CP antennas*

75 - G. Lubkowski, F. Hirtenfelder, R. Schuhmann, T. Weiland - *3D full-wave field simulations of double negative metamaterial macrostructures*

76 - T. Rouiller, B. Sauviac, E. Verney, G. Noyel - *Benefit of a magnetic wall on anisotropic ferrite components*

77 - B. Bandlow, R. Schuhmann - *Analysis of higher order modes in the design of metamaterials by the use of periodic unit cells*

78 - T.V. Teperik, F.J.G. de Abajo - *Spatial transfer of optical evanescent field by a photonic crystal slab: towards a remote biosensing device*

79 - A.G. Zhdanov, A.A. Fedyanin, A.V. Baryshev, A.B. Khanikaev, H. Uchida, M. Inoue - *Two-dimensional plasmon-assisted magnetophotonic crystals*

80 - R. Sainidou, T.V. Teperik, F.J.G. de Abajo - *Optical switching through nonlinearity of nanoparticle arrays*

81 - S.G. Moiseev, S.V. Sukhov - *Optical transparency of composite medium with dissipative and active components*

82 - A.M. Lerer, D.E. Zelenchuk, V.V. Makhno, P.V. Makhno, I.A. Kazmin - *Theoretical modeling of enhanced optical transmission through doubly periodic metallic nanostructures*

83 - C. Rockstuhl, T. Zentgraf, T.P. Meyrath, H. Giessen, T. Pertsch, F. Lederer - *Nanoaperture based metamaterials*

84 - C. Rockstuhl, F. Lederer - *Three-dimensional random photonic materials*

85 - F. Durbin, T. Lagutere, J. Russat, J.-M. Lerat - *A variational approach to the determination of metamaterials model parameters*

86 - S.P. Boruhovich - *Chirality measure model for two- and three-dimensional metamaterials*

87 - A.A. Onushchenko, V.V. Golubkov , V.P. Shepilov, A.A. Zhilin - *Structural features of nano-scaled metamaterials containing PbS nanocrystals*

88 - K. Postava, M. Foldyna, R. Ossikovsky, A. De Martino, S. Veremieiev, J. Pistora - *Effective medium description of nanogratings with general anisotropy*

89 - S. Veremieiev, K. Postava, A. Timofieiev, J. Bouchala, J. Pistora - *Optical properties of inhomogeneous materials consisting of superspherical particles*

90 - A. Kafaratzis, Zhirun Hu - *Envelope solitons in nonlinear left handed transmission lines*

91 - A. Maidikovski, J. Yongseok, S. Magnitskiy, N. Nagorsky, A. Ejov, F. Sychev - *Nonlinear optical microscopy of porous silicon layers*

92 - A. Jooß, H. Hohnle, H. Kumric, W. Kasparek, U. Stroth - *Plasma as a medium in metamaterials*

93 - R.H. Tarkhanyan, D.G. Niarchos - *Negative refraction of electromagnetic waves in birefringent periodic multilayered nanostructures*

94 - K. Aydin, E. Ozbay - *Influence of disorders on transmission and reflection characteristics of microwave metamaterials*

95 - H. Kettunen, H. Wallen, A. Sihvola - *Electric response of a small negative-permittivity hemisphere*

96 - R. Yusoff, K. Hingerl - *Electromagnetic propagation of conducting polymer/Ag/dielectric-material interface*

97 - A.M. Lerer, V.V. Makhno, P.V. Makhno, A.A. Yachmenov - *The investigation of metallic nanostructures using the method of approximate boundary conditions*

98 - A.B. Evlyukhin - *Micro-optical devices for surface plasmon polaritons on the base of nanoparticle structures*

99 - R. Vlokh, O. Krupych, Yu. Vasylkiv, D. Adamenko, O.G. Vlokh - *Small-angular polarimetric magnetooptical mapping and the problem of magnetogyration*

100 - G. Guida, J.J. Bonnefois, A. Priou - *Effect of two photon absorption on Kerr nonlinear photonic band gap materials*

101 - Z. Li, E. Ozbay, H. Chen, J. Chen, F. Yang, H. Zheng - *A compact and efficient antireflection structure designed for two-dimensional photonic crystals by an effective immittance method*

102 - P.J. Ferrer, J.M. Gonzalez-Arbesu, J. Romeu - *Metamaterial slabs with double side PMC response*

103 - C.-Y. Wu, S.-H. Yeh, H.-H. Lin - *High gain metamaterial antenna radome for 2.5-GHz band WiMAX operation*

104 - P. Colman, L. Santandrea, O. Ouchetto, S.Zouhdi - *Parallel computing for metamaterials modelling*

105 - M.G. Banciu, N. Militaru, G. Lojewski - *Compact planar microwave devices by using metamaterials*

106 - A.A. Radkovskaya, F. Hesmer, E. Tatartschuk, O. Zhuromskyy, M. Shamonin, T. Hao, C.J. Stevens, G. Faulkner, D.J. Edwards, E. Shamonina, L. Solymar - *Electric and magnetic contributions to the near field coupling between resonators of the split ring type*

107 - A. Monorchio, S. Genovesi, E. Carrubba, G. Manara - *Design of printed FSS for compact and bandwidth-enhanced metasurfaces*

108 - B. Kante, S.N. Burokur, A. Ourir, A. de Lustrac - *Left-Handed asymmetric monolayer metamaterial under normal-to-plane propagation*

109 - G. Brucoli, L. Martin-Moreno, S.I. Bozhevolnyi, F.J Garcia-Vidal, A.B. Evlyukhin - *Surface plasmon polariton scattering by finite-sized nano-objects*

110 - A. Monorchio, E. Carrubba, G. Manara - *Design of a metamaterial superstrate for enhancing directivity of low-profile antennas*

111 - B. Kante, S.N. Burokur, F. Gadot, A. de Lustrac - *New design of double negative metamaterial for IR wavelengths*

112 - C. Kossiavas, J.-L. Dubard - *Optimization of an artificial magnetic conductor for the design of wide band ultra compact antennas*

113 - Y. Qin, R. Liu, Q. Cheng, W. Tang, T.J. Cui - *Novel bandstop filtering waveguide based on complimentary split ring resonators*

114 - W. Abdouni, A.-C. Tarot, E. Akmansoy, A. Sharaiha - *Miniaturized patch antenna on an artificial magnetic substrate*

115 - P.A. Belov, S. Tse, Y. Zhao, Y. Hao - *Transmission of images into far-field-zone with subwavelength resolution*

116 - W. Khunsin, G. Kocher, S.G. Romanov, C.M. Sotomayor Torres - *Noise effect: Crystalline ordering improvement in the fabrication of self-assemble photonic crystals*

117 - M. Bergmair, K. Hingerl - *Band structure and coupled surface plasmons in onedimensional, frequency dependent photonic crystals*

118 - P. Melezhik, A. Poyedinchuk, N. Yashina, G. Granet, S.Tretyakov - *Resonance scattering of electromagnetic waves by layers of metamaterials with periodic boundaries or with grating*

119 - K. Moon, M. Cho, J. Kim, S. Lee, S. Kim, I. Park, H. Han - *Nearly flat impurity bands of photonic crystals with periodic vacancy defects*

120 - D.A. Pawlak, K. Kolodziejak, K. Rozniatowski, R. Diduszko, I. Vendik, K. Aydin, E. Ozbay - *TiO_2-$SrTiO_3$ eutectic with ferroelectric phase– growth and characterization*

121 - D. Dubreuil, P. Coleman, M. Pate , J.-P. Ganne - *Studies of metal-dielectric periodic structures in the diffraction regime: modelling and measurements*

122 - K. Kurihara, M. Ishii, T. Shioga, J. Baniecki, K. Yamanaka - *Doping effects on the electric properties of (Ba,Sr)TiO_3 tunable thin film capacitors*

123 - V. Kisel - *Antenna screen design based on the use of metafilms*

124 - O. Kuvandikov - *Fractals in magnetic and meta materials*

125 - T. Sengor - *Properties of a non-planar metamaterial elements: ring resonators on a spherical substrate*

126 - T.F. Gundogdu, N. Katsarakis, M. Kafesaki, G. Konstantinidis, A. Kostopoulos , E.N. Economou, C.M. Soukoulis - *Left-handed behaviour in multilayer system of short-slab pairs and continuous wires at ~3 THz*

127 - K.B. Alici, F. Bilotti, E. Ozbay - *Experimental demonstration of metamaterial loaded antennas*

128 - R. Qiang, J. Chen, F. Capolino, D. Jackson, D.R. Wilton - *The ASM-FDTD method and its application to PBG structures, metamaterials, and plasmonic structures*

129 - M. Gorkunov, M. Osipov – *Electrical tunability of wire medium immersed in liquid crystal*

15:00 – 16:30 Session 33 – Room N13

Modelling, fabrication and characterisation techniques for plasmonics and metamaterials (I) (focused session organized by D. Lippens)

Chairs: D. Lippens

15:00 *The emergence of metamaterial devices: applications at terahertz frequencies (invited)*
W.J. Padilla, J.F. O'Hara, H.-T. Chen, J.M.O. Zide, A.C. Gossard, C. Highstrete, M. Lee, A.J. Taylor, R.D. Averitt

Abstract: Recent research into a new class of artificial composites, called metamaterials, has seen an enormous amount of growth. The functional electromagnetic response of metamaterials arises from the ability to tune the resonant electric and/or magnetic response through design of subwavelength resonator elements. Furthermore, these resonant phenomena can be adjusted to occur at nearly any sub-optical region of the electromagnetic spectrum.

15:30 *Active metamaterials: Applications from broad bandwidth efficient electrically-small antennas to coated nano-particle lasers (invited)*
R.W. Ziolkowski, A. Erentok, J.A. Gordon
Abstract: A brief review of the use of active elements in microwave metamaterial-based/inspired electrically-small antenna systems and in optical electrically-small coated nano-particle scattering systems will be given. It will be demonstrated that active metamaterials could improve the bandwidth performance and overcome the losses of metamaterial-based/inspired efficient electrically small antennas. It will also be demonstrated that the inclusion of gain elements in the core of electrically-small metal coated nano-particles can be used in resonant scattering configurations to overcome the large losses associated with metals in the visible portion of the optical spectrum and to achieve a lasing state.

16:00 *Composite right/left handed (CRLH) transmission lines based on complementary split rings resonators (CSRRs) and applications (invited)*
M. Gil, J. Bonache, J. Garcia-Garcia, F. Martin
Abstract: In this paper, it is demonstrated that resonant-type metamaterial transmission lines based on series (capacitive) gaps and complementary split rings resonators (CSRRs) loading a host microstrip line exhibit a composite right/left handed (CRLH) behaviour and can, indeed, be balanced. These balanced lines typically exhibit a broad bandwidth which is of interest for high pass and ultra wide band (UWB) band pass filter applications, among others.

15:00 – 16:30 Session 34 – Room N16
Analysis and synthesis of metamaterials using numerical modeling (I) (special session organized by R. Mittra and Y. Hao)
Chairs: R. Mittra, Y. Hao

15:00 *On the synthesis of CRLH-TL based leaky wave antennas (invited)*
A. Rahman, Y. Hao, C.G. Parini
Abstract: Left-handed (LH) transmission-line (TL) is a subset of metamaterials and can be made by cascading a pair of inter-digital capacitor and stub inductor. The composite right-left handed (CRLH) structure developed from LH-TL has its promising application in the design of leaky wave antenna with a superior frequency scanning capability. However, a major problem regarding the design of CRLH-TL based leaky wave antenna is the lack of a generic design procedure.

15:30 *Efficient analysis of the canalization effect obtained with a Fabry-Perot wire medium (invited)*
X. Radu, X. Dardenne, C. Craeye
Abstract: In a first part, we present an efficient numerical analysis of a wire medium lens using the Array Scanning Method (ASM) and its interest to compute the structure's point spread function. In a second part, we simulate realistic canalization effects with a wire medium lens, and with a magnetic source placed in a dielectric. Both simulation results confirm the capacity of the medium to canalize images even in the presence of dielectric material.

16:00 *Analysis and design of coupled frequency selective surfaces as a novel kind of waveguide filter (invited)*
C. Amabile, F. Costa, A. Monorchio, E. Prati
Abstract: The design of coupled frequency selective surfaces for the realization of transverse planar filters in waveguides is addressed. Due to the boundary conditions imposed by the metallic waveguide walls, the filter design is reduced to the analysis of an infinite FSS illuminated by a set of plane waves with frequency-dependent incidence angle. This allows us to use a fast and efficient MoM solver to analyze its properties. The filters are designed by using a genetic algorithm to operate at 30 GHz.

15:00 – 16:30 Session 35 – Room N17
High impedance surfaces and thin layers
Chairs: V. Varadan, A. Vinogradov

15:00 *Enhancing bandwidth of ultra-thin absorbers by using resistive high-impedance surfaces (invited)*
A. Monorchio, F. Costa, G. Manara
Abstract: A novel approach for the design of thin wideband radar absorbers is presented. A properly dimensioned resisitive high impedance surface is employed that, despite of a very small thickness of the structure, reveals able to perform a wideband absorption of incident waves.

15:30 *Characterisation and measurements of a multilayer high-impedance surface at W-band*
D. Chicherin, S. Dudorov, D. Lioubtchenko, V. Ovchinnikov, A.V. Raisanen
Abstract: A multilayer high-impedance surface was designed, analytically studied, simulated and measured

at W-band. The loss tangent of the dielectric affects the impedance of the structure but not the resonant frequency. We have performed a detailed characterisation, loss analysis and feasibility study of the W-band high-impedance surface.

15:45 *Study of the influence of a layer of metamaterial over the performances of a coplanar isolator*

E. Verney, S. Kirouane T. Rouiller, F. Gambou

Abstract: We present an application of metamaterials as a resonant dielectric layer, used in isolators with thin layers of magnetic material to confine the fields in the active layer. A theoretical precedent study has shown that such a layer was of interest for that purpose and we present here the practical measurements of the parameters of the resonating S-grid layer.

16:00 *Artificial magnetic conductors realized by wideband frequency selective surface elements on a grounded dielectric slab*

G. Gampala, A.B. Yakovlev

Abstract: Artificial magnetic conductors are realized by periodic frequency selective surface elements printed on a grounded dielectric slab. New designs of FSS elements with a wideband response are proposed for the realization of artificial magnetic conductors behaving as high impedance surfaces. In particular, unclosed L-shaped rectangular loops and unconnected cross elements (cross with a slot at the center) are used in the design of high impedance surfaces with wideband characteristics. A theoretical study based on the equivalent circuit of self-resonant grid model is presented for the analysis of reflection phase characteristics.

16:15 *Electromagnetic response of nanocarbon-based composites to microwaves*

S.A. Maksimenko, P.P. Kuzhir, K.G. Batrakov, A.V. Gusinski, V.V.Ruhavets, D.S. Bychanok, O. Shenderova, V.L. Kuznetsov, S.I. Moseenkov, A. Mayer, R. Langlet, Ph. Lambin

Abstract: New experimental results are presented on the microwave characterization of a novel technological material- onion-like carbon polymer films. The electromagnetic response has been studied in Ka-band by free-space technique and demonstrates high potential of these composites as microwave absorbers. Modeling of static polarizability of isolated fullerenes and OLC is used for evaluation of effective parameters of composites.

15:00 – 16:30 Session 36 – Room VN2
Magnetic materials
Chairs: R. Marques, E. Semouchkina

15:00 *Effect of loss on spectra and properties of eigenwaves in imperfect metal films and magnetised semiconductor-dielectric structures (invited)*
A.G. Schuchinsky, X. Yan
Abstract: Impact of loss on spectra and properties of eigenwaves including plasmons, magnetoplasmons, dynamic and complex waves was explored using the rigorous solution of the full dispersion equations and field and Poynting vector distributions of individual modes. It is demonstrated that actual losses qualitatively alter the spectrum and properties of eigenwaves.

15:30 *Anisotropic metamaterial in planar technology: phenomena, model, and particle resonances*
G. Donzelli, F. Capolino, A. Schuchinsky
Abstract: The features of the two novel arrangements of anisotropic metamaterials have been explored in detail. It has been found that both structures exhibit negative refractive index performance. The equivalent network models of individual particles in the array arrangement have been devised and applied to identification of the specific types of resonances.

15:45 *Review on magnonic and phononic crystals*
S.A. Nikitov, Yu.A. Filimonov, I.V. Lisenkov, R.S. Popov, S.L. Vysotskii
Abstract: The results of theoretical and experimental investigation of magnetostatic spin wave (MSW) propagation in magnonic crystals (MC) and elastic wave propagation in phononic crystals (PhC) are reviewed. Magnonic crystals are analogues of photonic crystals consisting of layers of magnetic material in which propagating spin waves form a stop bands in microwave frequency range. Phononic crystals, respectively, possess acoustic band gaps for propagating ultrasound or hypersound. Respective crystals we developed and their physical properties studied.

16:00 *Numerical calculation for magnetic permeability of ferromagnetic nanocomposites*
C. Mitsumata, S. Tomita
Abstract: In this contribution we carried out micromagnetics calculations for the magnetic permeability of ferromagnetic nanocomposites. Structures of nanocomposites for left-handed meta-materials with negative permeability will be discussed.

16:15 *Direct integration of the constitutive relations for modeling dispersive metamaterials using the finite difference time-domain technique*
J. Manzanares-Martinez, J. Gaspar-Armenta
Abstract: We present results for propagation of femtosecond light pulses impinging a dielectric and magnetic dispersive media. We describe a new integration procedure of ε(ω) and μ(ω) functions based on the analytical solutions of the temporal and frequency integrations. We explore the situations where the combination of both functions are negative and present metamaterial characteristics. We propose animated visualizations in order to illustrate the most interesting physical characteristics.

16:30 Coffee

17:00 – 18:30 Session 37 – Room N13
Modelling, fabrication and characterisation techniques for plasmonics and metamaterials (II) (focused session organized by D. Lippens)
Chairs: D. Lippens

17:00 *The field summation method: an efficient route to determine epsilon and mu on metamaterials (invited)*
O. Acher, J.-M. Lerat, N. Mallejac
Abstract: The Field Summation Method allows the determination of the effective parameters of composite materials, including metamaterials, from appropriate averages of the local field within the unit cell. This method can be used to extract the effective parameters using an electromagnetic simulation software. It is also appropriate to derive analytical values of the effective parameters, as illustrated on different examples. The method is expected to be useful to investigate negative index media and gradient media.

17:30 *Nonlinear phenomena in metamaterials: from theory to applications (invited)*
M. Lapine, M. Gorkunov
Abstract: This review presentation is devoted to nonlinear metamaterials. Various phenomena and potential applications will be discussed, and future prospects will be highlighted. Particular attention will be paid to the history of the subject and to the peculiarities of analysis and implementation of nonlinear metamaterials.

18:00 *Prospects for left-handed nonlinear transmission line media (invited)*

A.B. Kozyrev, D.W. van der Weide

Abstract: We investigate wave propagation phenomena that occur in left-handed transmission line media. These include higher harmonic generation, parametric generation and amplification, as well as subharmonic generation. We also outline potential applications for left-handed nonlinear transmission lines.

17:00 – 18:30 Session 38 – Room N16

Analysis and synthesis of metamaterials using numerical modeling (II) (special session organized by R. Mittra and Y. Hao)

Chairs: R. Mittra, Y. Hao

17:00 *Field simulation based analysis and development of metamaterial structures (invited)*

E. Semouchkina, M. Lanagan, G. Semouchkin, R. Mittra

Abstract: A rigorous analysis of electromagnetic field distributions in different types of metamaterials simulated by using the Finite Difference Time Domain (FDTD) method has provided results that prompt us to reconsider some existing views on metamaterials related phenomena, in particular, on the mechanism of wave propagation in conventional metamaterials and on the subwavelength tunnelling phenomenon in waveguides loaded by resonators. All-dielectric metamaterial structures are also analysed and an opportunity to obtain left-handed properties by using an array of identical dielectric resonators is dem-onstrated. The study of the wire-pair resonators, proposed recently to obtain negative refraction in optical range, has revealed that their response is not related to double negativity of the effective medium parameters. An alternative unit cell able to provide for double negativity is described.

17:30 *A case for rigorous numerical simulation to model antenna/metamaterial composites (invited)*

R. Mittra, L.-C. Ma, N. Farahat

Abstract: Metamaterials have attracted considerable recent attention because they appear to offer much potential for improving the performance of electromagnetic devices, such as microwave circuits and antennas. The usual approach to modeling metamaterials is to begin with a thin slab of the artificial dielectric, which typically has metallic or dielectric inclusions, embedded in a background dielectric medium whose material parameters are different from those of the inclusions.

18:00 *Design of plasmonic THz metamaterials (invited)*
S.A. Maier
Abstract: For single interfaces, plasmonics offers sub-wavelength electromagnetic mode confinement only at frequencies that are an appreciable fraction of the intrinsic plasma frequency of the conductor. For metals, this implies that highly confinement modes can only be achieved at visible or near-infrared frequencies. At lower frequencies, the constraints for the confinement of optical modes below the diffraction limit are far more challenging, and at far-infrared frequencies in the technologically important THz regime, another approach is needed. We will show that the periodic structuring of highly (even perfectly) conducting surfaces allows sub-wavelength energy confinement via the establishment of spoof surface plasmon polaritons, designer electromagnetic surface modes.

17:00 – 18:30 Session 39 – Room N17
Modelling, extraction and measurements
Chairs: C. Simovski

17:00 *Extraction of metamaterial properties from measured S-parameters – effects of measurement accuracy, assumed constitutive models, periodicity and randomness (invited)*
V.V. Varadan
Abstract: The focus of this paper is the extraction of metamaterial 'effective' properties from measured S-parameters. Resonance and periodicity result in strong dispersion close to the resonance frequencies. This paper studies the effects of measurement accuracy, the assumed constitutive model (isotropic, anisotropic, magneto-electric, chiral, etc.), the size of the unit cell and the thickness of the sample used on the metamaterial properties.

17:30 *A review on metamaterial activities at LEMA-EPFL (invited)*
F. Bongard, J. Perruisseau-Carrier, A.K. Skrivervik, J.R. Mosig
Abstract: We present an overview of metamaterial activities performed at LEMA-EPFL. First, we describe an improved retrieval procedure which allows obtaining dyadic equivalent medium parameters from Fresnel-type reflection and transmission coefficients obtained for oblique incidences. Then, we present the current state of the work on a volumetric metamaterial based on the transmission line approach that could be used as material filling for antenna applications. Finally, we present various contributions to the CRLH-TL structure,

especially its realization using micromachining techniques as well as MEMS-reconfigurable implementations.

18:00 *Left-handed transmission line for permittivity measurements*
H. Maune, M. Schußler, A. Penirschke, C. Damm, R. Jakoby
Abstract: This paper discusses an application of left-handed transmission lines for sensitive permittivity sensors. Since the sensitivity of a LH-sensor depends on the electrical length it can easily be adjusted by the number of unit-cells. The presented sensor principle promises the possibility to design sensors in a wide range of applications such as gas/solids flow measurement and other in process monitoring.

18:15 *3D isotropic metamaterial based on dielectric resonant spheres*
M. Odit, I. Vendik, O. Vendik
Abstract: Artificial isotropic double negative material based on bispherical particles is considered. Improved analytical diffrac-tion model for describing effective parameters is introduced. New model takes into account mutual electromagnetic interaction between dielectric spherical particles. Distribution of the electromagnetic wave out-side the sphere was calcu-lated. Full-wave analysis taking into account symmetry of the structure has been implemented. Experimental results are presented.

17:00 – 18:30 Session 40 – Room VN2
Educational aspects of metamaterials
Chairs: E. Shamonina, E. Ozbay

17:00 *Metamaterials and photonic crystals: analogies and differences (invited)*
T.F. Krauss
Abstract: We discuss some of the communalities, differences and limitations of the metamaterial and the photonic crystal approach for the creation of desired optical properties.

17:30 *Negative refraction as a source of some educational problems*
V.G. Veselago
Abstract: Not available.

17:45 *Realization of an electromagnetic invisibility cloak by transmission-line networks*
P. Alitalo, L. Jylha, A. Karttunen, O. Luukkonen, G. Molera, H. Rimminen, M.

Vaaja, J. Venermo, V. Podlozny, A. Sihvola, S. Tretyakov, H. Wallen

Abstract: We consider a novel realization of an invisibility cloak for the microwave region. The cloak is cylindrically shaped and consists of a transmission-line network which is matched to free space. In the cloak the electromagnetic waves propagate inside the transmission lines and therefore the space between them is left undetected by the incident field.

18:00 *Electromagnetic cloaking with a mixture of spiral inclusions*

M. Asghar, I. Hakala, J. Jantunen, H. Kettunen, J. Qi, A. Varpula, K. Guven, I.V. Semchenko, S.A. Khakhomov, R. Gonzalo, E. Ozbay, V. Podlozny, A. Sihvola, S. Tretyakov, H. Wallen

Abstract: In this presentation a new realization for a metamaterial electromagnetic invisibility cloak is introduced. A cylindrical cloak can be implemented by an annular metamaterial region consisting of a racemic mixture of spiral-shaped, chiral inclusions. The geometry of the spirals makes it possible to create a composite material with equal permittivity and permeability along the spiral axis, which is a significant step towards the actual construction of a fully-functional electromagnetic cloaking device in practice. The work has been done as a student project work within the post-graduate course “Metamaterials in Electromagnetics and Radio Engineering”, http://www.tkk.fi/Yksikot/Sahkomagnetiikka/kurssit/S-96.4620/

18:15 *On a method of teaching the principles of metamaterials in the educational sphere of the Republic of Uzbekistan*

E.U. Arzikulov

Abstract: Development of science and technology always sets new tasks and problems for the teaching methods of various disciplines in different levels of educations. This is also characteristic for the physical studies. A synthesis of new materials with new and unique properties forces scientists to reconsider the formed conceptions, which are based on classical ideas or classical laws. It is well known that meta-materials possess absolutely new properties.

18:30 Closing ceremony

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