17th - 22nd **September**

Metamaterials 2012

St. Petersburg, **Russia**

6th International Congress on Advanced Electromagnetic Materials in Microwaves and Optics

Programme

http://congress2012.metamorphose-vi.org

St. Petersburg, **Russia**

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Metamaterials 2012

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St. Petersburg, **Russia**

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Metamaterials 2012

Foreword

With our great pleasure we welcome you to the 6th International Congress on Advanced Electromagnetic Materials in Microwaves and Optics (Metamaterials 2012) in the great Russian city of St. Petersburg. This event is organised by the Virtual Institute for Artificial Electromagnetic Materials and Metamaterials (Metamorphose VI) jointly with the National Research University of Information Technologies, Mechanics and Optics (ITMO) and St. Petersburg Electrotechnical University (ETU).

The Congress series, initiated by the European Network of Excellence Metamorphose, is widely recognised as the prime event in the metamaterial community. Owing to the multidisciplinary nature of artificial electromagnetic materials, the Congress brings together researchers and engineers working in material science and electromagnetic theory, optics and microwaves, physics of solids and acoustics, nanofabrication and device design. This provides a unique forum for presenting the latest results in the explosively expanding fields of metamaterials and their applications. The good traditions of the Congress, established by its preceding editions, held in Rome (2007), Pamplona (2008), London (2009), Karlsruhe (2010) and Barcelona (2011), will be further strengthened and developed by the St. Petersburg event.

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

The Congress is traditionally accompanied by the European Doctoral School on Metamaterials. This year school event is devoted to tunable and reconfigurable metamaterials.

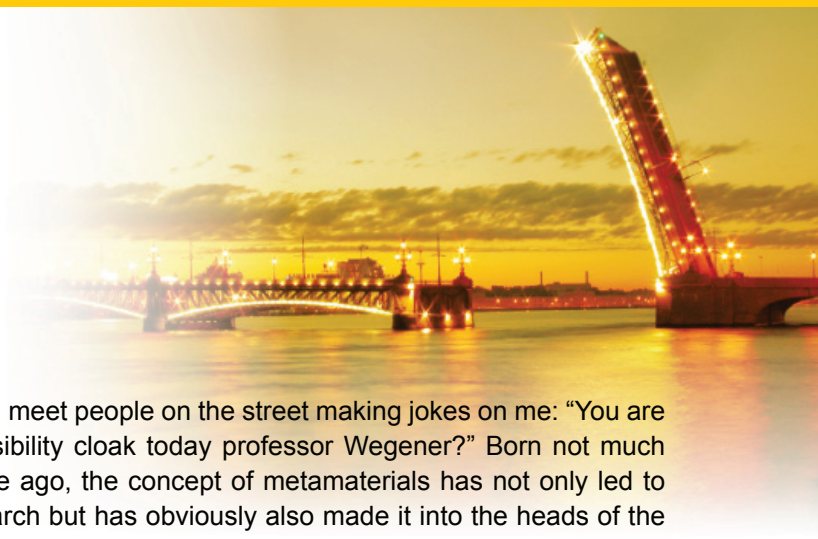
We would like to thank our sponsors and all colleagues who have helped with the Congress organisation and offered their scientific and technical contributions.

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

Sergei Tretyakov, General Chair

Alexander Schuchinsky, General Co-Chair

Filiberto Bilotti, Chair of the Steering Committee



St. Petersburg, **Russia**

Preface

Every once in a while I meet people on the street making jokes on me: “You are not wearing your invisibility cloak today professor Wegener?” Born not much more than one decade ago, the concept of metamaterials has not only led to a vibrant field of research but has obviously also made it into the heads of the general public. However, there is much more to metamaterials than just perfect imaging and invisibility cloaking. The idea of designing and realizing artificial materials with tailored and unusual effective properties is much broader than that and will likely fuel science for quite some more years to come. I love the creative designer aspect – it’s almost a bit like arts.

As an experimentalist working in optics, I have very much enjoyed learning many things from colleagues in the microwave, the plasmonics, or the materials-science community and I have also taken pleasure in hearing about emerging areas like acoustic metamaterials. I love listening to crazy new ideas of theorists, and theorists, I suppose, get motivated by the amazing progress in micro and nano-fabrication of three-dimensional architectures. All of these aspects come together in the 2012 congress on Advanced Electromagnetic Materials in Microwaves and Optics, which is the 6th of its kind and thus the oldest congress in this area. On this basis, I immediately said “yes” when the General Chairs approached me regarding becoming the 2012 Technical Program Committee (TPC) Chair.

The 2012 congress comprises 3 Invited Plenary Talks, 3 Invited Keynote Talks, 37 Invited Talks, 8 Extended Oral Talks, 189 accepted oral and 88 accepted poster presentations grouped in 3 poster sessions, 45 parallel sessions, and 2 plenary sessions. Altogether this makes more than 300 contributions to the congress from all around the globe. The selection has not been an easy one and I should like to take this opportunity to express my sincere and deep gratitude to all members of the Technical Program Committee (TPC) for their hard and effective work as well as for all the fun that we had. Many thanks also go to the numerous reviewers without whom the TPC decisions would not have had a sound and fair basis.

Now that you and I are reading this booklet in St. Petersburg, the fun part starts. Let us all enjoy hearing about the latest state-of-the-art in the field and then go back home loaded with tons of new ideas.

I wish you all a wonderful stay in St. Petersburg!

Martin Wegener, Chair of the Technical Program Committee

Metamaterials 2012

Welcome Message

Dear Colleagues!

I am very glad to welcome you to the 6th International Congress on Advanced Electromagnetic Materials in Microwaves and Optics, a conference that has been consolidated as an international reference meeting in the field of Metamaterials, covering the whole range of the electromagnetic spectrum (also including acoustics and other emerging areas) and a wide range of disciplines.

This year the Congress is held in St. Petersburg, Russia and is hosted by two famous Russian technical universities: St. Petersburg National Research University of Information Technologies, Mechanics and Optics (ITMO) and St. Petersburg Electrotechnical University (ETU). The Congress takes place in Hotel Moscow situated in the heart of St. Petersburg at the central street — Nevsky prospect.

St. Petersburg is a well-known historical and touristic city. The beginning of autumn is usually very beautiful in many parks of St. Petersburg and its suburbs such as Pushkin, Pavlovsk or Peterhof. You can also visit the Hermitage — world-famous museum of art. St. Petersburg has many rivers and channels. The glance over the city from water is incredible!

We hope we managed to create excellent atmosphere to interchange and discuss your ideas among the participants of the Congress and to meet your colleagues and friends. Also, we believe that in spite of rich technical program of the Congress you will have an opportunity to enjoy your stay in our beautiful city St. Petersburg!

To conclude, I would like to thank all the people of both Universities, Metamorphose Virtual Institute, sponsors and supporting companies for their contribution to make this conference a success!

Yours Sincerely,

Pavel Belov, Chair of the Local Organizing Committee

St. Petersburg, **Russia**

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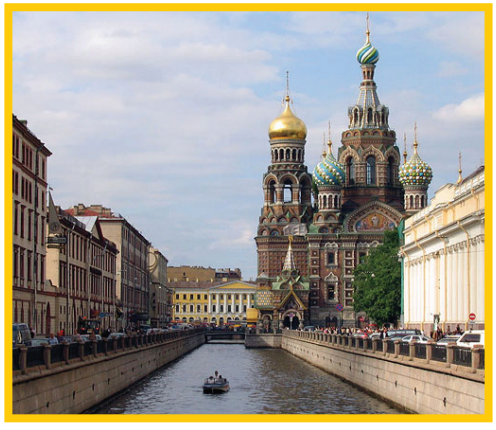
Metamaterials 2012

Location



St. Petersburg is situated in the North-West of Russia in the Neva river delta on the Eastern coast of the Gulf of Finland. The city is located on 44 islands formed by the Neva river and 90 more rivers and canals.

It is Russia's second largest city after Moscow with almost 5 million people population. St. Petersburg is a major European cultural center, and also an important Russian port on the Baltic Sea.

One of the world's most beautiful cities, St. Petersburg has all the ingredients for unforgettable travel experience: high art, lavish architecture, an extraordinary history and rich cultural traditions that have inspired and nurtured some of the modern world's greatest literature, music, and visual art. One of the most famous museums in the world – the Hermitage, which collection includes more than three million works of art and artefacts of the world culture is situated in St. Petersburg. You can see classical russian ballet in the Mariinsky theatre, which was visited by russians tsars in 18 and 19 centuries.

The Conference Venue is located in the city center on the main street Nevskiy Prospect close to one of the main orthodox monastery of the city Aleksandro-Nevskaya Lavra. It is well connected with other part of the city by underground and other kinds of public transport.

St. Petersburg, **Russia**

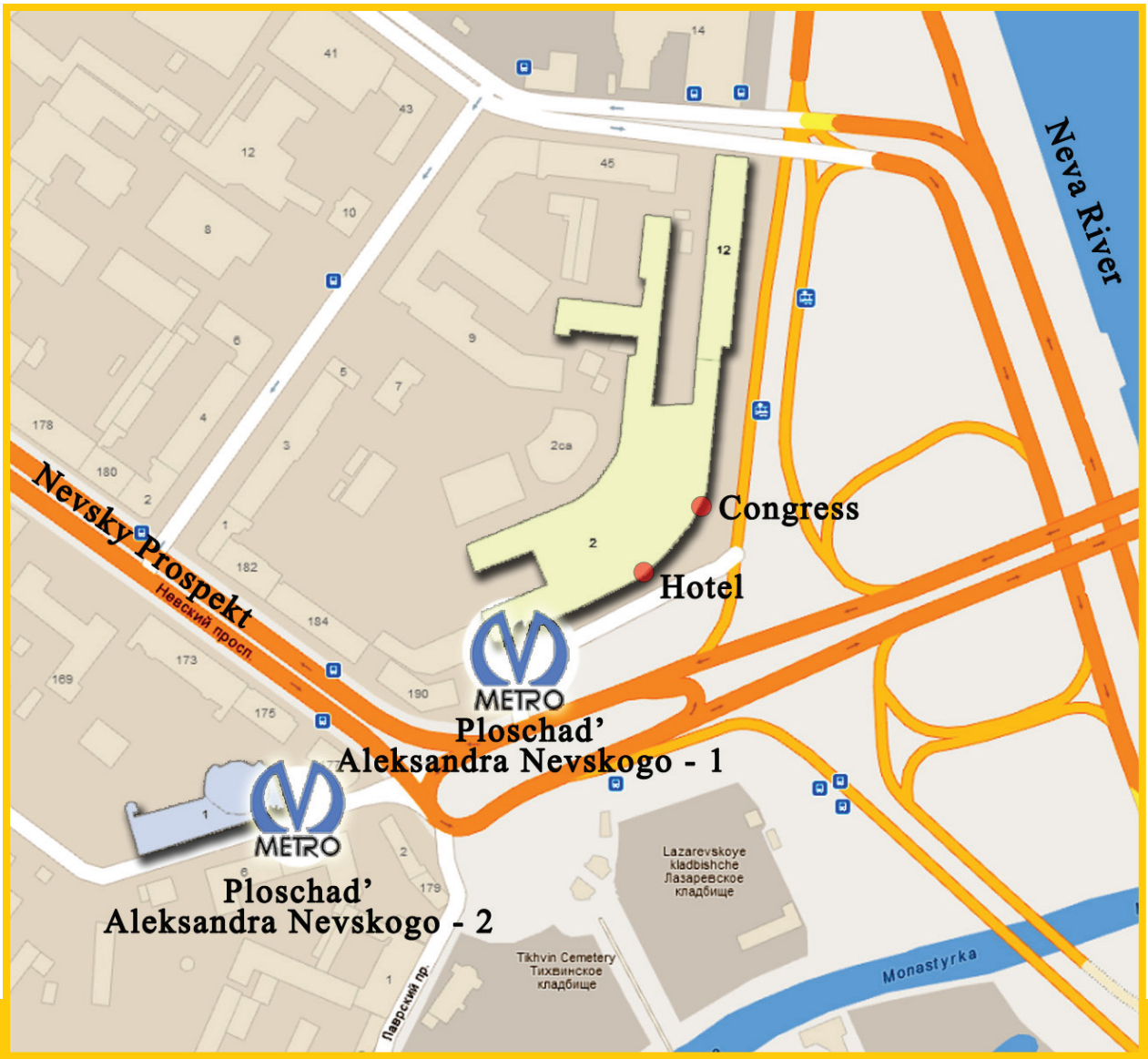
Conference Venue

The Congress activities will take place at the ground and first floors of the conference-hall area of Hotel Moscow.

Registration will take place at the ground floor at the second entrance (from the river side).

Three conference halls: Kremlyovsky, Tverskoy, and Nevsky are situated on the first floor, as well as coffee-break and poster session area.

Plenary sessions, lunches, and the conference dinner (banquet) will be held in the hotel restaurant at the ground floor.



Metamaterials 2012

St. Petersburg Attractions

The Peter and Paul Fortress

The Peter and Paul Fortress was founded by Peter the Great on a small island in the Neva delta on May 27, 1703 (May 16 according to the old calendar), which is now marked as St. Petersburg's City Day. In the middle of the fortress stands the impressive Peter and Paul Cathedral, the burial place of all the Russian Emperors and Empresses from Peter the Great to Nikolay II. On top of the cathedrals' gilded spire stands a magnificent golden angel holding a cross. This weathervane is one of the most prominent symbols of St. Petersburg, and at 404 feet tall, the cathedral is the highest building in the city.

The Stock Exchange and Rostral Columns

The Magnificent architectural ensemble built after the turn of the 19th century on Vasilevsky Island - just across the Neva river from the beautiful Winter Palace. Enjoy the Stock Exchange's grandiose columns, reminiscent of the architecture of ancient Greece, and the impressive red Rostral Columns, originally built as beacons for ships navigating the waters of the Neva river.

St. Isaac's Cathedral

Built in the first half of the 19th century by the French architect Auguste Montferrand, this enormous cathedral features impressive solid granite columns, incredibly detailed mosaic icons, a magnificent gilded dome and the most impressive views of the city from its high colonnade.

The Hermitage

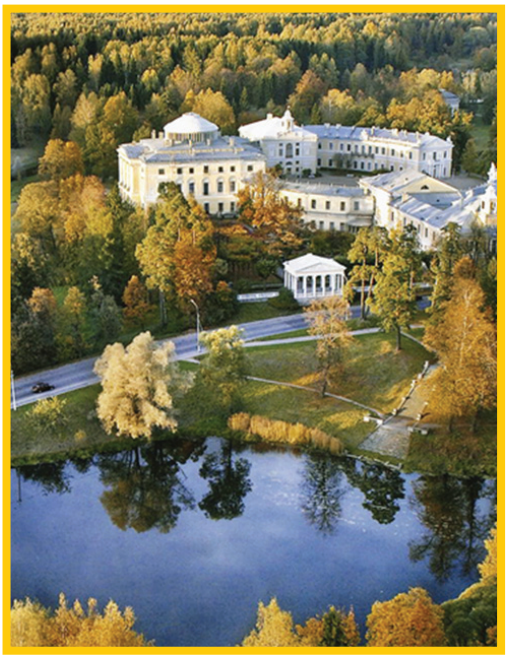
One of the largest and most impressive art collections in the world. The Hermitage was founded on the original 18th century collection of Empress Catherine the Great and is housed in the magnificent baroque Winter Palace and three other majestic buildings along the Neva River embankment.

St. Petersburg, **Russia**

St. Petersburg Attractions

Peterhof

One of St. Petersburg's most famous and popular visitor attractions, the palace and park at Peterhof (also known as Petrodvorets) are often referred to as «the Russian Versailles».



Pavlovsk

Pavlovsk is the youngest of the grand Imperial estates around St. Petersburg. Named in honour of Tsar Pavel, this fine neo-classical palace and its extensive landscaped gardens are stamped with his taste and even more so with that of his wife, the German-born Maria Fedorovna.

Pushkin

The town of Pushkin is St. Petersburg's most charming suburb. Renamed in Soviet times to honour Russia's greatest poet, the town has numerous sights connected to Alexander Sergeevich, including a museum in the former Imperial Lyceum, where he was schooled. Catherine palace in Pushkin, with its seemingly endless rows of gilded atlantes, has some of the most extravagant interiors in Europe, including the world-famous Amber Room.

Metamaterials 2012

Sunday, 16th September

16:00 – 18:00	Sunday registration	
18:00 – 20:00	Welcome reception	Kremlyovsky hall

Monday, 17th September

07:30 – 09:15	Monday registration	
09:15 – 09:30	Opening ceremony	

Oral sessions (Monday morning I)

09:30 – 11:00	Optical and UV Metamaterials	Kremlyovsky hall
09:30 – 11:00	Microwave Metamaterials	Tverskoy hall
09:30 – 11:00	Acoustic Metamaterials I	Nevsky hall

09:30 – 11:00 Optical and UV Metamaterials — Kremlyovsky hall

Session chairperson(s): Harald Giessen

09:30 – 10:00 **The exciting science of light with metamaterials** Invited oral

Vladimir M. Shalaev, *Birck Nanotechnology Center, Purdue University, USA*
A. Boltasseva, *Birck Nanotechnology Center, Purdue University, USA*
X. Ni, *Birck Nanotechnology Center, Purdue University, USA*
G. Naik, *Birck Nanotechnology Center, Purdue University, USA*
E. E. Narimanov, *Birck Nanotechnology Center, Purdue University, USA*
J. Liu, *Birck Nanotechnology Center, Purdue University, USA*
N. Emani, *Birck Nanotechnology Center, Purdue University, USA*
A. V. Kildishev, *Birck Nanotechnology Center, Purdue University, USA*

In this presentation, we discuss new approaches to negative refraction and light ending with plasmonic nanoantennae.

10:00 – 10:15 **High order asymptotic for periodic multilayers** Oral

Yan Liu, *Institut Freshnel, France*
Boris Gralak, *Institut Freshnel, France*
Sebastien Guenneau, *Institut Freshnel, France*

In this paper, we propose a rigorous transfer matrix formalism to analyze periodic multilayers. We derive explicit expressions for transfer matrix when the wavelength is comparable to the size of the periodic cell. We numerically validate our approach by comparing the dispersion law and transmission spectrum (Fresnel coefficients) of a stack alternating two dielectric layers against that of an effective bi-anisotropic medium.

St. Petersburg, **Russia**

Monday, 17th September

10:15 – 10:30

Homogeneous magnetic metamaterials due to extreme coupling Oral

Christoph Menzel, *Institute of Condensed Matter Theory and Solid Stat Optics; Abbe Center of Photonics; Jena, Germany*
Rasoul Alaee, *Institute of Condensed Matter Theory and Solid Stat Optics; Abbe Center of Photonics; Jena, Germany*
Ekaterina Pshenay-Severin, *Institute of Applied Physics; Abbe Center of Photonics; Jena, Germany*
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Thomas Paul, *Institute of Condensed Matter Theory and Solid Stat Optics; Abbe Center of Photonics; Jena, Germany*
Arkadi Chipouline, *Institute of Applied Physics; Abbe Center of Photonics; Jena, Germany*
Carsten Rockstuhl, *Institute of Condensed Matter Theory and Solid Stat Optics; Abbe Center of Photonics; Jena, Germany*
Thomas Pertsch, *Institute of Applied Physics; Abbe Center of Photonics; Jena, Germany*
Falk Lederer, *Institute of Condensed Matter Theory and Solid Stat Optics; Abbe Center of Photonics; Jena, Germanyconditions are discussed.*

We introduce an approach to design metamaterials that may be self-consistently described by effective material parameters. The key is the exploitation of an extreme coupling regime which arises if plasmonic particles exhibit only nm separation. This tiny separation can be achieved by atomic layer deposition techniques. In this regime, the wavelength-to-cell size ratio exceeds easily a factor of 10 at resonance. This results in effectively homogeneous magnetic metamaterials with negligible spatial dispersion. We extend our studies towards depositing these structures on curved surfaces. This allows e.g. for perfect absorbers that make an object invisible in reflection.

10:30 – 11:00

Optical metamaterials with a negative index of refraction in the UV Extended oral

Ruben Maas, *FOM-Institute AMOLF, Netherlands*
James Parsons, *FOM-Institute AMOLF, Netherlands*
Ewold Verhagen, *EPFL, Switzerland*
Albert Polman, *FOM-Institute AMOLF, Netherlands*

Metamaterials composed of Ag/Si3N4 multilayers were fabricated using focussed ion beam milling and reactive ion etching. The coupled plasmonic waveguide arrays were experimentally studied using UV interferometry. A -132 degree phase retardation was observed at a freespace wavelength of 363 nm, corresponding to a negative effective index.

09:30 – 11:00 **Microwave Metamaterials** **Tverskoy hall**

Session chairperson(s): Ricardo Marques

09:30 – 09:45

A dipole antenna design incorporating both electromagnetic bandgap and zero-refractive index metamaterials Oral

Vasa Radonic, *Faculty of technical sciences, Serbia*
Keith Palmer, *Department of E&E Engineering, University of Stellenbosch, South Africa*
Vesna Crnojevic-Bengin, *Faculty of technical sciences, Serbia*

A dipole antenna incorporating both a planar electromagnetic bandgap (EBG) and a zero-refractive index (ZRI) metamaterial surface has been investigated. The combination of the EBG surface and the effective ZRI have been used to enhance both the bandwidth and the directivity of the dipole. The proposed dipole type antenna topology has a directivity in excess of 16 dBi with an s11.

09:45 – 10:00

Artificial Magnetic Conductors replacing absorbers for packaging of microstrip circuits [Oral]

Eva Rajo-Iglesias, *University Carlos III of Madrid, Spain*

The use of different configurations of AMC as lid for packaging of microstrip circuits is proposed for different frequency bands. Experimental results show how they avoid the excitation of cavity modes as well as radiation losses and how compact unit cells can be designed for lower frequencies achieving 2:1 bandwidths.

10:00 – 10:15

Magnetoinductive lenses for reduction of correlated noise in parallel magnetic resonance imaging [Oral]

Manuel Freire, *University of Seville, Spain*
Marcos Lopez, *University of Seville, Spain*
Jose Algarin, *University of Seville, Spain*
Felix Breuer, *Research Center Magnetic Resonance Bavaria (MRB), Germany*
Ricardo Marques, *University of Seville, Spain*

In this work, it is shown the application of split-ring magnetoinductive (MI) lenses in parallel magnetic resonance imaging (MRI). MI lenses provide high localization of MRI coil sensitivities and higher signal-to-noise-ratio in comparison with split-ring mu = -1 lenses. This conclusion is supported by both numerical and experimental results.

10:15 – 11:00

Metamaterials – Beyond crystals, noncrystals, and quasicrystals: Microwave applications [Keynote]

Tie Jun Cui, *Radio Department, Southeast University, China*

For a long time, the natural materials have been classified into two types: crystals and noncrystals, until Daniel Shechtman discovered quasicrystals in 1982, who won the Nobel chemistry prize in 2011 for this work. In fact, crystals and noncrystals are composed of periodically-distributed and randomly-distributed atoms, while quasicrystals have a third material state between crystals and noncrystals: which are non-periodic structures of atoms with certain rules instead of random. Hence the two factors to affect natural material properties are the atoms themselves and the spatial arrangements of atoms. Quasicrystals have brought a lot of new features of materials and found applications in steel armour, non-stick frying pans, and devices in cars for recycling waste heat into electricity. However, it is very hard to control atoms themselves and their spatial arrangements to get more material properties. Metamaterials provide us a freedom to tailor the material properties, both for electric and magnetic. Metamaterials are composed of periodic or non-periodic structures of artificial “atoms” or “particles”, which have a size of subwavelength scale. The flexible design of single artificial particles, the feasible arrangements of such particles, and the high anisotropy make it possible to control the material properties as desired: metamaterials can be used to realize the effective permittivity and/or permeability which cannot be achieved in nature. Hence they have either unique features with unusual physical phenomena (such as negative refraction, invisibility cloak, optical illusion, etc.) or superior performance than the natural materials. In this paper, I will focus on microwave metamaterials and introduce their counterparts to crystals, noncrystals, and quasi-crystals: homogeneous metamaterials, random metamaterials, and inhomogeneous metamaterials. For all three cases, I will introduce the important experiments and applications in microwave frequencies conducted in my group, including the invisibility cloaks, electromagnetic black hole, radar illusion devices, planar gradient-index lenses, flattened Luneburg lens, Maxwell fisheye lens, high-gain Vivaldi antennas, and decoupling device for MIMO system.

St. Petersburg, **Russia**

Monday, 17th September

09:30 – 11:00 | **Acoustic Metamaterials I** | **Nevsky hall**

Session chairperson(s): Johan Christensen

09:30 – 09:45

Realization of hyper acoustic transmission through a subwavelength hole using membrane [Oral]

Jong Jin Park, *Institute of Physics and Applied Physics, Yonsei University, Korea (South)*
Seung Hwan Lee, *Institute of Physics and Applied Physics, Yonsei University, Korea (South)*
Sam Hyeon Lee, *Institute of Physics and Applied Physics, Yonsei University, Korea (South)*

We present the first experimental realization of extraordinary acoustic transmission through a subwavelength hole using membrane resonator which has high quality factor. Our transmission efficiency normalized to the aperture area is 57times larger than the impinging at a hole opening, which is strongly enhanced result than previous studies. The key role played by membrane resonance in transferring sound efficiently from the input to the output region is presented. This knowledge is opening up exciting new opportunities in applications ranging from subwavelength acoustics to chemical sensing and biophysics.

09:45 – 10:00

Anomalous transmission properties of ultranarrow, zero-density acoustic metachannels [Oral]

Andrea Alu, *The University of Texas at Austin, USA*
Romain Fleury, *The University of Texas at Austin, USA*
Caleb Sieck, *The University of Texas at Austin, USA*
Michael Haberman, *Applied Research Laboratories, USA*

We present the acoustic equivalent of supercoupling through subwavelength channels. Extraordinary matched transmission, energy squeezing and anomalous quasistatic tunnelling through narrow channels are obtained for acoustic waves by designing a 2D, density-near-zero metachannel. Transmission-line theory is used to describe this peculiar phenomenon, and full-wave simulations are presented to confirm the exotic transmission properties of the metamaterial. It is shown that acoustic waves may provide a unique possibility of squeezing energy in arbitrarily small channels in 3D, overcoming limitations usually arising in the electromagnetic case.

10:00 – 10:15

Negative effective mass density of acoustic metamaterial using dual-resonator spring-mass model [Oral]

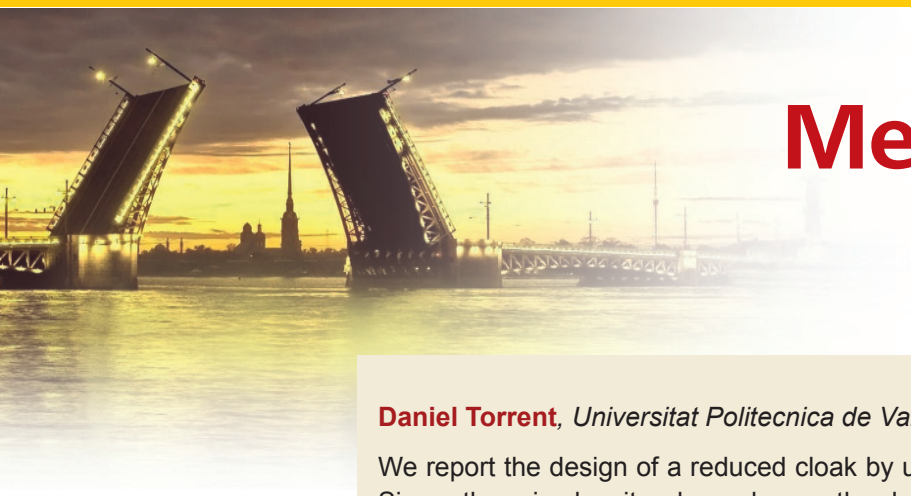
Kwek-Tze Tan, *Purdue University, USA*
H.H. Huang, *Purdue University, USA*
C.T. Sun, *Purdue University, USA*

We propose an acoustic metamaterial with a microstructure consisting of two internal resonators. Analytical findings show that the dual-resonator metamaterial exhibits its negative effective mass density over a larger frequency spectrum. Practical applications like vibration control and blast mitigation are demonstrated using finite element simulation.

10:15 – 11:00

Acoustic and mechanical metamaterials [Keynote]

Jose Sanchez-Dehesa, *Universitat Politecnica de Valencia, Spain*
Victor M. Garcia-Chocano, *Universitat Politecnica de Valencia, Spain*



Daniel Torrent, *Universitat Politecnica de Valencia, Spain*

We report the design of a reduced cloak by using a temperature gradient approach. Since the air density depends on the local temperature, a space-dependent temperature function generates a space-dependent mass density function, as required for acoustic cloaking. The temperature gradient is designed and implemented by heated rigid cylinders.

11:00 – 11:30 Coffee break — Poster area

Oral sessions (Monday morning II)

11:30 – 13:00	Nonlinear Metamaterials I	Kremlyovsky hall
11:30 – 13:00	Extraordinary Transmission	Tverskoy hall
11:30 – 13:00	Acoustic Metamaterials II	Nevsky hall

11:30 – 13:00 Nonlinear Metamaterials I — Kremlyovsky hall

Session chairperson(s): Jacob Khurgin

11:30 – 12:00 **Enhancement of second-harmonic generation from metal nanoparticles by passive elements** Extended oral

Martti Kauranen, *Tampere University of Technology, Finland*
Hannu Husu, *Centre for Metrology and Accreditation, Finland*
Roope Siikanen, *Tampere University of Technology, Finland*
Robert Czaplicki, *Tampere University of Technology, Finland*
Jouni Mäkitalo, *Tampere University of Technology, Finland*
Joonas Lehtolahti, *University of Eastern Finland, Finland*
Janne Laukkanen, *University of Eastern Finland, Finland*
Markku Kuittinen, *University of Eastern Finland, Finland*

We prepare arrays of gold nanoparticles that include both noncentrosymmetric particles with a second-order nonlinear optical response and centrosymmetric particles with no second-order response. The latter particles act as passive elements that modify the electromagnetic mode structure of the sample and en-hance second-harmonic generation from the active particles.

12:00 – 12:15 **Characteristics of soliton propagation in an isotropic chiral metamaterial** Oral

Nikolaos Tsitsas, *Department of Informatics, Aristotle University of Thessaloniki, Greece*
Akhlesh Lakhtakia, *Department of Engineering Science and Mechanics, Pennsylvania State University, USA*
Dimitri Frantzeskakis, *Department of Physics, University of Athens, Greece*

By using the reductive perturbation method, we found that the two Beltrami components of the electromagnetic field propagating along a fixed direction in an isotropic nonlinear chiral metamaterial obey a system of two coupled nonlinear Schredinger (NLS) equations. Certain spectral regimes exist wherein one of the two Beltrami components exhibits a negative-real refractive index and the NLS system can be approximated by the Manakov system. Bright-bright, dark-dark and dark-bright vector solitons can form in those spectral regimes.

12:15 – 12:30 **Enhancing nonlinear response with metamaterials: from nonlinear parameters engineering to one-way imaging** Oral

Ekaterina Poutrina, *Duke University, USA*
Alec Rose, *Duke University, USA*
David Smith, *Duke University, USA*

We first summarize the approaches developed in our group allowing for the description of a nonlinear metamaterial media in terms of the effective nonlinear susceptibilities. We subsequently discuss the nonlinear magneto-electric coupling and demonstrate that it can lead to a unidirectional or non-reciproocal nonlinear imaging using a three- or four-wave mixing process.

12:30 – 12:45 **Gaussian pulse mixing by nonlinear photonic crystals** Oral

Oksana Shramkova, *ECIT, Queen's University Belfast, United Kingdom*
Alexander Schuchinsky, *ECIT, Queen's University Belfast, United Kingdom*

The properties of mixing and scattering of two non-collinear Gaussian pulses with different centre frequencies and lengths, incident on the finite nonlinear periodic layered dielectric structures, have been analysed. It is shown that at the backward emission grows with the number of layers and can reach the level of the forward emission in the direction of combinatorial frequency scattering.

12:45 – 13:00 **Linear and nonlinear Tamm surface modes in layered metal-dielectric metamaterials** Oral

Ivan Iorsh, *National Research University of Information Technologies Mechanics and Optics, Russia*
Pavel Belov, *National Research University of Information Technologies Mechanics and Optics, Russia*
Ilya Shadrivov, *Nonlinear Physics Centre, Research School of Physics and Engineering, Australian National University, Canberra ACT 0200, Australia*
Alexander Zharov, *Institute for Physics of Microstructures, Russian Academy of Sciences, Nizhny Novgorod 603950, Russia*
Yuri Kivshar, *Nonlinear Physics Centre, Research School of Physics and Engineering, Australian National University, Canberra ACT 0200, Australia*

We study dispersion properties of linear and nonlinear Tamm surface modes at the interface separating two metal-dielectric metamaterials. In the linear regime, we demonstrate the existence of three types of surface modes, one being characterized by the negative group velocity. In the case of a thin nonlinear cap layer at the surface of the metal-dielectric nanostructure, we predict the existence of both TE- and TM- surface modes at the finite powers, even in the case when no linear surface modes exist. We analyze the dispersion properties of these nonlinear surface modes and compare our analytical results with the beam propagation numerical simulations.

11:30 – 13:00 Extraordinary Transmission

Session chairperson(s): Ortwin Hess

Tverskoy hall

11:30 – 11:45

Surface impedance and coupled-wave model for extraordinary optical transmission through realistic metallic screens Oral

Vicente Delgado, *University of Seville, Spain*
Ricardo Marqués, *University of Seville, Spain*
Lukas Jelinek, *Czech Technical University in Prague, Czech Republic*

The paper proposes an analytical theory for extraordinary optical transmission (EOT) in metallic screens perforated by a periodic array of subwavelength holes. The theory is based on coupled-wave analysis and on the surface impedance concept. The analytical model allows for a considerable reduction of CPU time in the analysis of EOT.

11:45 – 12:00

Control transmission of light through a single nanohole with the use of photon crystal microcavity Oral

Pavel Melentiev, *Institute for Spectroscopy Russian Academy of Sciences, Russia*
Anton Afanasiev, *Institute for Spectroscopy Russian Academy of Sciences, Russia*
Artur Kuzin, *Moscow Institute of Physics and Technology, Russia*
Alex Zablotskiy, *Moscow Institute of Physics and Technology, Russia*
Andrey Baturin, *Moscow Institute of Physics and Technology, Russia*
Victor Balykin, *Institute for Spectroscopy Russian Academy of Sciences, Russia*

We demonstrate an approach to control transmission of light through a single nanohole with the use of photon crystal microcavity. By using this approach the enhancement in transmission of light, photo induced luminescence and third harmonics generation for a single nanohole in Au film has been experimentally demonstrated for the first time.

12:00 – 12:15

On the nature of transmission in resonant metamaterial transmission lines Oral

Vesna Crnojevic-Bengin, *University of Novi Sad, Serbia*
Riana Geschke, *Stellenbosch University, South Africa*
Nikolina Jankovic, *University of Novi Sad, Serbia*
Norbert Cselyuszka, *University of Novi Sad, Serbia*

A detailed analysis of the transmission that occurs in various scenarios of a host medium with a capacitive gap and complementary split-ring resonator (CSRR) combination is presented. This is a typical situation where it is expected that left-handed propagation will occur in a certain band of frequencies. We now show that Epsilon-Near-Zero (ENZ) transmission may be obtained by tailor-ing the host structure geometry.

12:15 – 12:45

Efficient circuit models for extraordinary transmission structures CONSOLIDER project CSD2008-00066 presentation Oral

Francisco Medina, *University of Seville, Spain*
Francisco Mesa, *University of Seville, Spain*
Raul Rodriguez-Berral, *University of Seville, Spain*

In this contribution we review the application of circuit modeling techniques to the characterization of extraordinary transmission through metal screens perforated with periodic arrays of subwavelength apertures. A number of practical situations are analyzed using quasi-analytical and fully analytical models. The method provides an in-depth understanding of the underlying physics as well as accurate values of the transmissivity, reflectivity, and absorptivity of this kind of structures. Free-standing and dielectric loaded metal screens are considered.

12:45 – 13:00 **Efficient electrically small apertures and their applications in microwave components** Oral

Filiberto Bilotti, *Roma Tre University, Italy*
Luca Di Palma, *Roma Tre University, Italy*
Davide Ramaccia, *Roma Tre University, Italy*
Alessandro Toscano, *Roma Tre University, Italy*

We present the design of efficient electrically small apertures loaded with metamaterial-inspired subwavelength resonators whose resonant frequencies are independent from the surrounding environment. This interesting phenomenon is applied to design new microwave components, including electrically small aperture-antennas, self-filtering horn radiators, waveguide diplexers, filters, (un)balanced and switchable power splitters, etc.

11:30 – 13:00 Acoustic Metamaterials II — Nevsky hall

Session chairperson(s): Jose Sanchez-Dehesa

11:30 – 11:45 **On the feasibility of pentamode mechanical metamaterials** Oral

Tiemo Bückmann, *Institute of Applied Physics and DFG-Center for Functional Nanostructures, Karlsruhe Institute of Technology, Germany*
Muamer Kadic, *Institute of Applied Physics and DFG-Center for Functional Nanostructures, Karlsruhe Institute of Technology, Germany*
Nicolas Stenger, *Institute of Applied Physics and DFG-Center for Functional Nanostructures, Karlsruhe Institute of Technology, Germany*
Michael Thiel, *Institute of Nanotechnology, Karlsruhe Institute of Technology and Nanoscribe GmbH, Germany*
Martin Wegener, *Institute of Applied Physics and DFG-Center for Functional Nanostructures and Institute of Nanotechnology, Karlsruhe Institute of Technology, Germany*

Following the theoretical suggestion by Milton and Cherkaev in 1995, we fabricate pentamode metamaterials by dip-in direct-laser-writing optical lithography. Using finite element calculations and geometrical parameters corresponding to our fabricated three-dimensional microstructures, we find that the figure of merit, i.e., the ratio of bulk modulus to shear modulus, can realistically be made as large as about 1,000. This result opens new horizons for transformation acoustics.

11:45 – 12:00 **Acoustic metamaterials based on cavities drilled in two dimensional waveguides** Oral

Rogelio Graciá-Salgado, *Universitat Politècnica de València, Spain*
Daniel Torrent, *Universitat Politècnica de València, Spain*
José Sánchez-Dehesa, *Universitat Politècnica de València, Spain*

In this work we study the realization of quasi-two-dimensional acoustic metamaterials by complex fluid-like cavities drilled in a two dimensional waveguide. The cavities are filled with a metafluid and a rigid cylinder is placed at the center, then the system behaves like a soft fluid-like shell with a high density cylinder in the center. This system is known to present complex resonances and we have shown that by means of an array of these structures we can obtain either single or double negative acoustic metamaterials. Because the large number of parameters (height of the waveguide, depth of the cavity, radius of the internal cylinder, etc.) we have developed a new type of "phase diagrams" that can be used to fully understand this complex system.

12:00 – 12:30 **Quest for flexible acoustic circuitry with acousto-elastic metamaterials** Invited oral

Nicholas Xuanlai Fang, *MIT, USA*

In this invited talk, we will present our progress in bending and folding acoustic waves in a flexible acoustic circuitry. Motivated by our recent success in cloaking and beam shaping using coordinate transformation in acoustics, we will apply it to elastic and deformable systems that display strong acousto-elasticity.

12:30 – 13:00 **All-angle negative refraction with an acoustic fishnet structure** Extended oral

Johan Christensen, *IQFR-CSIC, Serrano 119, 28006 Madrid, Spain*
Javier Garcia de Abajo, *IQFR-CSIC, Serrano 119, 28006 Madrid, Spain*

We study a class of acoustic metamaterials formed by layers of perforated plates and producing negative refraction and backward propagation of sound. Our study constitutes a nontrivial extension of similar concepts from optics to acoustics, capable of sustaining negative refraction over extended angular ranges, with potential application to enhanced imaging for medical and detection purposes, acoustofluidics, and sonochemistry.

13:00 – 14:30 **Lunch** **Restaurant**

Oral sessions (Monday afternoon I)

14:30 – 16:00	**Nonlinear Metamaterials II**	**Kremlyovsky hall**
14:30 – 16:00	**Antenna Applications of Metamaterials**	**Tverskoy hall**
14:30 – 16:00	**Acoustic and Other Metamaterials**	**Nevsky hall**

14:30 – 16:00 **Nonlinear Metamaterials II** **Kremlyovsky hall**

Session chairperson(s): Martti Kauranen

14:30 – 14:45 **Symmetry resonance dependence of harmonic generation in metamaterials** Oral

Jörg Reinhold, *Institute of Applied Physics, Abbe Center of Photonics, Friedrich-Schiller-Universität Jena, Germany*

M. R. Shcherbakov, *Faculty of Physics, Lomonosov Moscow State University, Russia*
A. Chipouline, *Institute of Applied Physics, Abbe Center of Photonics, Friedrich-Schiller-Universität Jena, Germany*
V. I. Panov, *Faculty of Physics, Lomonosov Moscow State University, Russia*
T. Paul, Institute of Condensed Matter Theory and Solid State Optics, Abbe Center of Photonics, Friedrich-Schiller-Universität Jena, Germany
C. Rockstuhl, *Institute of Condensed Matter Theory and Solid State Optics, Abbe Center of Photonics, Friedrich-Schiller-Universität Jena, Germany*
F. Lederer, *Institute of Condensed Matter Theory and Solid State Optics, Abbe Center of Photonics, Friedrich-Schiller-Universität Jena, Germany*
C. Helgert, *Institute of Applied Physics, Abbe Center of Photonics, Friedrich-Schiller-Universität Jena, Germany*
E.-B. Kley, *Institute of Applied Physics, Abbe Center of Photonics, Friedrich-Schiller-Universität Jena, Germany*
A. Tünnermann, *Institute of Applied Physics, Abbe Center of Photonics, Friedrich-Schiller-Universität Jena, Germany*
A. A. Fedyanin, *Faculty of Physics, Lomonosov Moscow State University, Germany*
T. Pertsch, *Institute of Applied Physics, Abbe Center of Photonics, Friedrich-Schiller-Universität Jena, Germany*

An analytical model based on nonlinear dynamics of electrons inside the metallic structure of a metamaterial unit cell is proposed and used to describe the characteristic nonlinear radiation pattern at the excitation wavelength of magnetic resonance. Measured angular behavior of the third harmonic generation exhibits quantitative correspondence of the modeled results.

14:45 – 15:00

Transition to negative refractive index in plasma metamaterial with negative permeability Oral

Osamu Sakai, *Kyoto University, Japan*

Metamaterials partly composed of discharge plasmas exhibit a number of distinguishable points from ordinary metamaterials. In particular, states with negative refractive index are triggered in a process with saddle-node bifurcations, and negative permeability is a key factor to achieve such transitions. In this paper, theoretical predictions and experimental verifications are demonstrated, which confirm that “plasma metamaterials” are quite nonlinear in the microwave range.

15:00 – 15:15

Discrete dissipative switching waves and solitons in 1D–, 2D–, and 3D–nanostructures and metamaterials Oral

Nikolay Rosanov, *Vavilov State Optical Institute, Russia*
Anatoly Shatsev, *Vavilov State Optical Institute, Russia*
Nina Vyssotina, *Vavilov State Optical Institute, Russia*
Anton Desyatnikov, *Australian National University, Australia*
Ilya Shadrivov, *Australian National University, Australia*
Yuri Kivshar, *Australian National University, Australia*

In this paper we review and compare the main features of localized structures — switching waves, or kinks, and solitons in discrete dissipative systems. Some of these features have no known analogues in continuous systems. Especially rich are localized structures in magnetic metamaterials driven by coherent radiation, and they include knotted solitons not found in other optical and microwave systems.

15:15 – 15:30

Oscillons, solitons, and domain walls in arrays of nonlinear plasmonic nanoparticles Oral

Roman Noskov, *National Research University of Information Technologies, Mechanics and Optics (ITMO), Russia*
Pavel Belov, *National Research University of Information Technologies, Mechanics and Optics (ITMO), Russia*
Yuri Kivshar, *National Research University of Information Technologies, Mechanics and Optics (ITMO), Russia*

We study analytically and numerically modulational instability in arrays of nonlinear plasmonic nanoparticles, and demonstrate that it can lead to the formation of long-lived standing and moving nonlinear localized modes of three different types — domain walls connecting the states with different polarizations as well as solitons and oscillons with stationary and oscillating profiles.

15:30 – 16:00

Second harmonic generation of individual gold metallic nanoparticles Invited oral

Pierre-Francois Brevet, *University Claude Bernard Lyon 1, France*
Jérémy Butet, *University Claude Bernard Lyon 1, France*
Isabelle Russier-Antoine, *University Claude Bernard Lyon 1, France*
Noelle Lascoux, *University Claude Bernard Lyon 1, France*
Christian Jonin, *University Claude Bernard Lyon 1, France*
Emmanuel Benichou, *University Claude Bernard Lyon 1, France*

In this work, we report the Second Harmonic Generation (SHG) from individual gold metallic nanoparticles with an average diameter of 150 nm dispersed in a homogeneous and transparent solid matrix. This is achieved using a direction of collection for the harmonic photons at right angle from the 804 nm fundamental exciting beam direction with a scan of the cell in a plane perpendicular to the fundamental beam direction. A light polarization analysis of the SHG intensity is also performed, allowing us to provide a clear separation between single particles and aggregates.

14:30 – 16:00 Antenna Applications of Metamaterials — Tverskoy hall

Session chairperson(s): Alexander Schuchinsky

14:30 – 15:00

Recent progress on metamaterial–inspired antennas Invited oral

Richard W. Ziolkowski, *ECE Dept., University of Arizona, USA*
Ning Zhu, *ECE Dept., University of Arizona, USA*
Ming-chun Tang, *ECE Dept., University of Arizona, USA*

Many attributes of metamaterials have led to the consideration of engineering metamaterial-inspired structures for a variety of applications. This includes the miniaturization of resonators and their use for improving the performance characteristics of electrically small antennas from the microwave region up through to the optical region. Achieving higher directivity from electrically small antennas by introducing structured ground planes has been considered successfully. Active metamaterial constructs have been introduced to increase the bandwidths at low frequencies and to overcome the losses at high frequencies. They have led to recent non-Foster antenna designs which have some preliminary experimental results. Thus the development of an efficient, high directivity, large bandwidth electrically small antenna is rapidly becoming a possibility.

15:00 – 15:15

Linear-to-circular polarization transformer based on the employment of electrically small antennas Oral

Mirko Barbuto, *Roma Tre University, Italy*
Alessandro Toscano, *Roma Tre University, Italy*

In this contribution, we propose the use of electrically small antennas for the design of a new setup to increase power transmission through a subwavelength aperture. A linear-to-circular polarization transformer based on this concept is also presented. We show that the proposed structure placed at the end of an open-ended circular waveguide is able to change its linear polarization to a circular one. The overall structure is designed to efficiently radiate a circular polarized field at the GPS L1 frequencies (around 1575.42 MHz) with a realized gain greater than 5 dBi.

15:15 – 15:30

~~**Dual-operating band and high-gain planar horn antenna CONSOLIDER project CSD2008-00066 presentation**~~ ~~Oral~~, Withdrawal

Unai Beaskoetxea Gartzia, *Universidad Pública de Navarra, Spain*
Miguel Beruete, *Universidad Pública de Navarra, Spain*

A low-profiled dual-band operating planar horn antenna with semi-periodic grooves, is presented. This structure, fed by means of a waveguide, achieves a good gain level at both design frequencies of 60 and 77GHz, clearly improving the simple planar antenna. This enhancing behaviour is similar to the enhanced transmission observed at optical wavelengths used in similar structures, and shares the similar explanation. The antenna is proposed to be used in wireless telecommunication systems, such as a speed radars or short secure radiolinks.

15:30 – 15:45

Design of a broadband shortened horn loaded with a flat wire-medium annular lens Oral

Davide Ramaccia, *«RomaTre» University, Italy*
Francesco Scattone, *«RomaTre» University, Italy*
Filiberto Bilotti, *«RomaTre» University, Italy*
Alessandro Toscano, *«RomaTre» University, Italy*

In this contribution, we present the design of a flat wire-medium annular lens to be applied to the aperture of a shortened horn antenna in order to achieve gain performances similar to the ones of the corresponding optimum horn over a broad frequency range.

15:45 – 16:00

~~**Using metamaterials to exploit lateral waves for microwave applications**~~ ~~Oral~~, Withdrawal

Steven Weiss, *The Army Research Lab, USA*

In this paper the excitation of lateral (surface) waves in a layered media is investigated. This analysis is fundamental for applied microwave applications such as the realization of an antenna on a layered media and demonstrates the enormous design flexibility made possible by metamaterials.

14:30 – 16:00 Acoustic and Other Metamaterials — Nevsky hall

Session chairperson(s): Nicholas Xuanlai Fang

14:30 – 14:45

Propagating surface plasmons on nanoporous gold Oral

Joerg Schilling, *ZIK SiLi-nano, Martin-Luther-University Halle-Wittenberg, Germany*
Neha Sardana, *ZIK SiLi-nano, Martin-Luther-University Halle-Wittenberg, Germany*

Frank Heyroth, *Interdisziplinaeres Zentrum fuer Materialwissenschaften, Martin-Luther-University Halle-Wittenberg, Germany*

Nanoporous gold films are prepared using a dealloying method. The dispersion relation of the propagating surface plasmons on the air/nanoporous gold interface is determined from reflection measurements in Kretschmann configuration. A red-shift by ca. 0.85 eV compared to surface plasmons on solid gold layers is observed. The results agree well with calculated dispersion relations applying the Bruggeman effective medium theory for the nanoporous gold.

14:45 – 15:15 **Acoustic Metamaterials through Coiling up Space** Invited oral

Jensen Li, *City University of Hong Kong, Hong Kong*
Zixian Liang, *City University of Hong Kong, Hong Kong*

We show that by curving fluid perforations within a solid with proper control of phase delay, a two dimensional acoustic metamaterial with extreme indices can be constructed. It can be used to achieve a large refractive index, negative refraction and tunneling with a density-near-zero material in the effective medium regime.

15:15 – 15:45 ~~**Hybrid elastic solids**~~ Invited oral

Yun Lai, *Soochow University, China*

We show that elastic metamaterials can realize intriguing solid acoustic materials with unique features, such a[illegible]essure waves and forbid shear waves, "su[illegible]ssure or shear waves in different directions, [illegible]t only transfer shear waves and forbid pressure waves.

This paper was not presented at the conference ("no-show").

Poster session I + coffee break

16:00 – 17:30 **Optical, Nonlinear, Tunable Metamaterials** **Poster area**

~~**1. Theoretical investigations of a N-sided regular polygon split ring resonator with skew rotation**~~

Sumanta Bose, *National Institute of Technology, Trichy, India*
S Raghavan, *National Institute of Technology, Trichy, India*

In this paper, a theoretical [illegible]nant frequency of a N-sided Regular Polygo[illegible]ich is extended to the Circular Split Ring Res[illegible]The model also predicts the variation in the resonant frequency with the angle of rotation (skew) between the inner and the outer polygon. It is mathematically shown that the minimum resonant frequency is obtained at zero skew.

This paper was not presented at the conference ("no-show").

2. Nonlinear magnetoelastic metamaterial using gravitational restoring force

Iryna Khodasevych, *RMIT University, Australia*
Ilya Shadrivov, *Australian National University, Australia*
David Powell, *Australian National University, Australia*
Wayne Rowe, *RMIT University, Australia*
Arnan Mitchell, *RMIT University, Australia*

We present design and demonstration of a nonlinear magnetoelastic metamaterial consisting of engineered split rings with mechanical counterbalance allowing gravity to serve as the elastic restoring force countering the attraction between the currents induced on the split ring resonators suspended with mechanical degrees of freedom in the waveguide. Measurements show shift in resonant frequency of the structure due to changed mutual orientation of the rings in response to increased incident power.

~~3. Temperature tuning all-dielectric left-handed material~~

Bai Du, *Electronic Materials Research Laboratory, China*

We chose a special ceramic material to design an all-dielectric LHM that could be tuned by tem-per structure. In the X-band, the rods could prov nd the cubes produced negative effective requency range could be tuned from 8.4GHz to 11GHz when temperature changed. The S parameters and the retrieved effective electromagnetic parameters showed a wide frequency tun-ing range of this all-dielectric LHM.

This paper was not presented at the conference ("no-show").

4. ~~Optical response of plasmonic core-shell nanoparticles with optical gain~~

Alessandro Veltri, *University of Bordeaux, France*
Ashod Aradian, *University of Bordeaux, France*

We study theoretically the polarizability of core shell nanoparticles with a plasmonic core and a shell made of an active material (for example, silica doped with a dye) and of gain-assisted reverse-core-shell nanoparticles, with an active core and a shell made of a mple long-wavelength, macroscopic descripti be strongly amplified, until becoming singu nding gain; however, we find that gain-assi different from singular plasmons in idealized, lossless metals. More generally, we carry a systematic study of how the plasmonic response transforms under changes in the amount of gain. he resulting plasmons exhibit strongly distorted lineshapes with unusual but interesting features. One particularly attractive situation is that of «conjugate plasmons», which, at resonance, display a strong real response in association with minimal losses — in contrast with standard plasmons.

This paper was not presented at the conference ("no-show").

5. Tunable negative index liquid crystal metamaterial employing in-plane switching mode

Rafal Kowerdziej, *Military University of Technology, Poland*
Marek Olifierczuk, *Military University of Technology, Poland*
Janusz Parka, *Military University of Technology, Poland*

Authors analyze response of tunable liquid crystal metamaterial transducer in terahertz frequency range. Tunability of scattering parameters is achieving by In-Plane Switching (IPS) effect. Metamaterial (MTM) structure is based onshape

resonators. A full-wave analysis technique based on the finite-difference time-domain method (FDTD) was performed using QuickWave 3D electromagnetic solver. Terahertz transmission properties of the metamaterial structure can be controlled by director of liquid crystal layer. Effective refractive index for operation frequency varies from negative to positive values. Novel approach to switching of metamaterial transducer by IPS mode is presented.

6. Simple Analytical description of CNT nonlinear response enhanced by metamaterials

Arkadi Chipouline, *FSU Jena, Germany*
Srikanth Sugavanam, *Aston Institute of Photonic Technologies, Electronic Engineering, Aston University, Birmingham, UK*
Vassili Fedotov, *Optoelectronics Research Centre and Centre for Photonic Metamaterials, University of Southampton, UK*
Andrei Nikolaenko, *Optoelectronics Research Centre and Centre for Photonic Metamaterials, University of Southampton, UK*

We present an analytical model for describing complex dynamics of a hybrid system consisting of res-onantly coupled classical resonator and quantum structures. As a particular example of application of our model, we show that the saturation nonlinearity of carbon nanotubes increases multifold in the resonantly enhanced near field of a metamaterial.

7. ~~A probabilistic model for propagation of electromagnetic waves in 3D magnetic opal–based metamaterials~~ Withdrawal

Galina Makeeva, *Penza State University, Russia*
Oleg Golovanov, *Penza State University, Russia*
Anatoly Rinkevich, *Institute of Metal Physics, Russia*
Dmitry Perov, *Institute of Metal Physics, Russia*

A probabilistic approach for modelling, by solving Maxwell`s equations rigorously, the propagation of electromagnetic waves (EMWs) and their interactions with the 3D magnetic opal-based metamaterials is developed taking into account a normal distribution the magnetic fields of the ferromagnetic resonance (FMR) of nanoparticles. Using the deterministic electrodynamic model the propagation constants of clockwise, counterclockwise polarized waves and the ordinary, extraordinary modes for longitudinal and transverse orientations of DC magnetic field were calculated from the characteristic equation. The probabilistic method is demonstrated by calculating the bias field dependences of the complex diagonal and off-diagonal components of the effective permeability tensor for the 3D Ni0.7Zn0.3Fe2O4 particles-containing opal-based metamaterials at a frequency f =26 GHz. Comparison of numerical modeling results of microwave interactions depending on the damping parameter of magnetic nanoparticles and the standard deviation of random quantity of the FMR magnetic field of nanoparticles to experimental data is considered.

~~8. Tunable photonic band gaps and tunable gradient refractive index optics using plasmonic crystals with semiconductor rods~~

Borislav Vasic, *Institute of Physics, University of Belgrade, Serbia*
Rados Gajic, *Institute of Physics, University of Belgrade, Serbia*

We investigate tunable two-dimensional plasmonic crystals with semiconductor rods. The tuning is achie[This paper was not presented at the conference ("no-show").]tration in the rods. Tunable photonic band-g[This paper was not presented at the conference ("no-show").]asmon resonances in individual rods when e[This paper was not presented at the conference ("no-show").]ctric field is parallel to the rods, the tuning is applied to the graded plasmonic crystals in order to implement tunable gradient refractive index profile such as tunable lens.

9. Terahertz and infrared metamaterial polarization converter with tunable ellipticity

Dmitry Markovich, *Moscow Institute of Physics and Technology, Russia*
Andrei Andryieuski, *Technical University of Denmark, Denmark*
Andrei Lavrinenko, *Technical University of Denmark, Denmark*

In this contribution we present the metamaterial based polarization converter from linear to elliptical polarization with a desired ellipticity and ellipse orientation. We show two designs with the conversion efficiency 50% for the frequencies around 1 THz and 193 THz. The proposed device is realistic for fabrication and can be used as a polarizer or a polarization compensator.

10. Dispersive TLM model of lossy GRIN MTM structures

Tatjana Asenov, *Faculty of Electronic Engineering, University of Nis, Serbia*
Nebojsa Doncov, *Faculty of Electronic Engineering, University of Nis, Serbia*
Bratislav Milovanovic, *Faculty of Electronic Engineering, University of Nis, Serbia*

In this paper, dispersive numerical model of lossy composite right-left handed (CRLH) structures with gradient refractive index profiles is considered. Model to account for dispersive properties of left-handed metamaterials in the time-domain, is implemented into 3-D Transmission-Line Matrix Z-transform method. The accuracy, efficiency and stability of proposed model are verified for several gradient refractive index profiles across RH-LH interface using analytical solutions.

~~**11. On the theory of exciton states polarizability in open spherical quantum dot**~~

Nikita V. Korolev, *Voronezh State University, Russia*
Sergey E. Starodubtcev, *Voronezh State University, Russia*
Peter A. Meleshenko, *Voronezh State University, Russia*
Alexander F. Klinskikh, *V[This paper was not presented at the conference ("no-show").]*

We analyze theoretically t[This paper was not presented at the conference ("no-show").]gime for an open spherical quantum dot. B[This paper was not presented at the conference ("no-show").] method of self-consistent calculation of the dielectric constant for nanoparticles array is proposed.

12. Resonant mode analysis of metamaterials composed of conducting spheres and wires by equivalent circuit model

Keisuke Yoshida, *Department of Electrical Engineering, Kyoto University, Japan*
Takashi Hisakado, *Department of Electrical Engineering, Kyoto University, Japan*
Osami Wada, *Department of Electrical Engineering, Kyoto University, Japan*

This paper proposes a systematic method for deriving equivalent circuit models of metamaterials. Based on the electric field integral equations of Maxwell equations, we derive a lumped constant equivalent circuit model by Galerlin method. It clarifies the electromagnetic phenomena in metamateials such as their resonant modes and their frequencies.

13. Effect of damping coefficient of precession on the transmission of electromag-netic waves through a structure containing ferromagnetic material waveguide

Mohammed Shabat, *Islamic University of Gaza, Gaza Strip*
Muin Ubeid, *Islamic University of Gaza, Palestinian Authority, Gaza Strip*
Mohammed Sid-Ahmed, *Sudan University of Science and Technology, Sudan*

The electromagnetic wave propagation through a structure consisting of left-handed material (LHM) and dielectric slabs embedded in vacuum is analysed theoretically and numerically. The LHM is composed of magnetized ferrites to provide a negative permeability and a wire array to provide a negative permittivity. Maxwell's equations are used to determine the electric and mag-netic fields of the incident waves at each layer. Snell's law is applied and the boundary conditions are imposed at each layer interface to calculate the reflected, transmitted and loss powers of the structure. Numerical results are illustrated to show the effect of frequency, LHM thickness, applied magnetic fields and ferrite permittivity on the transmitted power of the structure as the damping coefficient of precession of ferrite changes. The obtained results are in agreement with the law of conservation of energy.

14. Nonlinear-transformation based cylindrical cloaks and their practical advantages

Transfered to oral, Thursday 15:45, Complex Electromagnetic Materials

Viktar Asadchy, *Gomel State University, Belarus*
Igar Faniayeu, *Gomel State University, Belarus*
Igor Semchenko, *Gomel State University, Belarus*
Sergei Khakhomov, *Gomel State University, Belarus*

Constitutive electromagnetic parameters of cloaks based on non-linear (quadratic and exponential) coordinate transformations are considered in this paper. The paper includes analysis and comparison of such parameters and parameters of cloaks based on the linear transformation found previously by other researchers. The shortcomings and advantages of found parameters are presented in this work. Also the results of numerical analysis of the cloak parameters done with COMSOL Multiphysics are shown.

15. Phase conjugation at normal incidence of signal wave on active metasurface with linear and nonlinear Huygens sources

Yuriy Rapoport, *Taras Shevchenko National University of Kyiv, Ukraine*
Sergei Tretyakov, *Dept. of Radio Science and Engineering, Aalto University, School of Science and Technology, Finland*
Stanislav Maslovski, *Instituto de Telecomunicações - Universidade de Coimbra, Portugal*

A possibility of almost perfect phase conjugation on metasurface with chiral metaparticles is shown for the normal incidence of the signal wave, using non-degenerate interaction with slightly different frequencies of the incident and phase conjugated waves. The use of linear and nonlinear Huygens sources ensures zero or very small reflection.

16. The features of nanoclusters and periodic structures formed at the surface of the crystal and amorphous silica by resonant CO2 laser irradiation

Anel Mukhamedgalieva, *Moscow State Mining University, Russia*
Anatolii Bondar, *Moscow State Mining University, Russia*
Mikhail Kononov, *Institute of General Physics of Russian Academy of Sciences, Russia*

Vladimir Laptev, *Institute of Spectroscopy of Russian Academy of Sciences, Russia*
Nadejda Novikova, *Institute of Spectroscopy of Russian Academy of Sciences, Russia*
Igor Shvedov, *Moscow State Mining University, Russia*

The pulsed CO2 laser irradiation (1 J, 70 ns, laser spot of 1.4 mm) of crystal and amorphous silica lead to creation both of the periodic microstructures and the nanoclusters at the irradiated surface.

17. Application of optical transformation for wavefront conversion by transmission-line method

Seyed Hassan Sedighy, *Department of Electrical Engineering and Computer Science University of California, Irvine , USA*
Mohammad Khalaj AmirHosseini, *Electrical Engineering, Iran University of Science and Technology , Iran*
Filippo Capolino, *Department of Electrical Engineering and Computer Science, University of California, USA*
Caner Guclu, *Department of Electrical Engineering and Computer Science, University of California, USA*

Cylindrical to planar optical transformation is proposed using a two-dimensional transmission line metamaterial. The simplified and realizable constructive parameters of the engineered medium are presented based on the introduced optical transformation. The design of transmission line cells is reported and the necessary constructive parameters are realized at 4GHz.

~~**18. Gain functionalized core-shell nanoparticles: the way to selectively compensate absorptive losses**~~

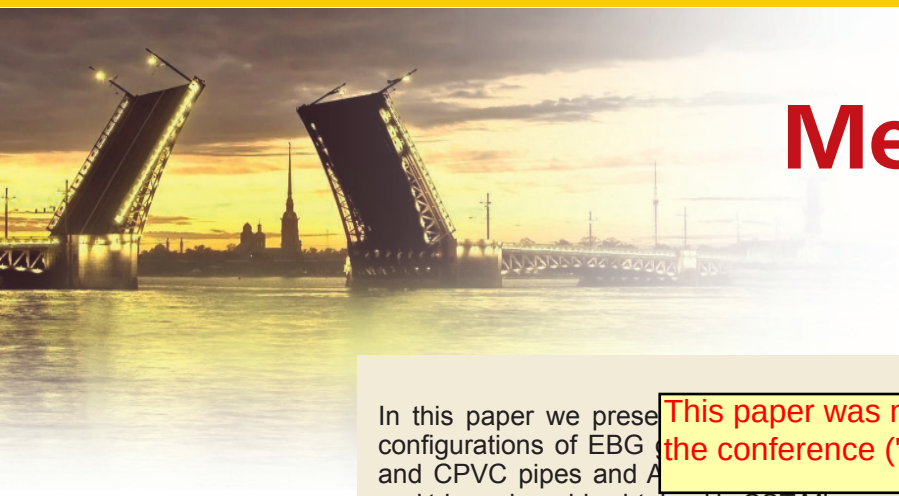
Antonio De Luca, *University of Calabria, Italy*
Melissa Infusino, *University of Calabria, Italy*
Serge Ravaine, *Centre de Recherche Paul Pascal, University of Bordeaux, France*
Alessandro Veltri, *University of Calabria, Italy*
Giuseppe Strangi, *University of Calabria, Italy*

We demonstrate that gain materials properly encapsulated into the shell surrounding metal nanoparticles (NPs) are responsible for the modification of the overall plasmon response of engineered nanostructures. A comparison between designed systems based on functionalized c ted dye molecules is presented. Experimer ng enhancement, accompanied by an incre ain, reveal striking optical loss compensation effects. Fluorescence lifetime measurements demonstrate a quenching of dye photoluminescence in functionalized core/shell NPs samples with respect to pure dye solutions, confirming the strong resonant coupling occurring between gain medium and gold NPs. The experimental evidence of a selective modification of gain functionalized core-shell Au NPs extinction curve is found in good agreement with simplified theoretical model results. The model verify the causality principle through Kramers-Kronig dispersion relations for the investigated gain functionalized plasmonic nanostructure.

This paper was not presented at the conference ("no-show").

~~**19. Investigation on the effect of defects in different types of EBG grids**~~

Eduardo Sartori, *UNISAL, Brazil*
Hugo Figueroa, *UNICAMP, Brazil*



In this paper we prese This paper was not presented at the conference ("no-show"). in many geometric configurations of EBG als as such as PVC and CPVC pipes and A results from square and triangular grids obtained in CST Microwave Studio® simulations and experimental measurements.

20. Focusing the acoustic emission by the crystal with nonlinear interaction

Evgeny Vinogradov, *Prokhorov General Physics Institute, Russian Academy of Sciences, Russia*
Galina Vinogradova, *Prokhorov General Physics Institute, Russian Academy of Sciences, Russia*
Alexander Melnikov, *Prokhorov General Physics Institute, Russian Academy of Sciences, Russia*

In this paper we describe experimentally observed radiation focusing of piezoelectric element placed in the center of the phonic crystal in the focal spot outside of the crystal with dimensions smaller than the wavelength ($\sim \lambda/3$) and with high contrast. We investigate the frequency dependence of the transmission coefficient as a permitted as prohibited the zones. Their maximum and minimum values differed up to 5 orders of magnitude. Observed non-linear parametric conversion of radiation due to the nonlinearity of the air excited by piezo vibration at frequencies lying inside the gap (as in a quantum dot). The intended use for the observed phenomenon further narrowing of the focal spot and enhance its intensity.

21. Coherent control of a terahertz metamaterial Transfered to oral, Thuesday 17:45, THZ and Microwave Metamaterials

Florian Enderli, *University of Bern, Switzerland*
Thomas Feurer, *University of Bern, Switzerland*

We present the first coherent control experiments of a metamaterial. We fabricated a planar metamaterial showing two separated resonances at THz frequencies. It acts similar to an atomic system with two uncoupled excited states. Through temporal coherent control with broadband THz pulses we can excite both, none, or individual resonances.

22. Analysis of acoustic metamaterials – acoustic scattering matrix an extraction of effective parameters

Norbert Cselyuszka, *University of Novi Sad, Serbia*
Milan Sečujski, *University of Novi Sad, Serbia*
Vesna Crnojević-Bengin, *University of Novi Sad, Serbia*

To allow straightforward characterization of acoustic metamaterials, we present a method for extraction of complex S-parameters, based on the analogies that exist between propagation of electromagnetic and acoustic waves. We then propose the method for extraction of effective material properties of acoustic metamaterials, namely the bulk modulus and density. The proposed methods are validated through simulations in COMSOL Multiphysics and can be used as useful tool in design of various acoustic metamaterials.

~~**23. Investigating the dispersion of plasmonic resonances in a fishnet structure by variable angle spectroscopic ellipsometry**~~

Milka Jakovljevic, *Institute of Physics, Serbia*
Goran Isic, *Institute of Physics, Serbia*

Tom Oates, *Leibniz Institut für Analytische Wissenschaften - ISAS - e.V, Germany*
Babak Dastmalchi, *Zentrum für Oberflächen- und Nanoanalytik, Universität Linz, Austria*
Borislav Vasic, *Institute of Physics, Serbia*
Karsten Hinrichs, *Leibniz Institut für Analytische Wissenschaften - ISAS - e.V, Germany*
Iris Bergmair, *Functional Surfaces and Nanostructures, PROFACTOR GmbH, Austria*
Kurt Hingerl, *Zentrum für Oberflächen- und Nanoanalytik, Universität Linz, Austria*
Rados Gajic, *Institute of Physics, Serbia*

Variable angle ellipsometric response of the rectangular fishnet structures at near-infrared and opti[This paper was not presented at the conference ("no-show").]xperimentally and numerically. Dispersions onances are extracted from the ellipsometric response. Magnetic field and current distributions at the resonant frequencies obtained from numerical calculations confirmed their nature. The positions of the Rayleigh anomalies are calculated and marked in spectra.

~~24. Investigation of DNG behaviour of a concentric Sierpinski sectoral SRR shaped metamaterial~~

Asit K. Panda, *Department of Electronic & Communication Engineering,National Institute of Science and Technology, Berhampur, Orissa, India*
Sudhakar Sahu, *School of Electronic Engineering, KIIT University, Bhubaneswar, ORISSA, India*
Bhabani S. Nayak, *National Institute of Science and Technology, Berhampur, Orissa, India*
Dipak R. Poddar, *Jadavpur University, Kolkata, West Bengal, India*

In this paper we study the DNG behaviour of a new concentric MTM structure whose unit cell is composed of concentric sierpinski sectoral SRR and CLS for S band. A modified NRW method [This paper was not presented at the conference ("no-show").]arameters, refractive index and also the dis parameters result. It is shown that the new MTM structure exhibits DNG behaviour in the frequency region of 2.75GHz-3.GHz. It also investigates the effect of geometrical parameters, like strip width, slit gap, length and width of each side, arc length on magnetic resonant frequency behaviour. When the electromagnetic wave interact with sierpinski sectoral metallic inclusions which when embedded in a host medium, lead to composite media with negative material parameters in the frequency region of interest

~~25. Permittivity determination of multi-sectional diaphragm with metamaterial layers in rectangular waveguide~~

Ekaterina Derevyanchuk, *Penza State University, Russia*
Yury Smirnov, *Penza State University, Russia*

In this paper we consider the inverse problem of electromagnetic waves — the permittivity determi[This paper was not presented at the conference ("no-show").]with metamaterial layers. The recurrent m developed. Based on the developed recurr al model for three-sectional diaphragm. Numerical results are presented.

~~26. Metamaterials based on glass metal nanocomposites~~

Mihail Petrov, *Saint-Petersburg Academic University RAS, Russia*

We investigate metal[illegible]nposite that are glasses with embedded meta[illegible]ty to control the optical properties of metama[illegible]anoparticle parameters: size, filling factor, composition. Fabrication technics of nanocomposites based gratings are also discussed

This paper was not presented at the conference ("no-show").

27. Losses dependence of wave transmission in the single negative metamaterials

Yanhong Liu, *Shanxi Datong University, China*

The losses-dependent properties of wave transmission in the single-negative (SNG) materials are experimentally investigated. Results show that the transmittance of the lossy SNG materials can be enhanced by increasing dissipation coefficient. The lossy ENG material is physically fabricated by using CRLH transmission lines grafted with radiation unit cell.

~~28. The increase of evanescent wave intensity on interface "uniaxial omega-medium - nonmagnetic insulator"~~

Andrey Savchenko, *Donetsk Institute for Physics and Engineering of the NAS of Ukraine, Ukraine*
Dmitry Kulagin, *Donetsk Institute for Physics and Engineering of the NAS of Ukraine, Ukraine*
Artem Tarasenko, *Donetsk Institute for Physics and Engineering of the NAS of Ukraine, Ukraine*
Sergey Tarasenko, *Donetsk Institute for Physics and Engineering of the NAS of Ukraine, Ukraine*
Vladimir Shavrov, *Kotel'nikov Institute of Radio Engineering and Electronics of the RAS, Russia*

It has been shown tha[illegible]e in the intensity of TM or TE evanescent elec[illegible]en the uniaxial omega-medium and non-ma[illegible]nes the dispersion law of the corresponding [illegible]e energy flux through the interface is zero at any time.

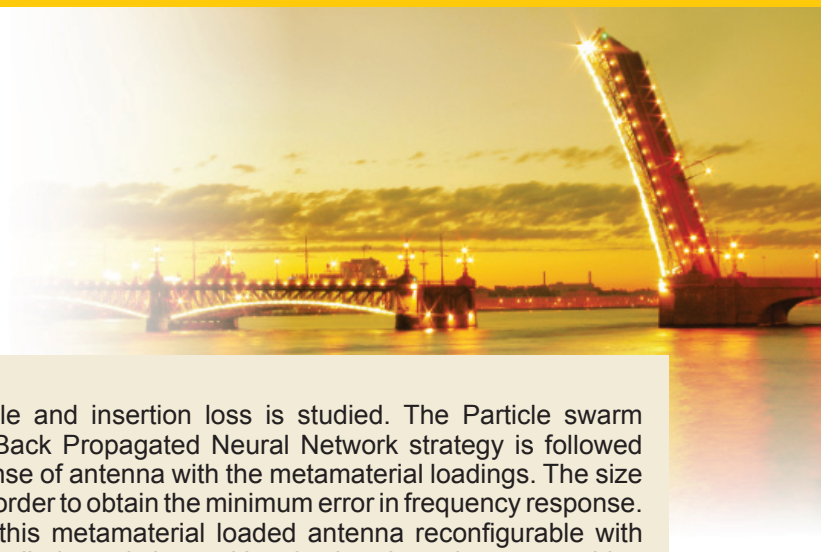
This paper was not presented at the conference ("no-show").

~~29. PSO-BPNN strategy for designing metamaterial loaded antenna with an attempt to make reconfigurable~~

Asit K. Panda, *National Institute of Science and Technology, Berhampur, Orissa, India*
Bhabani S. Nayak, *National Institute of Science and Technology, Berhampur, Orissa, India*
Sudhakar Sahu, *School of Electronics Engineering, KIIT University, Bhubaneswar, Orissa, India*
Rabindra K. Mishra, *Electronics Science dept. Berhampur University, Orissa, India*

In this paper we[illegible]thodology for designing metamaterial loade[illegible]tigated with simultaneous change in dimensi[illegible]ce of separation between

This paper was not presented at the conference ("no-show").



SRR and Antenna as variable and insertion loss is studied. The Particle swarm optimization hybridised with Back Propagated Neural Network strategy is followed to model the frequency response of antenna with the metamaterial loadings. The size of the structure is optimized in order to obtain the minimum error in frequency response. We also attempted to make this metamaterial loaded antenna reconfigurable with the help of using stub and diode switches with 50 ohm impedance matching by placing two SRRs in the both sides of the antenna. This enables the antenna to give rise resonating frequencies at different bands with appreciable gain.

Oral sessions (Monday afternoon II)

17:30 – 19:00	Nonlinear and Tunable Metamaterials	Kremlyovsky hall
17:30 – 19:00	RF and Microwave Metamaterials I	Tverskoy hall
17:30 – 19:00	Transformation Optics I	Nevsky hall

17:30 – 19:00 Nonlinear and Tunable Metamaterials — Kremlyovsky hall

Session chairperson(s): Pierre-Francois Brevet

17:30 – 17:45

Enhanced second harmonic generation in doubly resonant photonic crystal cavities made of silicon Oral

Claudiu G. Biris, *High Performance Computing Centre, West University of Timisoara, Romania*
Camelia D. Sold, *Faculty of Physics, West University of Timisoara, Romania*
Madalin O. Bunoiu, *Faculty of Physics, West University of Timisoara, Romania*
Nicolae C. Panoiu, *Department of Electronic and Electrical Engineering, University College London, UK*

We investigate numerically the formation of non-linear cavity modes in photonic crystal cavities made of silicon. We employ a numerical method based on the multiple scattering matrix algorithm to show that silicon based photonic crystal cavities exhibit doubly resonant defect modes, which can be generated via surface second harmonic generation. We show that by carefully designing the geometric parameters of the optical cavity the nonlinear effects can be strongly enhanced leading to increased efficiency of light generation at the second harmonic.

17:45 – 18:00

Frequency conversion of terahertz waves by ultrafast optical pumping of metamaterials Oral

Nao Sato, *Shinshu University, Japan*
Fumiaki Miyamaru, *Shinshu University, Japan*
Masanori Hangyo, *Osaka University, Japan*
Michael Bakunov, *University of Nizhny Novgorod, Russia*
Mitsuo Takeda, *Shinshu University, Japan*

We demonstrate the frequency conversion of terahertz waves by temporally changing the refractive index of semiconductor substrate that is attached on the metamaterial. The frequency of terahertz wave is up-converted by illuminating femtosecond optical pulses on the semiconductor surface when terahertz waves are localized in the vicinity of metamaterial.

18:00 – 18:30 **Semiconductor approaches for tunable metamaterials in the mid-infrared** Invited oral

Michael Sinclair, *Sandia National Laboratories, USA*
Igal Brener, *Sandia National Laboratories, USA*
Young Chul Jun, *Center for Integrated Nanotechnologies, USA*
Alon Gabbay, *Center for Integrated Nanotechnologies, USA*
Eric Shaner, *Sandia National Laboratories, USA*
John Reno, *Sandia National Laboratories, USA*

We will describe our efforts to develop tunable metamaterials operating in the mid-infrared. Our tunable metamaterials comprise planar metallic resonators fabricated on semiconductor heterostructures. The optical response of the metamaterial resonators is influenced by near-field coupling to the quantum well transitions in the semiconductor substrate and can be tuned through the application of electrical bias.

18:30 – 18:45 **Nonlinear cloaking of nanowires** Oral

Nina Zharova, *Institute of Applied Physics, RAS, Russia*
Ilya Shadrivov, *Nonlinear Physics Centre, RSPE, Australian National University, Canberra, Australia*
Alexander Zharov, *Institute for Physics of Microstructures, RAS, Nizhny Novgorod, Russia*
Yuri Kivshar, *Nonlinear Physics Centre, RSPE, Australian National University, Canberra, Australia*

We study scattering properties of multi-layer plasmonic nanowires with a nonlinear response. With a proper choice of parameters we can either increase or decrease the scattering cross-section by changing the intensity of the external field. We demonstrate the efficient control and even the possibility to reverse the scattering direction by means of small variations of the incident wave amplitude.

18:45 – 19:00 **Ultrasound-tunable dispersive optical medium** Oral

Vitold Pozhar, *STC Unique Instrumentation RAS, Russia*
Vladislav Pustovoit, *STC Unique Instrumentation RAS, Russia*
Kristina Tabachkova, *Bauman Moscow State Technical University, Russia*

There is considered designing materials with real-time variable dispersion characteristics and tunable spectral optical properties. It is based on dynamical structures technique generated in a medium by ultrasonic waves.

17:30 – 19:00 RF and Microwave Metamaterials I — Tverskoy hall

Session chairperson(s): Sergei Tretyakov

17:30 – 17:45 **Analysis of a CRLH SIW dual band antenna** Oral

Jan Machac, *Czech Technical University in Prague, Czech Republic*
Milan Polivka, *Czech Technical University in Prague, Czech Republic*
Kirill Zemlyakov, *St. Petersburg Electrotechnical University, Russia*

This paper presents the results of an investigation of a new version of a CRLH substrate integrated waveguide leaky wave antenna. The antenna operates in two frequency bands and its main beam can be scanned by changing frequency from backward to forward. The antenna structure is planar and can be fabricated by a standard PCB technology, so it is suitable for mass production.

17:45 – 18:00

Chirp as a tool to control the propagation velocity of a femtosecond laser pulse in negative index metamaterials Oral

Vladimir Fedorov, *Institute of Advanced Energy, Kyoto University, Japan*
Takashi Nakajima, *Institute of Advanced Energy, Kyoto University, Japan*

We study theoretically propagation of a femtosecond laser pulse in a negative-index metamaterial (NIM). Our results show that at a certain wavelength range one can control the propagation velocity of the pulse simply by changing its initial chirp.

18:00 – 18:15

Entwined spiral arrays on ferrite substrates Oral

Gwendal Cochet, *Queen's University Belfast & University of Brest, United Kingdom & France*
Andrea Vallecchi, *University of Siena, Italy*
Alexander Schuchinsky, *Queen's University Belfast, United Kingdom*
Patrick Queffelec, *University of Brest, France*

The properties of metasurfaces formed by entwined spiral arrays on ferrite substrates are explored. Significant increase of the fractional bandwidth has been achieved by coupling the ferromagnetic and array topological resonances. The features of resonance transmittance assisted by the volume spin waves in the ferrite substrate are discussed.

18:15 – 18:30

Real-time video-accesses to internal, external and surface microwaves in and around a two-dimensional metamaterial sample by live electrooptic imaging Oral

Masahiro Tsuchiya, *National Institute of Information and Communications Technology, Japan*
Takahiro Shiozawa, *Kagawa National College of Technology, Japan*

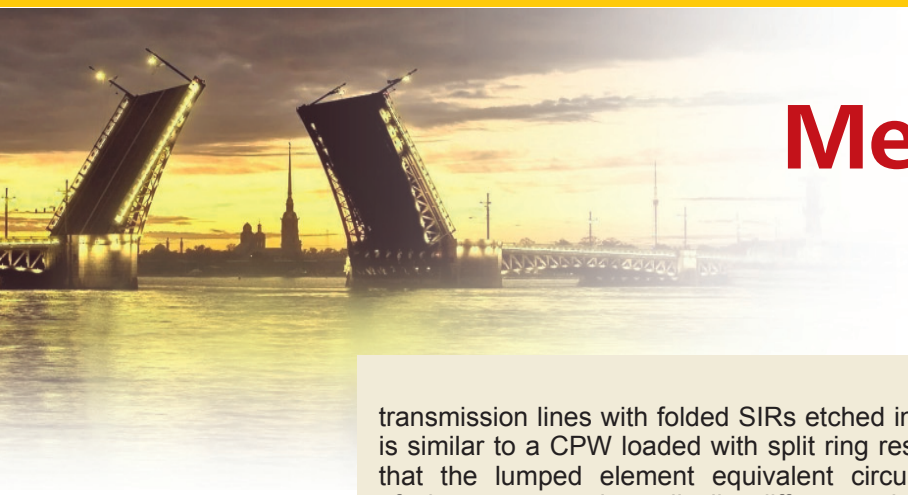
Successful demonstration of real-time video-accesses to microwaves in and around a two-dimensional metamaterial sample is reported, which was performed by 10,000-parallel vector measurements for RF electric fields. Besides external forward waves, internal backward-travelling plane waves accompanied with Bloch function features and a symptom of surface wave have been visually observed.

18:30 – 19:00

Transmission lines loaded with folded stepped impedance resonators (SIRs): modeling and applications CONSOLIDER project CSD2008-00066 presentation

Jordi Naqui, *CIMITEC - Departament d'Enginyeria Electrònica- Universitat Autònoma de Barcelona, Spain*
Miguel Duran-Sindreu, *CIMITEC - Departament d'Enginyeria Electrònica-Universitat Autònoma de Barcelona, Spain*
Ferran Martin, *CIMITEC - Departament d'Enginyeria Electrònica-Universitat Autònoma de Barcelona, Spain*

Transmission lines loaded with folded stepped impedance resonators (SIRs) are studied. Specifically, the paper is focused on coplanar waveguide (CPW)



transmission lines with folded SIRs etched in the back substrate side. The structure is similar to a CPW loaded with split ring resona-tors (SRRs). However, it is shown that the lumped element equivalent circuit model that describes the unit cell of the structure is radically different, since the interaction between the line and the folded SIRs is dominated by electric coupling, rather than magnetic coupling (as occurs in SRR-loaded CPWs). Advantages and potential applications of these artificial lines are highlighted.

17:30 – 19:00 Transformation Optics I — Nevsky hall

Session chairperson(s): Vladimir M. Shalaev

17:30 – 18:00 ~~**Revisit the carpet cloak from optical conformal mapping**~~ ~~Invited oral~~, Withdrawal

Huanyang Chen, *School of Physical Science and Technology, Soochow University, China*
Hui Li, *School of Physical Science and Technology, Soochow University, China*

The original carpet cloak [Phys. Rev. Lett. 101, 203901 (2008)] was designed by a numerical method, the quasi-conformal mapping. Therefore its refractive index profile was obtained numerically. In this paper, we propose a new carpet cloak based on the optical conformal mapping, with an analytical form of a refractive index profile, thereby facilitating future designs.

18:00 – 18:15 **Design of invisibility cloaks using surface integral equation method** Oral

Javier Rivero, *University of Extremadura, Spain*
José Manuel Taboada, *University of Extremadura, Spain*
Luis Landesa, *University of Extremadura, Spain*

Plasmonic cloaking is a scattering cancellation technique consisting of covering the scatterer by an invisibility cloak made up multiple layers of homogeneous plasmonic. A suitable selection of the cloak geometry and materials allows reducing the scattered field. We propose a novel cloaking optimization technique based on the application of surface integral equation formulations and optimization techniques.

18:15 – 18:30 **Metal–dielectric metamaterials for transformation–optics and gradient–index devices at visible wavelengths** Oral

Andreas Rottler, *Institute for Applied Physics, University of Hamburg, Germany*
Daniel Diedrich, *Institute for Applied Physics, University of Hamburg, Germany*
Detlef Heitmann, *Institute for Applied Physics, University of Hamburg, Germany*
Stefan Mendach, *Institute for Applied Physics, University of Hamburg, Germany*

We theoretically investigate an optical metamaterial consisting of periodically arranged silver spheres embedded in a host medium of PMMA. We demonstrate that this metamaterial can be used to fabricate a cylindrical cloaking device operating at visible wavelengths. The presented metamaterial utilizes the tunability of the plasmonic interactions between the metallic nanoparticles which depend on distance and size. The presented concept is also applicable to gradient-index devices with an isotropic permittivity distribution. We show this for the optical black hole.

18:30 – 18:45 **Subwavelength imaging with materials of in–principle arbitrarily low index contrast** Oral

Yungui Ma, *Zhejiang University, China*
Sahar Sahebdivan, *University of St Andrews, United Kingdom*

St. Petersburg, **Russia**

Monday, 17th September

C.K. Ong, *National University of Singapore, Singapore*
Tomas Tyc, *Masaryk University, Czech Republic*
Ulf Leonhardt, *University of St Andrews, United Kingdom*

Perfect imaging with Maxwell's fish eye opens the exciting prospect of passive imaging systems with a resolution no longer limited by the wave nature of light. But it also challenges some of the accepted wisdom of super-resolution imaging and therefore has been subject to controversy and discussion. Here we discuss an idea for even simpler perfect-imaging systems based on geometrical optics and prove by experiment that it works.

18:45 – 19:00 **Manipulating light by rotating optical axes** Oral

Jensen Li, *City University of Hong Kong, Hong Kong*
Zixian Liang, *City University of Hong Kong, Hong Kong*
Ming Kang, *City University of Hong Kong, Hong Kong*
Xu Jiang, *University of Maryland, USA*

We investigate how light is manipulated using a single type of anisotropic metamaterial. We construct a 2D transformation medium utilizing effective media of layers of varying optical axes, associating to an area-conserving map. For out-of-plane wave propagation, an optical axis profile using the same metamaterial structure can engineer the wavefront.

Tuesday, 18th September

Oral sessions (Tuesday morning I)

08:30 – 10:00	Transformation Optics and Cloaking	Kremlyovsky hall
08:30 – 10:00	Homogenization I	Tverskoy hall
08:30 – 10:00	Tunable Metamaterials	Nevsky hall

08:30 – 10:00 **Transformation Optics and Cloaking** — Kremlyovsky hall
Session chairperson(s): Ulf Leonhardt

08:30 – 09:00 **Field transformation: A paradigm for designing wide band, wide-angle dual-polarized lenses and cloaks with physically realizable materials** Invited oral

Raj Mittra, *EMC Lab, USA*

In this paper, we review the Transformation Optics (TO) approach to designing cloaks, superlenses and identify some of the difficulties associated with the practical devices realized by using this approach, for instance polarization dependence, physical

realizability and dispersion. Following this we present an alternative method based upon Field Transformation (FT), as a way to mitigate some of these problems.

09:00 – 09:30 **Transformation optics based cloaked sensors** Invited oral

Matti Lassas, *University of Helsinki, Dept. of Mathematics, Finland*
Allan Greenleaf, *Univ. of Rochester, US*
Yaroslav Kurylev, *UCL, UK*
Gunther Uhlmann, *Univ. of California Irvine, US*

Ideal transformation optics cloaking at positive frequency, besides rendering the cloaked region invisible to detection by scattering of incident waves, also shields the region from those same waves. In contrast, we demonstrate that approximate cloaking permits a strong coupling between the cloaked and uncloaked regions; careful choice of parameters allows this coupling to be amplified, leading to effective cloaks with degraded shielding. The sensor modes we describe are close to but distinct from interior resonances, which destroy cloaking. As one application, the sensor mode of a cloak makes it possible to use transformation optics to hide sensors in the cloaked region and yet enable the sensors to efficiently measure waves incident on the exterior of the cloak, an effect similar to the plasmon based approach of Alu and Engheta.

09:30 – 09:45 **Analytical modeling of conformal metasurface mantle cloaks for cylindrical objects** Oral

Yashwanth Reddy Padooru, *Department of Electrical Engineering, The University of Mississippi, USA*
Alexander B. Yakovlev, *Department of Electrical Engineering, The University of Mississippi, USA*
Pai-Yen Chen, *Department of Electrical and Computer Engineering, The University of Texas at Austin, USA*
Andrea Alu, *Department of Electrical and Computer Engineering, The University of Texas at Austin, USA*

In this work, we demonstrate the concept of mantle cloaking for cylindrical objects using realistic ultra-thin metasurfaces composed of 2-D printed (patches, Jerusalem crosses, and cross dipoles) and slotted structures (meshes, slot-Jerusalem crosses, and slot-cross dipoles). We use a rigorous analytical model based on Lorenz-Mie scattering theory which utilizes the two-sided impedance boundary conditions at the metasurface. Specifically, the analytical expressions for the metasurface surface impedances are borrowed from the analysis of planar grid-array elements. It is shown that, by properly tailoring the surface reactance of the metasurface mantle cloaks, the scattering from a given object can be significantly reduced.

09:45 – 10:00 **Cloaked half-wave dipole antennas using the mantle-cloaking approach** Oral

Alessio Monti, *Roma Tre University, Italy*
Andrea Alù, *University of Texas at Austin, United States*
Filiberto Bilotti, *Roma Tre University, Italy*

In this paper, we show how it is possible to realistically cloak half-wave dipole antennas in transmitting and receiving regimes by using the mantle-cloaking approach. In particular, we first propose the design of a cloaked half-wave receiving dipole and, next, we apply the mantle-cloaking approach to a multiple-antenna transmitting scenario.

St. Petersburg, **Russia**

Tuesday, 18th September

08:30 – 10:00 | **Homogenization I** | **Tverskoy hall**

Session chairperson(s): Constantin Simovski

08:30 – 08:45 **Basics of homogenization of Maxwell equations** Oral

Arkadi Chipouline, FSU Jena, Germany

In this work we show that there are some basic principles for the averaging procedure (irrespective to what type of material is studied) which have to be satisfied. Any homogenization model has to be consistent with the basic principles. In case of absence of this correlation of a particular model with the basic principles the model could not be accepted as a credible one.

08:45 – 09:00 ~~**Effective conductivity and magnetic permeability of nanostructured media with sharp interfaces in magnetic field**~~ ~~Oral~~, Withdrawal

Anatoly Rinkevich, *Institute of Metal Physics, Russia*
Dmitry Perov, *Institute of Metal Physics, Russia*
Mikhail Samoilovich, *TcNITI Tekhnomash, Russia*
Svetlana Klescheva, *TcNITI Tekhnomash, Russia*

The problem of homogenization the nanostructured materials placed in DC magnetic field has been discussed. The experimental data are obtained using metallic superlattices, metal-dielectric thin films and 3D-nanostructured materials. All these materials contain ferro- or ferrimagnetic component. The transmission and reflection coefficients were measured on the waves of millimeter waveband. It has been shown that the experimental frequency spectra of the coefficients in zero magnetic field can be described by the effective conductivity and dielectric permittivity. The spectra of ferromagnetic resonance, however, can not be calculated correctly with the averaged magnetization.

09:00 – 09:15 **Effect of coupling between stacked resonators of an inkjet-printed THz metamaterial** Oral

Stefan Waselikowski, *University of Freiburg, Germany*
Patrick Bollgruen, *University of Freiburg / IMTEK, Germany*
Dario Mager, *University of Freiburg / IMTEK, Germany*
Jan Korvink, *University of Freiburg / IMTEK, Germany*
Markus Walther, *University of Freiburg, Germany*

Double and multi-layer metamaterials consisting of stacked, L-shaped resonators have been fabricated by ink-jet printing of silver nanoparticle ink onto the opposite sides of dielectric substrates. Using THz time-domain spectroscopy and numerical simulations the effect of coupling between the stacked structures is investigated.

09:15 – 09:30 **Experimental determination of effective parameters in a layered metamaterial** Oral

Sebastian Engelbrecht, *Institute of Solid State Physics, Vienna University of Technology, Austria*
Alexey M. Shuvaev, *Institute of Solid State Physics, Vienna University of Technology, Austria*
Andrei Pimenov, *Institute of Solid State Physics, Vienna University of Technology, Austria*

Using millimeter wave spectroscopy we extract the effective parameters of a layered metamaterial made from split ring resonators. In agreement with recent theoretical

considerations the effective model for a bulk metamaterial strongly contradicts the experimental spectra. On the contrary, the description within the concept of a layered metamaterial well reproduce the transmittance and reflectance data. We demonstrate that the thickness of the metamaterial layer is not a well-defined parameter of the model. Instead, the product of the layer thickness and the dielectric susceptibility can be used to account for the experiments.

09:30 – 09:45 **Core–shell spherical particles for near–infrared isotropic negative refraction** Oral

Dmitry Morits, *Aalto University, Finland*
Constantin Simovski, *Aalto University, Finland*

In this paper we suggest a design solution of metamaterial composed of coated non-magnetic spheres, which possess negative refractive index in the inter-band (visible/near-infrared bound) range. The electromagnetic response of the particles was studied using an analytical theory and full-wave numerical simulations. The effect of negative refraction was confirmed by simulations of the Gaussian beam incidence on the metamaterial prism.

09:45 – 10:00 **Losses from lossless building blocks?** Oral

Ari Sihvola, *Aalto University, Finland*
Henrik Wallén, *Aalto University, Finland*
Henrik Kettunen, *Aalto University, Finland*

In this paper the focus is in the generation of dielectric losses from lossless or extremely low-loss component materials by a suitable mixing process. In ordinary mixing, the macroscopic continuum “inherits” the properties of its constituents. Here we show by several examples, that it is possible to break this rule. The dissipative character of dielectric materials can be drastically changed by mixing.

Tunable Metamaterials

08:30 – 10:00 **Nevsky hall**

Session chairperson(s): Andrea Alu

08:30 – 08:45 **Tuning nonlinear metamaterials with light** Oral

Polina Kapitanova, *National Research University of Information Technologies, Mechanics and Optics (ITMO), Russia*
Dmitry Filonov, *National Research University of Information Technologies, Mechanics and Optics (ITMO), Russia*
Alexey Slobozhanyuk, *National Research University of Information Technologies, Mechanics and Optics (ITMO), Russia*
Pavel Voroshilov, *National Research University of Information Technologies, Mechanics and Optics (ITMO), Russia*
Ilya Shadrivov, *Nonlinear Physics Centre, Research School of Physics and Engineering, Australian National University, Australia*
Stanislav Maslovski, *Instituto de Telecomunicações, Universidade de Coimbra, Portugal*
Pavel Belov, *Queen Mary University of London, United Kingdom*
Yuri Kivshar, *Nonlinear Physics Centre, Research School of Physics and Engineering, Australian National University, Australia*

We introduce a novel approach for creating tunable electromagnetic metamaterials. We demonstrate experimentally that magnetic resonance of a split-ring resonator (”meta-atom” of a composite material) with a photodiode and a varactor diode can be tuned by changing the intensity of an external light source. Moreover, for two coupled

resonators we show that we can achieve light-induced switching between dark and bright modes. We study experimentally dynamic tunability and self-induced nonlinearity of the light-tunable "meta-atoms", and also demonstrate a light-controllable magnetic reflector array based on tunable split-ring resonators.

08:45 – 09:00

Low–loss tunable metamaterials using superconducting thin–film circuits with Josephson junctions Oral

Susanne Butz, *Physikalisches Institut, Karlsruhe Institute of Technology, Germany*
Philipp Jung, *Physikalisches Institut, Karlsruhe Institute of Technology, Germany*
Sergey S. Shitov, *National University of Science and Technology MISIS, Russia*
Alexey V. Ustinov, *Physikalisches Institut, Karlsruhe Institute of Technology, Germany*

We report on recent experiments with superconducting Josephson metamaterials. In such a mate-rial conventional split ring resonators are replaced by superconducting loops that are interrupted by one Josephson junction, so called SQUIDs. As the split ring resonators, they can be seen as LC-resonators that couple to the magnetic component of the incoming wave. However, due the tunable intrinsic inductance of the Josephson junction, the resonance frequency of the SQUID can be changed by applying an external dc magnetic field. We present experimental results that show the tunability of the resonance frequency of these devices.

09:00 – 09:15

Electrically tunable open split–ring resonators based on liquid crystal material Oral

Matthias Maasch, *Institute for Microwave Engineering and Photonics, Technische Universität Darmstadt, Germany*
Alexander Groudas, *Institute for Microwave Engineering and Photonics, Technische Universität Darmstadt, Germany*
Onur Hamza Karabey, *Institute for Microwave Engineering and Photonics, Technische Universität Darmstadt, Germany*
Christian Damm, *Institute for Microwave Engineering and Photonics, Technische Universität Darmstadt, Germany*
Rolf Jakoby, *Institute for Microwave Engineering and Photonics, Technische Universität Darmstadt, Germany*

This work presents an array of tunable open split-ring resonators (OSRR) at 16GHz with liquid crystal (LC) in microstrip technology. Simulations and measurements show the tuning of the Bloch impedance and dispersion diagram of the OSRR with an insertion loss of less than 0.3dB per unit cell.

09:15 – 09:30

Tunable terahertz metamaterial based on a dielectric cube array with disturbed Mie resonance Oral

Dmitry Kozlov, *St. Petersburg Electrotechnical University "LETI", Russia*
Michail Odit, *St. Petersburg Electrotechnical University "LETI", Russia*
Irina Vendik, *St. Petersburg Electrotechnical University "LETI", Russia*
Young-Geun Roh, *Samsung Advanced Institute of Technology, Korea*
Sangmo Cheon, *Samsung Advanced Institute of Technology, Korea*
Chang-Won Lee, *Samsung Advanced Institute of Technology, Korea*

Tunable metamaterial operating in terahertz (THz) frequency range based on dielectric cubic particles with deposited conducting resonant strips was investigated. The frequency of the Mie resonances depends on the electric length of the strip. The simulated structure shows tunability over 20 GHz with -30 dB on/off ratio. This method of control can be applied for a design of tunable metamaterial based on various dielectric resonant inclusions.

09:30 – 09:45

Experimental verification of wideband tuning of the tunnelling frequency in ENZ channel Oral

Miranda Mitrovic, *Institute of Physics Belgrade, University of Belgrade, Serbia*
Branka Jokanovic, *Institute of Physics Belgrade, University of Belgrade, Serbia*
Nebojsa Vojnovic, *Institute of Physics Belgrade, University of Belgrade, Serbia*

In this paper we propose a novel design of ε-near-zero (ENZ) waveguide consisting of a microwave substrate which serves as a channel and as a carrier for input foam waveguides. A novel method for shifting the tunnelling frequency by using two longitudinal slots on the broad side of the channel was also proposed. In the end, experimental verification is presented. Shift of the tunnel-ling frequency Δf=300 MHz (6.79-6.49 GHz) was observed after adding slots.

09:45 – 10:00

Optically tunable metamaterial based on semiconductor superlattice Oral

Andrey Bogdanov, *Ioffe Physical-Technical Institute RAS, Russian Federation*
Robert Suris, *Ioffe Physical-Technical Institute of the Russian Academy of Sciences, Russian Federation*

In this work we theoretically analyzed new type of tunable metamaterial for terahertz optics based on semiconductor superlattice. We show that the signs of the dielectric function tensor components of suggested metamaterial can be optically manipulated by incident light of the visible or near-infrared spectrum. Density of the photon states in the metamaterial is controlled by the incident light intensity.

Poster session II + coffee break

10:00 – 11:30 **Microwave and Terahertz Metamaterials** Poster area

1. Negative-index metamaterials composed of three-concentric dielectric or magnetodielectric spheres

Boris Tomasic, *Air Force Research Laboratory, USA*
Kristopher Kim, *Air Force Research Laboratory, USA*
Naftali Herscovici, *Air Force Research Laboratory, USA*

In this paper we analyze an infinite periodic planar array of multiple-layer spheres where each concentric layer is made of different electric and/or magnetic materials. Each sphere can have up to three concentric layers to facilitate the optimization of metamaterial structure with respect to performance and ease of fabrication processes. Numerical results for the effective constitutive parameters of representative examples are given.

2. Terahertz wave propagation through metal hole array-dielectric multi-layers: toward fabrication of bulk hyperlens in terahertz region

Shohei Shimada, *Shinshu University , Japan*
Fumiaki Miyamaru, *Shinshu University , Japan*
Masanori Hangyo, *Osaka University, Japan*

Michael Bakunov, *University of Nizhny Novgorod, Russia*
Mitsuo Takeda, *Shinshu University, Japan*

We propose an approach to fabricate the hyperlens in terahertz (THz) region by using a metal hole array-dielectric multilayer structure. Fabricated multilayer structure has the anisotropic effective permittivity required for the hyperlens. In our simulated results, the diffraction of light was extremely suppressed by our structure.

3. Surface plasmon polaritons in subwavelength semiconductor–dielectric periodic structure in an external magnetic field

Illia Fedorin, *NTU KhPI, Ukraine*
Aleksej Bulgakov, *IRE NASU, Ukraine*

The problem of the surface waves existence in a subwavelength periodic semiconductor-dielectric structure is studied theoretically. The interface of such structure and semi-infinite isotropic media is considered. The dispersion equation is derived for the surface waves under consideration. The influence of artificial anisotropy on excitation of surface waves is theoretically investigated.

4. Laser micromaching for metamaterials manufacture

Pawel Koziol, *Wroclaw University of Technology, Poland*
Przemyslaw Gorski, *Wroclaw University of Technology, Poland*
Arkadiusz Antonczak, *Wroclaw University of Technology, Poland*
Maciej Nowak, *Wroclaw University of Technology, Poland*
Pawel Kabacik, *Wroclaw University of Technology, Poland*
Krzysztof Abramski, *Wroclaw University of Technology, Poland*

This paper presents an alternative method of metamaterials manufacture for radio frequency (S-band). We propose laser micromaching for directional changing properties of aluminium nitride (AlN) surface in order to obtain a conductive trace. This method was verified and compared with the traditional method – photolithography.

5. Investigations into minimization of mutual coupling between patch antennas with a row of metamaterial cells

Przemyslaw Gorski, *Wroclaw University of Technology, Poland*
Pawel Koziol, *Wroclaw University of Technology, Poland*

A signal-negative metamaterial can be used for the purpose of suppressing mutual coupling be-tween adjacent antenna elements in arrays. In carried out studies, we examined mutual coupling between two a pair of patches with inserted an artificial magnetic row in-between.

~~6. Dynamic magnetic metamaterials – new perspectives for terahertz applications. Theory and dispersion characteristics~~

Natalia Grigoryeva, *Saint-Petersburg Electrotechnical University, Russia*
Boris Kalinikos, *Saint-Petersburg Electrotechnical University, Russia*

A theory of propagating dipole-exchange spin waves in anisotropic dynamic magnetic metamaterial is pres ial is formed dynamically during the spin-wa on characteristics with parameters of struct sotropy of ferromagnetic film the operating frequency in such metamaterial can be shifted to terahertz zone.

This paper was not presented at the conference ("no-show").

7. Terahertz metamaterials based on resonance in TiO2 microspheres

Filip Dominec, *Institute of Physics, Academy of Sciences of the Czech Republic, Czech Republic*
Christelle Kadlec, *Institute of Physics, Academy of Sciences of the Czech Republic, Czech Republic*
Hynek Němec, *Institute of Physics, Academy of Sciences of the Czech Republic, Czech Republic*
Filip Kadlec, *Institute of Physics, Academy of Sciences of the Czech Republic, Czech Republic*
Riad Yahiaoui, *Université Bordeaux, France*
Patrick Mounaix, *Université Bordeaux, France*
U-Chan Chung, *Institut de Chimie de la Matière Condensée de Bordeaux, France*
Petr Kužel, *Institute of Physics, Academy of Sciences of the Czech Republic, Czech Republic*

Metamaterials composed of high-permittivity TiO2 microspheres with diameters of 30-100 micrometers show a magnetic resonance in the THz range. The resonances observed in terahertz spectra were broadened by nonuniform sizes of microspheres and match those predicted by numerical simulations.

~~8. Metamaterial superstrates of antenna for directivity enhancement based on Fabry-Perot resonant theory~~

Long Li, *Xidian University, China*
Weiqiang Han, *Xidian University, China*
Shuo Lei, *Xidian University, China*
Haixia Liu, *Xidian University, China*
Changhong Liang, *Xidian University, China*

Metamaterial superstrate is a significant method to obtain high directivity of one or a few antennas. In this paper, the characteristics of directivity enhancement using different metamateria uch as electromagnetic bandgap (EBG) stru FSS), and left-handed material (LHM), are y of Fabry-Perot (F-P) resonant cavity. Furthermore, a new design of the optimum reflection coeffi-cient of superstrates for the maximum antenna directivity is proposed and validated.

This paper was not presented at the conference ("no-show").

9. Dual band branch-line coupler using novel CRLH transmission lines

Iulia Andreea Mocanu, *University Politehnica of Bucharest, Romania*
Gheorghe Sajin, *National Institute for Research and Development in Microtechnologies, Bucharest, Romania*

In this paper is presented the design, simulation and electric characterization of a new CRLH dual band branch-line coupler. The novelty of this coupler is that it uses Composite Right / Left- Handed (CRLH) transmission lines with only one unit cell designed to act as a quarter wavelengths. The design relations for this quarter wavelengths CRLH transmission lines are deduced analytically and validated accordingly to simulation and measurement of the coupler's perfo-rmances. The unit cells have been implemented using lumped components and the impact of the parasitic effects of the capsules has been analyzed and discussed.

10. Advantages of metamaterials based on double-stranded DNA-like helices

Sergei Khakhomov, *Gomel State University, Belarus*
Igor Semchenko, *Gomel State University, Belarus*
Alexey Balmakou, *Shizuoka University, Japan*
Masaaki Nagatsu, *Shizuoka University, Japan*

Here we consider three optimal helices: double-stranded (ds) DNA-like helix of one half-turn, optimal single-stranded (ss) helices of one- and two-turns, and compare the ratios of susceptibilities for them. Metamaterials with equal permittivity and permeability can be created on the basis of such optimal helices. It is shown that ds-DNA-like helix has highest susceptibilities among other optimal helices. This advantage can be used for creation metamaterials with negative refraction of electromagnetic waves.

11. Absorption-induced circular dichroism in metamaterials consisting of chiral molecules and non-chiral dyes

Yuuka Kosaka, *Nara Institute of Science and Technology (NAIST), Japan*
Satoshi Tomita, *Nara Institute of Science and Technology (NAIST), Japan*
Kei Sawada, *RIKEN SPring-8 Center, Japan*
Hisao Yanagi, *Nara Institute of Science and Technology (NAIST), Japan*

We experimentally demonstrate that circular dichroism (CD) is induced in visible region by chiral metamaterials consisting of chiral molecules and non-chiral dyes. More interestingly, multilayer-type metamaterials shows a polarity reversal of a CD peak when measured from opposite direction. Analytical calculation explains the enhancement of optical activity of the chiral medium by attaching a non-chiral medium.

12. Planar THz metamaterial with chiral symmetry breaking

Justyna Fabiańska, *University of Bern, Institute of Applied Physics, Switzerland*
Thomas Feurer, *University of Bern, Institute of Applied Physics, Switzerland*

We demonstrate a planar metamaterials with chiral symmetry breaking array in THz frequency range. Our results show that applying very interesting chiral metamaterial with the two x and y polarization induces the split of the transmission peak and it strongly afftects on the behavior of the electric field in the two resonances.

13. ~~Micromachined double-layer chiral metamaterial~~ Withdrawal

Wu Zhang, *Nanyang Technological University, Singapore*
Wei Ming Zhu, *Nanyang Technological University, Singapore*
M. L. Julius Tsai, *Institute of Microelectronics, Singapore*
Guo Qiang Lo, *Institute of Microelectronics, Singapore*
Dim Lee Kwong, *Institute of Microelectronics, Singapore*
Er Ping Li, *Institute of High Performance Computing, Singapore*
Ai Qun Liu, *Nanyang Technological University, Singapore*

This paper reports a double layer micromachined chiral metamaterial. The coupling of the two layers can be tuned via shifting the unit cells of the top layer. The tunable metamaterial shows large optical activity and asymmetric transmission as well. The rotation angle and asymmetry can be actively tuned through micromachined actuator.

~~14. Surface magnon polaritons in bianisotropic antiferromagnetic structures~~

Roland Tarkhanyan, *Inst. of Radiophysics & Electronics, NAS, Armenia, Armenia*

A novel class of surface [illegible]meric bianisotropic antiferromagnetic structu[illegible]vo distinct modes with unusual dispersion a[illegible]The role of losses is investigated and the pr[illegible]determined.

This paper was not presented at the conference ("no-show").

~~15. Chiral media based on five segments cranks~~

Gregorio J. Molina-Cuberos, *University of Murcia, Spain*
Ivan J. Martinez-Soler, *University of Murcia, Spain*
Angel J. Garcia-Collado, *Catholic Universtity of Murcia, Spain*
Maria J. Nuñez, *University of Murcia, Spain*
Jose Margineda, *University of Murcia, Spain*

A new chiral material is designed by grouping three dimensional chiral cranks composed by five segments. The unit cell is constituted by four pairs of cranks, all with the same handedn[illegible]allelepiped shape. The material has been [illegible]xperimental setup and by numerical simu[illegible]otatory dispersion and circular dichroism at microwave frequency range. The material presents two resonant frequencies, where the rotation angle reaches a peak of ±90º and the transmitted wave changes from linear to elliptical polarization. Between the two resonances, the structure behaves as a rotator, with a rotation angle of 17º±3º

This paper was not presented at the conference ("no-show").

16. Calculation and analysis of the tensors of electric, magnetic and chiral susceptibilities of the helices with optimal shape

Igor Faniayeu, *Francisk Skorina Gomel State University, Belarus*
Victor Asadchy, *Francisk Skorina Gomel State University, Belarus*
Igor Semchenko, *Francisk Skorina Gomel State University, Belarus*
Sergei Khakhomov, *Francisk Skorina Gomel State University, Belarus*

In this paper all components of tensors of electric, magnetic and chiral susceptibilities of one-turn and double-turn helices are calculated. The equality of axial components of above-named susceptibilities has been confirmed at the frequency close to the resonance. The comparison of frequency dispersion and anisotropic properties of the susceptibilities for both kinds of the helices is performed.

17. Hybridisation in coupled-dipole chiral meta-atoms Transfered to oral, Thursday 08:30, Chiral Metamaterials II

Mingkai Liu, *Australian National University, Australia*
David Powell, *Australian National University, Australia*
Ilya Shadrivov, *Australian National University, Australia*
Yuri Kivshar, *Australian National University, Australia*

We analyse the optical activity in twisted dimers, the meta-atoms of a chiral metamaterial, by introducing a simple yet accurate model for the coupling between them. The near-field interaction coefficients are derived from a Lagrangian model and include the effects of retardation, whereas the far-field radiation is based on a multipole expansion. Our approach is accurate over a wide frequency range, including the resonant regions with the highest optical activity. In contrast to other models of near-field interaction, it requires no fitted parameters or homogenization procedure and is directly applicable to a wide variety of resonant particles.

18. Insertion loss and dispersion of spin waves in magnonic crystals of finite length

Andrey Drozdovskii, *Electrotechnical University, Russia*
M.A. Cherkasskii, *Electrotechnical University, Russia*

The specific features of the dispersion characteristics of the magnonic crystals having the finite length are discussed. It is demonstrated that the spin-wave spectrum of a spatially finite magnonic crystal (MC) is characterized by the presence of the allowed bands of frequencies where the spin waves may propagate, and the stop-bands (Bragg resonances) where propagation of the spin waves is hindered. It is found that inside the stop-bands the dispersion properties of the finite-length MC differ from that characteristic for an infinite-length MC. It was shown that such a difference depends on the length of the magnonic crystal.

19. Dispersion of spin–electromagnetic waves in ferrite–ferroelectric n–layered structures

Andrey Nikitin, *Saint Petersburg Electrotechnical University, Russia*
Pavel Beliavskiy, *Saint Petersburg Electrotechnical University, Russia*
Vitaliy Vitko, *Saint Petersburg Electrotechnical University, Russia*
Aleksey Ustinov, *Saint Petersburg Electrotechnical University, Russia*
Alexander Semenov, *Saint Petersburg Electrotechnical University, Russia*

Artificial multiferroics in the form of ferrite-ferroelectric multilayered structures are considered as metamaterials that could be used for increasing functionality of the microwave devices. A theory of quasi-surface spin-electromagnetic waves (SEW) is developed for multilayered ferrite-ferroelectric (FF) structures consisted of several ferrite and ferroelectric layers. Spectra of SEW in the multilayered structures are numerically simulated. An influence of the different FF structure parameters on the dispersion of SEW is analyzed.

20. Tuning Fano resonances in a SRR based metamaterial

Jan Wallauer, *University of Freiburg, Germany*
Stefan Waselikowski, *University of Freiburg, Germany*
Markus Walther, *University of Freiburg, Germany*

Narrow Fano resonances are generated in a metamaterial consisting of coupled split-ring resonators (SRRs). We show that their asymmetric lineshape can be tuned dramatically by controlling the coupling between the symmetric and antisymmetric eigenmode of the metamaterial.

21. On the orientation of split–ring resonators excited by guided waves

Radovan Bojanic, *Institute of Physics, University of Belgrade, Serbia*
B. Jokanovic, *Institute of Physics, University of Belgrade, Serbia*
V. Milosevic, *Institute of Physics, University of Belgrade, Serbia*

We investigate how different positions of a gap influence the characteristics of SRRs coupled to microstrip line. We show that SRR with a gap perpendicular to microstrip line exhibits a strong electric response. Its magnetic response is a very weak despite of the external magnetic field that is perpendicular to the SRR plane. Influence of via is also examined.

22. EIT-like response in asymmetrically coupled split ring resonators

Vojislav Milosevic, *Institute of Physics, University of Belgrade, Serbia*
R. Bojanic, *Institute of Physics, University of Belgrade, Serbia*
B. Jokanovic, *Institute of Physics, University of Belgrade, Serbia*
B. Jelenkovic, *Institute of Physics, University of Belgrade, Serbia*

We investigate EIT-like effects in coupled split ring resonators, excited with guided waves. We demonstrate following effects: transmission peak at certain frequency, extreme values of group index of refraction and group delay, and pair of resonators which act as bright and dark element. We also provide method to tune the frequency where EIT-like effects occur.

23. Reduction of effect of water absorption for metamaterial sensing applications

Fumiaki Miyamaru, *Department of Physics, Faculty of Science, Shinshu University, Japan*
Satoshi Kawashima, *Department of Physics, Faculty of Science, Shinshu University, Japan*
Nao Sato, *Department of Physics, Faculty of Science, Shinshu University, Japan*
Shohei Shimada, *Department of Physics, Faculty of Science, Shinshu University, Japan*
Yuichi Ogawa, *Kyoto University, Japan*
Masanori Hangyo, *Osaka University, Japan*
Michael Bakunov, *University of Nizhny Novgorod, Russia*
Mitsuo Takeda, *Department of Physics, Faculty of Science, Shinshu University, Japan*

We investigate the effect of absorption coefficient of water, which is attached on split ring resonators (SRRs) surface, for a reflection spectrum in terahertz region. By inserting a thin dielectric film between SRRs and water, we can remain the apparent resonant dip, and simultaneously observe the shift of resonant frequency.

24. Surface plasmon induced transmission in a wire-medium metamaterial with diffraction gratings

Yujiro Kushiyama, *Tokyo University of Agriculture & Technology, Japan*

We present an experimental demonstration of surface plasmon induced transmission in the microwave region. A plasmonic material slab consists of a wire-medium metamaterial with metallic auxiliary elements. A coupling/decoupling between the TM-polarized plane wave and surface plasmons is achieved by placing diffraction gratings on both sides of the metamaterial slab. Numerical study shows the induced transmissions are attributed to dispersion relations of the metamaterial for surface plasmons and the periodicity of the diffraction gratings.

25. Balanced composite right/left-handed metamaterial CPW transmission line with improved bandwidth

Víctor Sanz, *Universidad de Castilla-La Mancha, Spain*
Alejandro L Borja, *Universidad de Castilla-La Mancha, Spain*

Joaquín Cascón, *Universidad de Castilla-La Mancha, Spain*
Ángel Belenguer, *Universidad de Castilla-La Mancha, Spain*

We present a balanced metamaterial-inspired coplanar waveguide transmission line with enhanced bandwidth. The coplanar waveguide line is composed of a basic cell with two split-ring resonators, two series capacitances, two wide shunt inductances, and four shunt capacitances. The configuration exhibits a wide bandpass response as a result of a balance between advance and delay phase characteristics.

~~26. Characteristic of magnetostatic waves at the interface between ferrite and MTMs parallel plate waveguide~~

Hala El-Khozondar, *Islamic University of Gaza, Palestine*
Zeyad Al-Sahhar, *Al-Aqsa University, Palestine*
Mohammed Shabat, *Islamic University of Gaza, Palestine*

This work considers magnetostatic surface waves propagation in parallel structure composed of ferrite film (TMs) placed on metal substrate and from top. o analyse propagation of slow (magnetostatic) ructure. Results show that propagating waves depends on the thickness for both ferrite and MTMs.

This paper was not presented at the conference ("no-show").

27. Using a via-less composite Right/Left handed transmission line to design a high compact Wilkinson power divider

Hossein Rahmanian, *School of Electrical Engineering, Iran University of Science and Technology, Iran*
Seyed Hassan Sedighy, *School of Electrical Engineering, Iran University of Science and Technology, Iran*
Mohammad Khalaj AmirHosseini, *School of Electrical Engineering, Iran University of Science and Technology, Iran*

The design and implementation method of a new less CRLH transmission line is presented. The CRLH transmission line characteristics are explored versus the parameters variation. The prototype is optimized to reach impedances as low as 30 ohms. Finally a very compact 1-4 Wilkinson power divider is designed and fabricated.

28. RF ENZ dielectric waveguide

Damir Muha, *FER, Croatia*

Recently, it has been shown possible to tunnel the flow of EM energy trough a slab (or a rod) made out of an ENZ material, transversal dimension of which can be arbitrarily smaller than a wavelength. Here, a complementary structure (a dielectric slab of subwavelength thickness), embedded within an ENZ metamaterial) is analyzed. Numerical results revealed behaviour similar to the behaviour of an ordinary dielectric waveguide, but with considerably longer guiding wavelength (for a fixed width of a core slab). Numerical analysis is complemented by the measurements on the RF scaled replica of an ENZ waveguide, operating in 4 GHz frequency band.

Oral sessions (Tuesday morning II)

11:30 – 13:00	Metamaterial Based Sensors I	Kremlyovsky hall
11:30 – 13:00	RF and Microwave Metamaterials II	Tverskoy hall
11:30 – 13:00	Quantum Aspects of Metamaterials I	Nevsky hall

11:30 – 13:00 Metamaterial Based Sensors I — Kremlyovsky hall

Session chairperson(s): Constantin Simovski

11:30 – 12:00 **Metamaterial biological sensors** Invited oral

Hatice Altug, *Boston University, USA*

Sensing of proteins and identification of their interactions is fundamental to our understanding of cellular biology and could greatly contribute to early diagnosis and treatment of diseases. We will demonstrate plasmonic metamaterials can be used to realize advanced spectroscopy tools that can extract structural and functional information of proteins.

12:00 – 12:15 **Low-cost large-area fabrication method and surface-enhanced infrared nanoantenna sensors and 3D chiral plasmonic nanostructures** Oral

Harald Giessen, *University of Stuttgart, 4th Physics Institute, Germany*
Jun Zhao, *University of Stuttgart, 4th Physics Institute, Germany*
Bettina Frank, *University of Stuttgart, 4th Physics Institute, Germany*
Stefano Cataldo, *University of Stuttgart, 4th Physics Institute, Germany*
Frank Neubrech, *Kirchhoff-Institut für Physik, Universität Heidelberg, Germany*

We use low-cost hole-mask colloidal nanolithography to manufacture large-area resonant split-ring metamaterials, and measure their infrared optical properties. This novel substrate is applied for antenna-enhanced SEIRA measurement using ODT and deuterated ODT, which demonstrates easy adjustability of our material to the vibrational modes. We further show fabrication of 3D staircase-type plasmonic nanospirals. The latter ones exhibit as expected a large circular di-chroism.

12:15 – 12:30 **Coupling effects in tuneable layers of metal nanoparticles** Oral

Stefan Mühlig, *Friedrich-Schiller-Universität Jena, Germany*
Alastair Cunningham, *University of Geneva, Switzerland*
Dana Cialla, *Friedrich-Schiller-Universität Jena, Germany*
Karina Weber, *Friedrich-Schiller-Universität Jena, Germany*
Thomas Bürgi, *University of Geneva, Switzerland*
Falk Lederer, *Friedrich-Schiller-Universität Jena, Germany*

In this contribution we study stacked planar arrays of amorphously arranged metallic nanoparticles. These large-scale arrays are fabricated by bottom-up techniques based on electrostatic forces. The system exhibits a high degree of flexibility

and allows for a tuning of the separation of consecutive layers at nanometer scale with ultra-high precision. This permits in-depth investigations of coupling effects in such systems. We also study asymmetric stacks where consecutive layers are made from nanoparticles of different materials. This break in symmetry entails the excitation of dark eigenmodes usually inaccessible in symmetric systems made of identical nanoparticles. Properties of these eigenmodes are disclosed experimentally as well as by simulations.

12:30 – 12:45 **Comparison of plasmon enhanced fluorescence and Raman processes near metal nanoparticles** Oral

Greg Sun, *University of Massachusetts Boston, USA*
Jacob Khurgin, *Johns Hopkins University, USA*

Fluorescence and Raman spectroscopy are both precise and versatile techniques for indentifying small quantities of chemical and biological substances. One way to improve the sensitivity and specificity of these measurement techniques is to use enhancement of optical fields in the vicinity of metal nanoparticles. We present a comparative study on the enhancement of Fluorescence, normal and resonance Raman processes by a single metal nanoparticle. Taking an analytical approach, we explain the physics behind the quenching effect observed in both fluorescence and resonance Raman measurements but not in normal Raman scattering. We establish limits for attainable enhancement, and outline the path to optimization of all three processes.

12:45 – 13:00 **Nanorod-based glucose sensor** Oral

Luigi La Spada, *University of Roma Tre, Italy*
Renato Iovine, *University of Roma Tre, Italy*
Filiberto Bilotti, *University of Roma Tre, Italy*
Lucio Vegni, *University of Roma Tre, Italy*

A metamaterial-based sensor consisting in a nanorods array is presented. An analytical model, describing their electromagnetic response, is proposed. Good agreement between analytical and numerical results was achieved (above 95%). The sensor is able to detect the presence of glucose and its concentration in aqueous solutions in an accurate way.

11:30 – 13:00 RF and Microwave Metamaterials II — Tverskoy hall

Session chairperson(s): Filiberto Bilotti

11:30 – 11:45 **Photovoltaic panel with reactance elements for dual-band antenna radome** Oral

Hung-Hsuan Lin, *ITRI, Taiwan*
Ta-Chun Pu, *Industrial Technology Research Institute, Taiwan*
Chun-Yih Wu, *Industrial Technology Research Institute, Taiwan*
Jui-Hung Chen, *Industrial Technology Research Institute, Taiwan*

In this work we present an innovative approach to design a dual-band microwave antenna radome using a photovoltaic panel. A 20-wafers photovoltaic panel is treated as a microwave frequency selective surface on top of a microwave radiator. The transparent and the semi-transparent modes cooperated with different antenna radiating mechanism are utilized for dual-band operation. A layer with reactance elements is attached to the PV panel to modify the transmission response

for desired 900MHz/1800MHz bands without degrading the PV efficiency. A proposed prototype, with dimensions 675 mm × 644 mm × 90 mm, achieves remarkable 16 dBi antenna gain at 1750 MHz with single radiator. The very combination of PV cell and antenna exhibits high fill-factor, high-gain, and simple construction characteristics and is potential for various kinds of applications.

11:45 – 12:00 **Applications of wire media as antenna radomes** Oral

Rostyslav Dubrovka, *Queen Mary University of London, United Kingdom*
Pavel Belov, *Queen Mary University of London, United Kingdom*

The paper presents a recent development of wire media for antennas and communication applications. An antenna is concealed within the metal cavity. Characteristic distortions, expected from cavity influence, is decreased by a wire media block, which translates near field of the antenna towards the outer interface of the cavity. A reasonable agreement between theory and measurements has been obtained.

12:00 – 12:15 **All-pass slot-based artificial transmission line unit-cell CONSOLIDER project CSD2008-00066 presentation** Oral

Elena Abdo-Sánchez, *Universidad de Málaga, Spain*
Teresa María Martín-Guerrero, *Universidad de Málaga, Spain*
Carlos Camacho-Peñalosa, *Universidad de Málaga, Spain*
Juan Enrique Page, *Universidad Politécnica de Madrid, Spain*
Jaime Esteban, *Universidad Politécnica de Madrid, Spain*

In this contribution a novel artificial TL unit-cell implementation is presented, which uses superimposed slot and stub fed by a microstrip TL. The equivalent circuit of the resultant structure is a lattice network and, therefore, can be designed for all-pass behaviour. Simulated results of the proposed unit-cell compared to those of the unit-cell with alternate stub and slot highlight the improvement achieved through the superposition of the stub and slot.

12:15 – 12:30 **A direct synthesis method for UWB bandpass filters based on metamaterial transmission lines** Oral

Alexander Rusakov, *St. Petersburg Electrotechnical University 'LETI', Russia*
Irina Vendik, *St. Petersburg Electrotechnical University 'LETI', Russia*
Shilong Qian, *Heriot-Watt University, United Kingdom*

In this paper, a direct synthesis method for designing metamaterial transmission line based bandpass filter (BPF) is presented. As a start, a wideband filter is designed as symmetric network implemented in low temperature co-fired ceramics (LTCC) technology. The proposed synthesis method was applied to an ultra-wideband (UWB) BPF with additional transmission zero designed using composite right/left-handed (CRLH) transmission lines. All the design parameters can be found using the proposed synthesis method, which dramatically simplifies the design process of the UWB BPF with transmission zero. A home-made software is also developed and used to obtain the final design.

St. Petersburg, **Russia**

Tuesday, 18th September

12:30 – 12:45 **Millimeter wave CRLH BP filter: Standard photolitography vs. laser ablation** Oral

Florea Craciunoiu, *IMT Bucharest, Romania*
Gheorghe Ioan Sajin, *IMT Bucharest, Romania*
Iulia Andreea Mocanu, *Politechnica University Bucharest, Romania*
Adrian Dinescu, *IMT Bucharest, Romania*
Marian Zamfirescu, *NILPRP – Bucharest, Romania*

This work deals with the development and manufacturing of a Composite Right/ Left Handed (CRLH) filter structure in the millimeter-wave range. The devices were microprocessed on a 0.5 mm thick silicon substrate with a 3000 Å Au/500 Å Cr metallization layers using two technologies: standard photolithography and direct laser ablation. The results obtained by using these two microprocessing technologies were compared and the results were presented.

12:45 – 13:00 **Radial photonic crystals for microwave operation CONSOLIDER project CSD2008-00066 presentation** Oral

Ana Díaz, *Universitat Politècnica de València, Spain*
Jorge Carbonell, *Universitat Politècnica de València, Spain*
Daniel Torrent, *Universitat Politècnica de València, Spain*
Francisco Cervera, *Universitat Politècnica de València, Spain*
Matt Kirleis, *Naval Research Laboratory, USA*
Alberto Piqué, *Naval Research Laboratory, USA*
José Sánchez-Dehesa, *Universitat Politècnica de València, Spain*

We analyze the properties of electromagnetic metamaterials with anisotropic constitutive parameters. Particularly, we analyze the so-called Radial Photonic Crystals, which are radially periodic structures verifying the Bloch theorem. This type of crystals can be designed and implemented in acoustics as well as in electromagnetism by using anisotropic metamaterials. They were originally proposed in acoustics, but similar functionalities are here proven in the electromagnetic domain together, for the first time, with an analysis of their behavior operating in the microwave regime. Finally, we present a complete discussion concerning their electromagnetic properties together with a practical design of such a microwave structure.

11:30 – 13:00 **Quantum Aspects of Metamaterials I** **Nevsky hall**

Session chairperson(s): Carsten Rockstuhl

11:30 – 11:45 **Casimir–Lifshitz interactions in a one–way waveguide** Oral

Stanslav Maslovski, *Instituto de Telecomunicações, Coimbra Univ., Portugal*
Mario Silveirinha, *Instituto de Telecomunicações, Coimbra Univ., Portugal*

We investigate the Casimir-Lifshitz interaction in a strongly nonreciprocal system: a waveguide filled with a hypothetical metamaterial representing a moving medium. We implement a one-way mode of propagation in such a waveguide and study how this may affect the Casimir force exerted on a body placed in it.

11:45 – 12:00 **Purcell factor engineering in plasmonic nanostructures for the enhanced generation of energy–time entangled states** Oral

Pavel Ginzburg, *Department of Physics, King's College London, United Kingdom*
Alexander Poddubny, *National University for Information Technology, Mechanics and Optics, and Ioffe Physical-Technical Institute, Russia*
Pavel Belov, *National University for Information Technology, Mechanics and Optics, Russia, and Queen Mary University, U.K.*
Anatoly Zayats, *Department of Physics, King's College London, U.K.*
Yuri Kivshar, *Australian National University, Canberra, Australia, and National University for Information Technology, Mechanics and Optics, St. Petersburg, Russia*

We summarize our studies of the plasmonic enhancements of the spontaneous two-photon emission. In particular, we draw attention to the rigorous investigation of quantum framework for the multi-photon spontaneous decay rates in an environment with arbitrary structure of electromagnetic modes. We demonstrate that nanostructured environment can be used for tailoring the basic characteristics of the two-photon emission such as spectrum, lifetime, and entanglement. Moreover, careful engineering of the two-photon Purcell enhancement may provide any desired spectral response and may serve as an ultimate route for designing light sources with novel properties.

12:00 – 12:30 **Casimir forces in chiral metamaterials** Invited oral

C. M. Soukoulis, *Institute of Electronic Structure and Laser, Foundation for Research and Technology, Hellas, Greece*
R. Zhao, *Blackett Lab, Dept. of Physics, Imperial College, London, United Kingdom*
E. N. Economou, *Institute of Electronic Structure and Laser, Foundation for Research and Technology, Hellas, Greece*
Th. Koschny, *Ames Lab and Dept of Physics and Astronomy, Iowa State University, USA*

We use the extended Lifshitz theory to study the behavior of the Casimir forces between chiral metamaterials and regular metamaterials. We have shown that the chirality, if strong enough, is of critical importance to reduce the Cassimir attractive force and can find new designs to obtain repulsive Casimir forces. We will re-view chiral metamaterials and find some analytical expression for the strengths of electrical permittivity, magnetic permeability and chirality for passive materials.

12:30 – 13:00 **Pulling particles backward using a forward propagating beam** Invited oral

Jack Ng, *Hong Kong Baptist University, Hong Kong*
Jun Chen, *Fudan University, China*
Zhifang Lin, *Fudan University, China*
C. T. Chan, *Hong Kong Baptist University, Hong Kong*

A photon carries a momentum of hbar*k , so one may expect light to push against any object standing in its path. Here, we discuss a new possibility — a backward scattering force which always pulls a particle in a direction opposite to the beam propagation direction.

13:00 – 14:30 **Lunch** **Restaurant**

St. Petersburg, **Russia**

Tuesday, 18th September

Oral sessions (Tuesday afternoon I)

14:30 – 16:00	Transformation Optics II	Kremlyovsky hall
14:30 – 16:00	Homogenization II	Tverskoy hall
14:30 – 16:00	Quantum Aspects of Metamaterials II	Nevsky hall

14:30 – 16:00 Transformation Optics II — Kremlyovsky hall

Session chairperson(s): Raj Mittra

14:30 – 15:00 **Transformation thermodynamics: Playing with fire** Invited oral

Sebastien Guenneau, *CNRS/AIx-Marseille University, France*

It has been recently proposed to control heat fluxes using tools of transformation optics in the context of thermodynamics. A thermic cloak protecting a region from heat and a concentrator increasing gradient of temperature in a region have been theorized. Here, we propose an extension of this work to time-harmonic heat sources.

15:00 – 15:15 **Broadband selective thermal emitters and absorbers based on Brewster plasmonic funneling** Oral

Andrea Alu, *The University of Texas at Austin, USA*
Christos Argyropoulos, *The University of Texas at Austin, USA*

In this paper, we show the possibility to realize a plasmonic metallic grating with ultra-broadband selective thermal emission at IR and visible frequencies. By reciprocity, the proposed structure can also demonstrate broadband perfect absorption confined to a narrow angular beamwidth. With few modifications of the device dimensions, the plasmonic grating can also operate as a broadband omnidirectional absorber for visible, IR and terahertz radiation. The physical mechanisms at the basis of these phenomena lay on the recently introduced concept of plasmonic Brewster transmission, which, here, is combined with adiabatic metallic tapering to achieve strong localization and absorption of the electromagnetic energy. We believe that the proposed devices may potentially lead to the design of more efficient energy harvesting structures and novel directional thermal emitters.

15:15 – 15:30 **Plasmon–assisted energy transfer near metal nanostructures** Oral

Tigran Shahbazyan, *Jackson State University, USA*

A unified theory of plasmon-assisted resonance energy transfer (RET) between molecules near metal nanostructures is developed. In a wide parameter range, RET is dominated by plasmon-enhanced radiative transfer mechanism.

14:30 – 16:00 Homogenization II

Session chairperson(s): Ari Sihvola

Tverskoy hall

14:30 – 14:45 **Reflection/transmission of obliquely incident TE waves from metasurfaces homogenized via surface susceptibility models** Oral

Alexandros Dimitriadis, *Dept. of Electrical and Computer Engineering, Aristotle University of Thessaloniki, Greece*
Nikolaos Kantartzis, *Dept. of Electrical and Computer Engineering, Aristotle University of Thessaloniki, Greece*
Theodoros Tsiboukis, *Dept. of Electrical and Computer Engineering, Aristotle University of Thessaloniki, Greece*

In this paper, analytical expressions for the S-parameters for periodic metasurfaces under TE wave incidence, are extracted. The derived formulas include the effect of off-diagonal terms of the susceptibility matrix. The results are compared to numerical simulations, in order to reveal the importance of the proposed generalization.

14:45 – 15:00 **Local framework for nonlocal wire media** Oral

Stanslav Maslovski, *Instituto de Telecomunicações, Coimbra Univ., Portugal*
Mario Silveirinha, *Instituto de Telecomunicações, Coimbra Univ., Portugal*

In this presentation we outline a framework applicable to wire media formed by sets of nonconnected wires. In this framework, the macroscopic material response is described with more independent degrees of freedom than usual. This allows formulating a system of local field equations with which both boundary value problems and problems of radiation of the sources embedded into wire medium can be solved efficiently.

15:00 – 15:15 **Effective parameter extraction of SRR structures by means of first-principles homogenization techniques** Oral

Theodosios Karamanos, *Dept. of Electrical and Computer Engineering, Aristotle University of Thessaloniki, Greece*
Alexandros Dimitriadis, *Dept. of Electrical and Computer Engineering, Aristotle University of Thessaloniki, Greece*
Nikolaos Kantartzis, *Dept. of Electrical and Computer Engineering, Aristotle University of Thessaloniki, Greece*

In this paper, the effective parameters of typical SRR structures are extracted via first-principles homogenization techniques. Each metamaterial unit-cell is assumed to be an electrically small scatterer, and its polarizabilities are obtained through dynamic approaches. The retrieved polarizabilities are used in homogenization formulas to derive the desired effective medium parameters.

15:15 – 15:30 **Effective optical properties of dilute and dense polymer-gold nanoparticle films: theory and experiments** Oral

Olivier Merchiers, *University of Bordeaux and CNRS, France*
Julien Vieaud, *University of Bordeaux and CNRS, France*
Kevin Ehrhardt, *University of Bordeaux and CNRS, France*
Yves Borensztein, *Institut des Nanosciences de Paris, France*
Ponsinet Virginie, *University of Bordeaux and CNRS, France*
Ashod Aradian, *University of Bordeaux and CNRS, France*

We study the effective optical properties of composite films made of 14-nm spherical gold nanoparticle in a polymer matrix, both in dilute (5% gold fraction) and dense (20%) regimes. Optical indices and permittivities are extracted from spectroscopic ellipsometry measurements and show effective resonant properties around the plasmon resonance, exhibiting effective negative permittivity for dense samples in a finite frequency range (finite-band metallic behaviour). Measurements are compared to Maxwell-Garnett (MG) predictions: we show that the classical MG formula does not reproduce the experimental results, even in the dilute regime, due to nanoagregation effects in the samples which entails couplings between particles. Since couplings create deformations of the polarizability tensor of the individual particles, we propose to take them into account in an empirical way using a modified MG formula based on a distribution of ellipsoids. We show that this modified Maxwell Garnett model works sucessfully, allowing for good fits of the experimental data in the dilute regime (using a distribution of ellispoidal polarizabilities centered on a mean isotropic polarizability) as well as in the dense regime up to 20% (using polarizability distribution centered on a mean ellipsoidal polarizability)

15:30 – 16:00

Review of recent progress on the homogenization theory and applications of wire media Extended oral

Alexander B. Yakovlev, *Department of Electrical Engineering, University of Mississippi, USA*
Mario G. Silveirinha, *Department de Engenharia Electrotécnica, Univirsity de Coimbra, Instituto de Telecomunicações, Portugal*
Stanislav I. Maslovski, *Department de Engenharia Electrotécnica, Univirsity de Coimbra, Instituto de Telecomunicações, Portugal*
Chandra S. R. Kaipa, *Department of Electrical Engineering, University of Mississippi, USA*
Pavel A. Belov, *National Research University of Information Technologies, Mechanics and Optics (ITMO), Russia, School of Electronic Engineering and Computer Science, Queen Mary University of London, Russia, UK*
George W. Hanson, *Electrical Engineering Department, University of Wisconsin-Milwaukee, USA*
Olli Luukkonen, *Nokia Research Center, Finland*
Igor S. Nefedov, *Aalto University, School of Electrical Engineering, SMARAD Center of Excellence, Finland*
Constantin R. Simovski, *Aalto University, School of Electrical Engineering, SMARAD Center of Excellence, Finland*
Sergei A. Tretyakov, *Aalto University, School of Electrical Engineering, SMARAD Center of Excellence, Finland*
Yashwanth R. Padooru, *Department of Electrical Engineering, University of Mississippi, USA*

We review recent contributions to the homogenization theory of wire media and discuss a variety of applications at microwave and THz frequencies. The analysis is based on spatially dispersive homogenization models for unloaded and loaded wire media with additional boundary conditions derived for different interface scenarios. The applications include, but are not limited to, metamaterial-based antenna and waveguide technology, subwavelength imaging, super lenses, absorbers, and have been recently extended to carbon-based nanomaterials.

14:30 – 16:00 Quantum Aspects of Metamaterials II

Nevsky hall

Session chairperson(s): Jack Ng

14:30 – 14:45 **A scalable architecture for solid-state quantum metamaterials** Oral

Richard Wilson, *Loughborough University, United Kingdom*
Mark Everitt, *Loughborough University, United Kingdom*
Sergey Savel'ev, *Loughborough University, United Kingdom*
Alexandre Zagoskin, *Loughborough University, United Kingdom*

Quantum metamaterials provide a promising potential test bed for probing the quantum-classical transition. We propose a feasible and scalable architecture for a solid-state quantum metamaterial. This consists of an ensemble of superconducting flux qubits inductively coupled to a superconducting transmission line. We make use of a quasi-classical model to study the transmission properties of the proposed architecture and we also discuss the possibilities for experimentation with this type of extended quantum system.

14:45 – 15:30 **Purcell effect in hyperbolic media** Oral

Alexander Poddubny, *National Research University for Information Technology, Mechanics and Optics ITMO, Russia*
Pavel Belov, *National Research University for Information Technology, Mechanics and Optics ITMO, Russia*
Pavel Ginzburg, *King's College London, United Kingdom*
Anatoly Zayats, *King's College London, United Kingdom*
Yuri Kivshar, *Australian National University, Australia*

We study theoretically the properties of hyperbolic medium modelled as cubic lattices of uniaxial resonant dipoles. We investigate the dependence of the Purcell factor on the source position in the lattice unit cell and visualize the collective origin of the Purcell factor enhancement by the lattice Green function.

15:00 – 15:30 **Observation of the dynamical Casimir effect in a superconducting circuit** Invited oral

Christopher Wilson, *Chalmers University of Technology, Sweden*

Using a superconducting circuit, we have observed the dynamical Casimir effect for the first time. The circuit consists of a coplanar transmission line with an electrical length that can be changed at a substantial fraction of the speed of light. The length is changed by modulating the inductance of a SQUID at high frequencies.

15:30 – 16:00 **Controlling the dynamics of quantum mechanical systems using meta-atoms** Extended oral

Carsten Rockstuhl, *Friedrich-Schiller-Universität Jena, Germany*
Robert Filter, *Friedrich-Schiller-Universität Jena, Germany*
Stefan Mühlig, *Friedrich-Schiller-Universität Jena, Germany*
Toni Eichelkraut, *Friedrich-Schiller-Universität Jena, Germany*
Stefan Fischer, *Fraunhofer Institute for Solar Energy Systems, Germany*
Jan Christoph Goldschmidt, *Fraunhofer Institute for Solar Energy Systems, Germany*
Falk Lederer, *Friedrich-Schiller-Universität Jena, Germany*

We provide an overview of our latest activities on using optical meta-atoms to mediate the interaction of light with molecular systems. The first subject concerns the control

of the dynamics of quantum mechanical systems featuring dipole-forbidden transitions. There, the meta-atoms provide local fields that exhibit a large electric quadrupole moment. The second issue is related to the enhancement of the upconversion process in erbium-doped glasses. There, the optical meta-atom has to show a resonance at multiple frequencies which matches the term schema of erbium. It will be concluded that optical meta-atoms are promising to enable inaccessible processes in a quantum mechanical system which will allow groundbreaking applications.

16:00 – 16:30 **Coffee break** **Poster area**

Oral sessions (Tuesday afternoon II)

16:30 – 18:00	**Metamaterial Based Sensors II**	**Kremlyovsky hall**
16:30 – 18:00	**THz and Microwave Metamaterials I**	**Tverskoy hall**
16:30 – 18:00	**Chiral Metamaterials I**	**Nevsky hall**

16:30 – 18:00 **Metamaterial Based Sensors II** **Kremlyovsky hall**

Session chairperson(s): Hatice Altug

16:30 – 17:00 ~~**Fano-resonant metamaterials for sensing and vibrational fingerprinting: from protein monolayers to single-layer graphene**~~ ~~Invited oral~~, Withdrawal

Chihhui Wu, *Department of Physics, The University of Texas at Austin, USA*
Alexander B. Khanikaev, *Department of Physics, The University of Texas at Austin, USA*
Kamil Alici, *Department of Physics, The University of Texas at Austin, USA Ronen Adato, Department of Electrical Engineering and Computer Science, Boston University, USA*
Nihal Arju, *Department of Physics, The University of Texas at Austin, USA*
Ahmet Ali Yanik, *Department of Electrical Engineering and Computer Science, Boston University, USA*
Hatice Altug, *Department of Electrical Engineering and Computer Science, Boston University, USA*
Gennady Shvets, *Department of Physics, The University of Texas at Austin, USA*

We demonstrate how precise information about the structure of protein and monolayers (thickness, bond orientation, dipole strength) can be obtained using difference-reflectivity spectroscopy of functionalized Fano-resonant asymmetric metamaterials. Experimental results for graphene, peptide, single-protein, and two-protein monolayers will be presented.

17:00 – 17:15 **Fano resonance in layered structures with disorder** Oral

Mikhail Rybin, *National Research University for Information Technology, Mechanics and Optics (ITMO), Russia*
Alexander Poddubny, *National Research University for Information Technology, Mechanics and Optics (ITMO), Russia*

Mikhail Limonov, *National Research University for Information Technology, Mechanics and Optics (ITMO), Russia*
Yuri Kivshar, *National Research University for Information Technology, Mechanics and Optics (ITMO), Russia*

Transport properties of the layered structures with disorder was studied numerically and analytically both. We find extinction spectra of disordered structure demonstrate the Fano-like line shape on the Bragg frequencies. Besides disorder can transforms conventional stop-band into pass-band. This transformation is governed by disorder-induced Fano resonance. Different regimes of light localizations were considered.

17:15 – 17:30 **Plasmonic photonic-crystal slab as efficient optical sensor** Oral

Alexander Baryshev, *Electronics-Inspired Interdisciplinary Research Institute, Toyohashi University of Technology, Toyohashi, Japan*
Alexander Merzlikin, *Institute for Theoretical and Applied Electromagnetics, Moscow, Russia*
Mitsuteru Inoue, *Toyohashi University of Technology, Toyohashi, Japan*

A one-dimensional photonic crystal terminated by a noble metal film–plasmonic photonic-crystal slab has been analysed for the optical response at variation of the dielectric permittivity of an analyte. Sensor based on such a slab exhibited an enhanced sensitivity and a larger qualitative robustness than that of conventional surface-plasmon and Bloch surface wave sensors. In particular, the responses of considered sensor are a more tolerant to a variation of the angle of incidence and the sensor's structural parameters.

17:30 – 18:00 **Antenna-assisted surface-enhanced infrared absorption based on nanogaps for ultrasensitive sensors** Invited oral

Frank Neubrech, *University of Heidelberg, Germany*
Andrea Toma, *Italian Institute of Technology, Italy*
Enzo Di Fabrizio, *Italian Institute of Technology, Italy*
Annemarie Pucci, *University of Heidelberg, Germany*

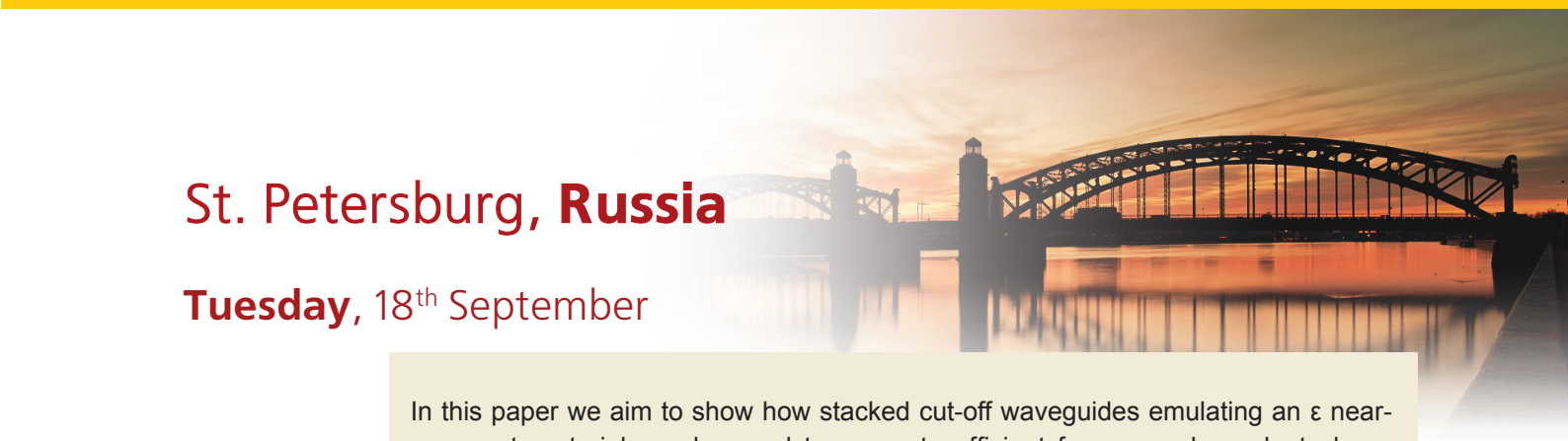
We report on a increased vibrational signal enhancement in antenna-assisted surface-enhanced infrared spectroscopy induced by inter-particle near-field coupling. In our experiments we found an increasing vibrational signal enhancement for decreasing gap sizes demonstrating the additional enhancement induced by nanosized gaps, which can be applied for ultrasensitive IR sensors.

16:30 – 18:00 **THz and Microwave Metamaterials I** **Tverskoy hall**

Session chairperson(s): Maria Kafesaki

16:30 – 16:45 **Plano-Planar lenses using near-zero stacked waveguides at millimeter waves CONSOLIDER project CSD2008-00066 presentation** Oral

Víctor Pacheco-Pena, *Universidad Pública de Navarra, Spain*
Víctor Torres, *Universidad Pública de Navarra, Spain*
Miguel Navarro-Cía, *Imperial College London, United Kingdom*
Miguel Beruete, *Universidad Pública de Navarra, Spain*
Mario Sorolla, *Universidad Pública de Navarra, Spain*
Nader Engheta, *University of Pennsylvania, USA*



In this paper we aim to show how stacked cut-off waveguides emulating an ε near-zero metamaterial can be used to generate efficient frequency-dependent plano-planar lenses. First, an array of cut-off waveguides is cut at 30º to steer a plane wave at that angle. Afterwards, a graded index lens is designed to perform the same 30º redirection but with a flat metamaterial lens.

16:45 – 17:15 **Passive THz metamaterials** Invited oral

Andrei Lavrinenko, *Technical University of Denmark, Denmark*
Radu Malureanu, *Technical University of Denmark, Denmark*
Maksim Zalkovskij, *Technical University of Denmark, Denmark*
Peter Jepsen, *Technical University of Denmark, Denmark*
Andrey Novitsky, *Technical University of Denmark, Denmark*
Dmitry Chigrin, *Bergische Universitat Wuppertal, Germany*
Christian Kremers, *Bergische Universitat Wuppertal, Germany*
Zhengyong Song, *Fudan University, China*
Qiong He, *Fudan University, China*
Lei Zhou, *Fudan University, China*

In this work we present our activities in the fabrication and characterization of passive THz metamaterials. We use two fabrication processes to develop metamaterials either as free-standing metallic membranes or patterned metallic multi-layers on the substrates to achieve different functionalities. Our interest lies in metamaterials for a broad spectrum of linear properties in operations with THz waves, such as linear and circular polarizers, absorbers and devices with enhanced transmittivity, single layer dichroic and chiral systems. All the three steps (modelling, fabrication and characterization) will be discussed during the talk.

17:15 – 17:30 **Electromagnetic response of two-dimensional metamaterials constructed of a metal-mesh and dielectric spheres in the terahertz region** Oral

Yuya Yakiyama, *Institute of Laser Engineering, Osaka University, Japan*

Dielectric spheres made of TiO2 are periodically arranged on a metal-mesh. The transmission peaks are obtained, which suggests that the negative refractive index is realized. It's caused by the combination of the negative permittivity of the metal-mesh and the negative permeability of TiO2 spheres of the Mie resonance.

17:30 – 17:45 **Collective and localized plasmon modes in a periodically gated two-dimensional electron system: tunable planar plasmonic crystal at terahertz frequencies** Oral

Vyacheslav Popov, *Kotelnikov Institute of Radio Engineering and Electronics (Saratov Branch), Russia*

We show that a periodically gated two-dimensional electron system constitutes a tunable planar plasmonic crystal for terahertz frequencies. Different plasmon modes of the planar plasmonic crystal and their interaction are considered. The problem of coupling between the plasmon modes in the planar plasmonic crystal and terahertz radiation is discussed.

17:45 – 18:00

Coherent control of a terahertz metamaterial Oral

Florian Enderli, *University of Bern, Switzerland*
Thomas Feurer, *University of Bern, Switzerland*

We present the first coherent control experiments of a metamaterial. We fabricated a planar metamaterial showing two separated resonances at THz frequencies. It acts similar to an atomic system with two uncoupled excited states. Through temporal coherent control with broadband THz pulses we can excite both, none, or individual resonances.

16:30 – 18:00 Chiral Metamaterials I — Nevsky hall

Session chairperson(s): Hongqiang Li

16:30 – 16:45

Wide-band perfect absorption in optically thin layers composed of indefinite media with tilted optical axes Oral

Igor Nefedov, *School of Electrical Engineering , Aalto University, Finland*
Seyed Hasnemi, Iran University of Science and Technology, Department of Electrical Engineering, Iran

In this paper we discuss new property of indefinite media, namely, a capability of the per-fect absorption in optically ultrathin layers. Example of a perfectly absorbing layer for the near-infrared range, made of silver nanowires, is described.

16:45 – 17:00

Analysis of waveguides containing Minkowskian isotropic media (MIM) and the perfect electromagnetic conductor (PEMC) Oral

Filipa Prudêncio, *Instituto de Telecomunicações, IST, Portugal*
Sérgio Matos, *Instituto de Telecomunicações, ISCTE-IUL, Portugal*
Carlos Paiva, *Instituto de Telecomunicações, IST, Portugal*

Minkowskian Isotropic Medium (MIM) is the most general medium that is isotropic for the whole class of inertial observers. It enables a unique electromagnetic field in the interior of a Perfect Electromagnetic Conductor (PEMC). In this paper a PEMC-SIM-PEMC slab is analyzed as the limit case of a MIM-SIM-MIM slab.

17:00 – 17:30

Rolling up gold nanoparticle-dressed DNA origami into three-dimensional plasmonic chiral nanostructures Extended oral

Na Liu, *Rice University, USA*
Baoquan Ding, *National Center for Nanoscience and Technology, Beijing, China*

Construction of three-dimensional plasmonic architectures using structural DNA nanotechnology is an emerging multidisciplinary area of research. This technology excels in controlling spatial addressability at a sub-10 nm resolution, which has thus far been beyond the reach of traditional top-down techniques. In this paper, we dem-onstrate the realization of three-dimensional plasmonic chiral nanostructures through programmable transformation of gold nanoparticle-dressed DNA origami. Gold nanoparticles are assembled along two linear chains on a two-dimensional rectangular DNA origami sheet with well-controlled positions and particle spacing. By rationally rolling of the 2D origami template, the gold nanoparticles can be automatically arranged in a helical geometry, suggesting the possibility to achieve engineerable chiral nanomaterials in the visible range.

St. Petersburg, **Russia**

Tuesday, 18th September

17:30 – 18:00

Twisted plasmonic metamaterials Invited oral

Andrea Alu, *The University of Texas at Austin, USA*
Yang Zhao, *The University of Texas at Austin, USA*

In this work, twisted metamaterials composed of stacks of strongly coupled, resonant plasmonic metasurfaces with a uniform rotational twist along the stacking direction are analytically modelled and experimentally analysed. The unit cell is composed of the simplest anisotropic nanoparticle, a gold nanorod, which exhibits a large form of birefringence between retrieved effective ordinary and extraordinary refractive indices (ne and no) based on simple effective medium theory. We show, both with full-wave numerical simulations and analytical calculations, that the rotational twist of these anisotropic nanoparticles can create strong circular dichroism spanning a large frequency bandwidth in the visible spectrum. We have also experimentally verified this functionality in a five-layer stack.

Wednesday, 19th September

Oral sessions (Wednesday morning I)

08:30 – 10:00	**Imaging Using Metamaterials**	**Kremlyovsky hall**
08:30 – 10:00	**THz and Microwave Metamaterials II**	**Tverskoy hall**
08:30 – 10:00	**Novel Concepts I**	**Nevsky hall**

08:30 – 10:00 **Imaging Using Metamaterials** **Kremlyovsky hall**

Session chairperson(s): Martin Wegener

08:30 – 08:45

Near–field enhancement using uniaxial wire medium with impedance loadings Oral

Chandra S. R. Kaipa, *Department of Electrical Engineering, University of Mississippi, USA*
Alexander B. Yakovlev, *Department of Electrical Engineering, University of Mississippi, USA*
Mario G. Silveirinha, *Departamento de Engenharia Electrotecnica, Instituto de Telecomunicações, Universidade de Coimbra, Portugal*
Stanislav I. Maslovski, *Departamento de Engenharia Electrotecnica, Instituto de Telecomunicações, Universidade de Coimbra, Portugal*

Uniaxial wire-medium slab loaded with patches and impedance insertions (as lumped loads) is proposed for the resonant amplification of evanescent waves. The analysis is based on the nonlocal homogenization model for the mushroom structure with a generalized additional boundary condition for loaded vias. It is shown that by appropriately tuning the value of the lumped capacitance, it is possible to achieve a flat dispersion behavior for surface waves resulting in a significant amplification of the near field.

08:45 – 09:00 **Suppression of the chromatic aberrations using a nanowire metamaterial** Oral

João T. Costa, *Universidade de Coimbra, Instituto de telecomunicações, Portugal*
Mário G. Silveirinha, *Universidade de Coimbra, Instituto de telecomunicações, Portugal*

Achromatic doublets have been used for decades to minimize the effects of chromatic aberrations inherent to single-glass optical lenses. Here, we propose a fundamentally different solution to correct the chromatic aberrations based on a nanowire metamaterial with low loss anomalous dispersion. We show that by coating a standard glass lens with the metamaterial it may be possible to design a compensated bi-layer lens with nearly no chromatic aberrations.

09:00 – 09:15 **Perfect imaging with spin waves** Oral

Sebastian Mansfeld, *Institut fuer Angewandte Physik, Germany*
Jesco Topp, *Institut fuer Angewandte Physik, Germany*
Jan-Niklas Toedt, *Institut fuer Angewandte Physik, Germany*
Kim Martens, *Institut fuer Angewandte Physik, Germany*
Wolfgang Hansen, *Institut fuer Angewandte Physik, Germany*
Detlef Heitmann, *Institut fuer Angewandte Physik, Germany*
Stefan Mendach, *Institut fuer Angewandte Physik, Germany*

We demonstrate perfect imaging with spin waves in a ferromagnetic film utilizing their tailorable anisotropic dispersion relation in analogy to subwavelength imaging concepts known from anisotropic optical metamaterials.

09:15 – 09:30 **Design and modeling of Luneburg lens based on dodecagonal photonic quasicrystal** Oral

Pavel Dyachenko, *Image Processing Systems Institute of the Russian Academy of Sciences, Russia*

We introduce graded photonic quasicrystals (GPQs) and investigate properties of such structures on the example of Luneburg lens based on a dodecagonal photonic quasicrystal. It is shown that the graded photonic quasicrystal lens has better focusing properties as compared with the graded photonic crystal lens in a frequency range suitable for experimental realization. The proposed graded photonic quasicrystals can be used in optical systems where compact and powerful focusing elements are required.

09:30 – 10:00 **Perfect imaging of point sources with positive refraction** Invited oral

Juan C. Miñano, *Universidad Politecnica de Madrid, Spain*
Juan C. González, *Universidad Politecnica de Madrid, Spain*
Pablo Benítez, *Universidad Politecnica de Madrid, Spain*
Dejan Grabovičkić, *Universidad Politecnica de Madrid, Spain*

Perfect image formation in the Maxwell Fish Eye (a positive refractive index distribution) is analyzed by means of its equivalent Spherical Geodesic Waveguide using a microwave circuit model which also emulates the point source and the drain. Extension for more general source cases is also considered.

St. Petersburg, **Russia**

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08:30 – 10:00 | **THz and Microwave Metamaterials II** | **Tverskoy hall**

Session chairperson(s): Alexandra Boltasseva

08:30 – 08:45 **Towards the application of MNG-loaded slow wave structures in spatial harmonic magnetrons** Oral

Nasrin Nasr Esfahani, *Technical University of Hamburg (TUHH), Germany*
Klaus Schünemann, *Technical University of Hamburg (TUHH), Germany*

It is shown that MNG loaded anode blocks can considerably improve the performance of millimeter wave spatial harmonic magnetrons in terms of output power and efficiency. Theoretical limitations of conventional anode structures and analysis of MNG loaded anode blocks are presented. Finally, the improvements provided through the use of MNG-loaded anode blocks are confirmed using warm cathode simulation results.

08:45 – 09:00 **Near-surface beaming and non-plasmon suppression of specular reflection from metal gratings in THz** Oral

Mihail Timchenko, *Usikov Institute for Radiophysics and Electronics , Ukraine*
Ivan Spevak, *Usikov Institute for Radiophysics and Electronics , Ukraine*
Yurii Kamenev, *Usikov Institute for Radiophysics and Electronics , Ukraine*
Alexandre Kats, *Usikov Institute for Radiophysics and Electronics , Ukraine*
Vladimir Gavrikov, *Institute of Radio Astronomy, Ukraine*

In this paper we present the study of THz laser beam reflection from a metallic grating. We show both theoretically and experimentally that unlike in visible and IR spectrum ranges, suppression of the specular reflection in THz is not associated with a surface plasmon resonance, but rather is conditioned by a resonance energy transfer to a near-surface propagating diffracted wave. Moreover, we suppose that this result is a general one for metal interfaces in the THz region, and all existing experiments are to be reinterpreted taking into account this fact.

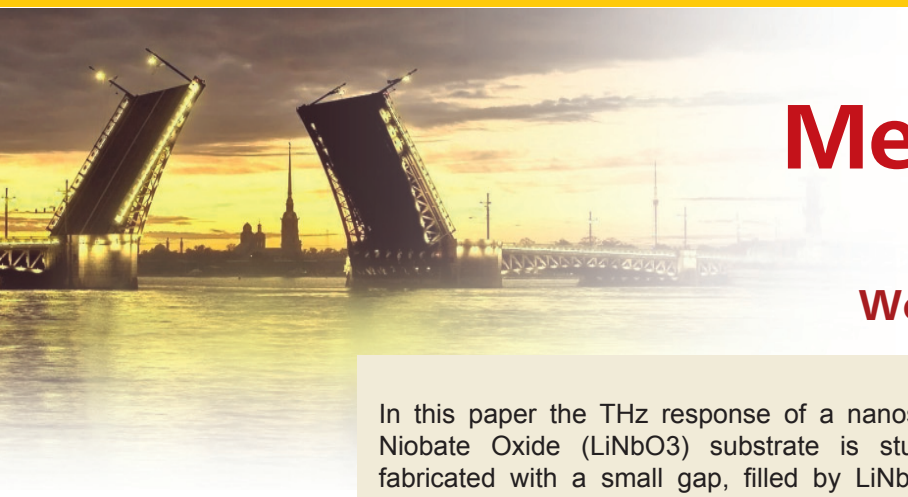
09:00 – 09:30 **Gradient index optics for terahertz waves and confined surface waves** Invited oral

Jens Neu, *University of Kaiserslautern, Germany*
Benjamin Reinhard, *University of Kaiserslautern, Germany*
Tassilo Fip, *University of Kaiserslautern and Fraunhofer IPM, Germany*
Martin Volk, *University of Kaiserslautern and Fraunhofer IPM, Germany*
Oliver Paul, *University of Kaiserslautern, Germany*
Bernd Krolla, *DFKI, Germany*
Marco Rahm, *University of Kaiserslautern and Fraunhofer IPM, Germany*

We present a number of various gradient index (GRIN) devices for the manipulation of freely propagating terahertz (THz) waves and confined, surface plasmon polariton-like THz surface waves on meta-surfaces.

09:30 – 09:45 **High electric field enhancement in THz regime using a gold-nanoslit filled with Lithium Niobate oxide** Oral

Salvatore Bagiante, *Paul Scherrer Institut, Switzerland*
Florian Enderli, *University of Bern, Switzerland*
Justyna Fabianska, *University of Bern, Switzerland*
Ismo Vartiainen, *Paul Scherrer Institut, Switzerland*
Hans Sigg, *Paul Scherrer Institut, Switzerland*
Thomas Feurer, *University of Bern, Switzerland*



In this paper the THz response of a nanoslit gold array fabricated on a Lithium Niobate Oxide (LiNbO3) substrate is studied. Theses structures have been fabricated with a small gap, filled by LiNbO3. These structures exhibit stronger electric field enhancement, if compared with the measurement performed on silicon substrate using the same slit width. Good overall agreement between theoretical and experimental results is obtained.

09:45 – 10:00 **Practical realization of DB unit cell** Oral

Davor Zaluški, *University of Zagreb, FER, Croatia*
Damir Muha, *University of Zagreb, FER, Croatia*
Silvio Hrabar, *University of Zagreb, FER, Croatia*

Recently introduced DB boundary is a hypothetical surface, on which cancellation of normal components of the D and B field occurs. Such a DB surface behaves either as a low impedance surface or a high impedance surface, depending whether the incident plane wave is TE or TM polarized, respectively. Basic EM properties of an artificial surface based on recently proposed DB unit cell in 8 GHz frequency band are investigated numerically in various waveguide environments. Preliminary experimental results of unit cell scaled down to frequency band of 300 MHz are reported.

08:30 – 10:00 Novel Concepts I — Nevsky hall

Session chairperson(s): Jensen Li

08:30 – 08:45 **Inhomogeneous waves of light in isotropic metamaterials** Oral

Vladimir Fedorov, *Institute of Advanced Energy, Kyoto University, Japan*
Takashi Nakajima, *Institute of Advanced Energy, Kyoto University, Japan*

We theoretically investigate the propagation of inhomogeneous waves of light in metamaterials. Our results show that to obtain the true refractive index and extinction coefficient of light transmitted to metamaterial one needs to take into account inhomogeneity of the transmitted wave. Also we show that presence of negative refraction at the interface with metamaterial depends not only on the properties of metamaterial itself but also on the geometry of a problem.

08:45 – 09:00 **Lossy wave transmission through graded interfaces between RHM and LHM media – Case of different loss factors in the two media** Oral

Mariana Dalarsson, *Royal Institute of Technology, Stockholm, Sweden*
Martin Norgren, *Royal Institute of Technology, Stockholm, Sweden*
Zoran Jaksic, *University of Belgrade, Belgrade, Serbia*

We present an exact analytical solution to Helmholtz' equation for a lossy case with the graded both real and imaginary parts of permittivity and permeability profile changing according to a hyperbolic tangent function along the direction of propagation. The expressions and graphical results for the field intensities are presented.

09:00 – 09:15 **Transmission line model of noise: application to negative–index metamaterials** Oral

Richard Syms, *Imperial College London, United Kingdom*
Laszlo Solymar, *Imperial College London, United Kingdom*
Oleksy Sydoruk, *Imperial College London, United Kingdom*

St. Petersburg, **Russia**

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A direct transmission line model of noise in 1D electromagnetic media is presented, and used to find the emittance and noise factor of a negative index metamaterial based on resonators and rods. The results are compared with the indirect prediction of standard electromagnetic theory, and shown to be identical.

09:15 – 09:45 **Metaboundary materialization with extreme anisotropy** Extended oral

Ari Sihvola, *Aalto University, Finland*
Pasi Ylä-Oijala, *Aalto University, Finland*
Johannes Markkanen, *Aalto University, Finland*
Ismo Lindell, *Aalto University, Finland*

This paper focuses on synthesizing metasurfaces and complex boundary conditions. In particular, it is shown how extremely anisotropic materials can be exploited to solve this problem. An example demonstrates how a DB surface can be materialized froman anisotropically covered conductor plane.

09:45 – 10:00 **Numerical and experimental demonstration of nonlinear metamaterial surfaces designed for high power surface current absorption** Oral

Hiroki Wakatsuchi, *University of California, San Diego, USA*
S. Kim, *University of California, San Diego, USA*
J.J. Rushton, *University of California, San Diego, USA*
D.F. Sievenpiper, *University of California, San Diego, USA*

We demonstrate both numerically and experimentally absorbing performance of nonlinear metamaterial surfaces (MSs) for high power surface currents. The use of the diodes in the MSs allows rectification of incident waves to DC, which results in absorption for high power incident waves but with low loss for low power incidences.

10:00 – 10:30 **Coffee break** **Poster area**

Oral sessions (Wednesday morning II)

10:30 – 12:00	**Graphene-Based Metamaterials**	**Kremlyovsky hall**
10:30 – 12:00	**THz and Microwave Metamaterials III**	**Tverskoy hall**
10:30 – 12:00	**Slow Light and 3D Metamaterials**	**Nevsky hall**

10:30 – 12:00 **Graphene-Based Metamaterials** **Kremlyovsky hall**
Session chairperson(s): Nikolay Zheludev

10:30 – 11:15 **A metamaterial-inspired effective-medium theory for electron waves in graphene and semiconductor superlattices** Keynote

Mario Silveirinha, *University of Coimbra, Portugal*
Nader Engheta, *University of Pennsylvania, USA*

It is demonstrated that ideas previously developed under the context of electromagnetic metamaterials can be extended to a wide class of physical systems whose dynamics is described by a Hamiltonian. An effective-medium approach that enables characterizing the propagation of electron waves in graphene and semiconductor superlattices is outlined. In our framework, the time evolution of macroscopic states, as well as the electronic band structure, can be exactly determined by an effective Hamiltonian.

11:15 – 11:30

Wide-band enhanced terahertz wave modulation by a graphene-on-silicon modulator Oral

Peter Weis, *TU Kaiserslautern, Germany*
Juan-Luis Garcia-Pomar, *TU Kaiserslautern and Fraunhofer Institute for Physical Measurement Techniques IPM, Germany*
Michael Höh, *TU Kaiserslautern and Fraunhofer Institute for Physical Measurement Techniques IPM, Germany*
Benjamin Reinhard, *TU Kaiserslautern, Germany*
Alexander Brodyanski, *Institut für Oberflächen-und Schichtanalytik IFOS GmbH, Germany*
Marco Rahm, *TU Kaiserslautern and Fraunhofer Institute for Physical Measurement Techniques IPM, Germany*

We report experimental results on all-optical modulation of terahertz waves over a wide band from 0.2 to 1.5 THz with a modulation depth of up to 99% by means of a graphene-on-silicon (GOS) modulator. We observed a significantly enhanced modulation depth of the GOS in comparison with a pure silicon modulator.

11:30 – 11:45

Switching teraherz waves with gate-controlled active graphene metamaterials Oral

Seung Hoon Lee, *Department of Mechanical Engineering, Korea Advanced Institute of Science and Technology, Republic of Korea*
Muhan Choi, *Electronics and Telecommunications Research Institute, Republic of Korea*
Teun-Teun Kim, *Department of Mechanical Engineering, Korea Advanced Institute of Science and Technology, Republic of Korea*
Seungwoo Lee, *Department of Mechanical Engineering, Korea Advanced Institute of Science and Technology, Republic of Korea*
Ming Liu, *Nanoscale Science and Engineering Center, University of California, Berkeley, USA*
Xiaobo Yin, *Nanoscale Science and Engineering Center, University of California, Berkeley, USA*
Hong Kyw Choi, *Electronics and Telecommunications Research Institute, Republic of Korea*
Seung S. Lee, *Department of Mechanical Engineering, Korea Advanced Institute of Science and Technology, Republic of Korea*
Choon-Gi Choi, *Electronics and Telecommunications Research Institute, Republic of Korea*
Sung-Yool Choi, *Department of Electrical Engineering, Korea Advanced Institute of Science and Technology, Republic of Korea*
Xiang Zhang, *Nanoscale Science and Engineering Center, University of California, Berkeley, USA*
Bumki Min, *Department of Mechanical Engineering, Korea Advanced Institute of Science and Technology, Republic of Korea*

In this paper we demonstrate an electrically controllable light-matter interaction in a gate-controlled active graphene metamaterial, which shows an electrically controlled memory effect as well as the modulation of terahertz waves in the extreme subwavelength-scale.

St. Petersburg, **Russia**

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11:45 – 12:00

Absorption of higher-order modes in millimeter-wave waveguides using graphene sheets Oral

Stamatios Amanatiadis, *Dept. of Electrical and Computer Engineering, Aristotle University of Thessaloniki, Greece*
Georgios Bouzianas, *Dept. of Electrical and Computer Engineering, Aristotle University of Thessaloniki, Greece*
Nikolaos Kantartzis, *Dept. of Electrical and Computer Engineering, Aristotle University of Thessaloniki, Greece*
Theodoros Tsiboukis, *Dept. of Electrical and Computer Engineering, Aristotle University of Thessaloniki, Greece*

A technique for the design of millimeter-wave, graphene-loaded waveguides that prevent the propagation of higher-order modes and do not allow a significant energy portion to be reflected back to the source plane, is developed. The location of graphene films is obtained via the calculation of field patterns inside the waveguide.

10:30 – 12:00

THz and Microwave Metamaterials III

Session chairperson(s): Marco Rahm

Tverskoy hall

10:30 – 10:45

Strongly confined metamaterial-mediated terahertz surface waves on silicon Oral

Tassilo Fip, *University of Kaiserslautern, Germany*
Benjamin Reinhard, *University of Kaiserslautern, Germany*
Marco Rahm, *University of Kaiserslautern, Germany*

We investigated the excitation, propagation and optimization of strongly confined metamaterial-mediated terahertz surface waves on silicon. The spatial confinement of surface waves can be strongly enhanced by judicious design of a single metamaterial layer. We experimentally evidenced the excitation of bound surface waves and obtained excellent agreement with numerical calculations.

10:45 – 11:00

Terahertz ratchet effect in two-dimensional electron system gated by a periodic metal grating with asymmetric unit cell Oral

Denis Fateev, *Kotelnikov Institute of Radio Engineering and Electronics, RAS, Saratov, Russia, Russia*
Vyacheslav Popov, *Kotelnikov Institute of Radio Engineering and Electronics, RAS, Saratov, Russia, Russia*
Taiichi Otsuji, *Reseach Institute of Electrical Communication, Tohoku University, Sendai, Japan, Japan*
Yahya Meziani, *Dpto. de Fisica Aplicada, Universidad de Salamanca, Spain*
Dominique Coquillat, *Laboratoire Charles Coulomb, CNRS&Université Montpellier 2, France*
Wojciech Knap, *Laboratoire Charles Coulomb, CNRS&Université Montpellier 2, France*
Sergey Nikitov, *Kotelnikov Institute of Radio Engineering and Electronics of RAS, Moscow, Russia*

Terahertz ratchet effect in a two-dimensional electron system gated by a periodic metal grating with an asymmetric unit cell is studied theoretically. It is shown that the galvanoplasmonic response based on ratchet and plasmon-drag effects is several orders of magnitude stronger than conventional photogalvanic response in two-dimensional electron system. Because of that the galvanoplasmonic effects can be used for sensitive detection of terahertz radiation.

11:00 – 11:30

THz metamaterials made of polaritonic materials Invited oral

Maria Kafesaki, *Foundation for Research and Technology Hellas (FORTH), Greece*
Alexey Basharin, *FORTH, Greece*
Alejandro Reyes-Coronado, *FORTH, Greece*
Eleftherios Economou, *FORTH, Greece*
Costas Soukoulis, *FORTH and Iowa State University, Greece and USA*

We demonstrate through simulations a variety of phenomena and possibilities that can be realized in THz metamaterials made of polaritonic materials. Such phenomena include hyperbolic dispersion relation, subwavelength imaging using backward propagation and backward radiation, and total transmission, reflection and subwavelength guiding exploiting subwavelength Mie resonances. The particular systems that we use to demonstrate these phenomena are two-dimensional periodic systems of μm-scale rods in a host, where both rods and host are made of polaritonic alkali-halide materials

11:30 – 11:45

Temperature dependence of THz generation from plasmonic structures Oral

Dmitry Polyushkin, *University of Exeter, United Kingdom*
Euan Hendry, *University of Exeter, United Kingdom*
William Barnes, *University of Exeter, United Kingdom*

We investigate the efficiency of optically-induced THz generation from plasmonic structures as a function of temperature. Over a range of temperatures 300-10K we observe 6-fold enhancement of the generated THz intensity. We suggest this effect is most likely due to a reduction the ohmic losses resulting from diminished electron-phonon scattering.

11:45 – 12:00

Tunable THz band-pass filter Oral

Mikhail Odit, *St. Petersburg Electrotechnical University LETI, Russia*
Dmitry Kozlov, *St. Petersburg Electrotechnical University LETI, Russia*
Irina Vendik, *St. Petersburg Electrotechnical University LETI, Russia*
Chang-Won Lee, *Samsung Advanced Institute of Technology, Korea*

In this paper we present a design of tunable band-pass filter for THz frequency. The filter consists of several layers of conducting wire grids separated by a layer of metal strips. The structure is filled with nematic liquid crystal providing tunability of the filter frequency response.

10:30 – 12:00 Slow Light and 3D Metamaterials — Nevsky hall

Session chairperson(s): Nader Engheta

10:30 – 11:00

Slow and stopped light in metamaterials Invited oral

Ortwin Hess, *Imperial College London, United Kingdom*

The prospect of achieving extreme slow- and stopped-light in metamaterial and plasmonic waveguides has recently attracted intense attention. Here we will elucidate the mechanisms by which complete stopping of light may be achieved based on the 'trapped rainbow' principle. While decoherence mechanisms may destroy the zero-group-velocity condition for real-frequency/complex-wavevector modes, we show that metamaterial and nanoplasmonic waveguides also support complex-frequency/real-wavevector modes that uphold the light-stopping condition.

St. Petersburg, **Russia**

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11:00 – 11:15

Three-dimensional coaxial plasmonic metamaterial at visible/UV frequencies [Oral]

Marie Anne van de Haar, *FOM institute AMOLF, Netherlands*
Hinke Schokker, *FOM institute AMOLF, Netherlands*
James Parsons, *FOM institute AMOLF, Netherlands*
Albert Polman, *FOM institute AMOLF, Netherlands*

We demonstrate a three dimensional metamaterial in the blue/UV spectral region composed of coupled coaxial plasmonic waveguides. Cathodoluminescence spectroscopy shows evidence for localized modes in the cavities and coupling between the coaxes. Results of interferometric transmission measurements at λ = 476 nm are presented and show a positive phase shift of 180° compared to a reference beam through air.

11:15 – 11:30

Negative refraction by a hyperbolic metamaterial formed by helical-shaped wires [Oral]

Tiago Morgado, *University of Coimbra, Instituto de Telecomunicações, Portugal*
Stanislav Maslovski, University of Coimbra, Instituto de Telecomunicações, Portugal
Mário Silveirinha, *University of Coimbra, Instituto de Telecomunicações, Portugal*

We demonstrate that a racemic array of helical-shaped metallic wires may behave as a local uniaxial Epsilon-Negative (ENG) material. It is shown that by increasing the geometrical inductance of the wires it is possible to nearly suppress the spatial dispersion effects that are inherent to wire media at low frequencies, which in turn favors the emergence of negative refraction.

11:30 – 11:45

Self-assembled nanostructured metamaterials for applications in visible light [Oral]

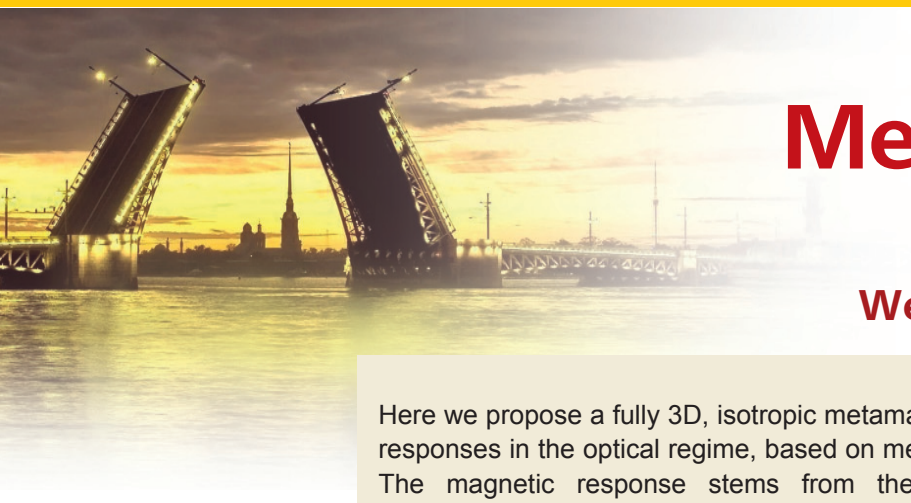
Philippe Barois, *CRPP - CNRS - Univ. Bordeaux, France*
Ludivine Malassis, *CRPP - CNRS - Univ. Bordeaux, France*
Pascal Massé, *ICMCB - CNRS - Univ. Bordeaux, France*
Mona Treguer-Delapierre, *ICMCB - CNRS - Univ. Bordeaux, France*
Etienne Duguet, *ICMCB - CNRS - Univ. Bordeaux, France*

We present the fabrication of self-assembled nanostructured metal-dielectric composite materials that exhibit dielectric resonances at visible light frequencies. The resonators constituted of silver nanoparticles coated with a dielectric silica shell are self assembled in 3D metamaterials of large area and controlable thickness. The electromagnetic behaviour is investigated by reflectance experiments at normal incidence. Sharp variations of the refractive index are measured near resonance.

11:45 – 12:00

Metallo-dielectric core-shell nanospheres and their application as building blocks for isotropic 3d optical metamaterials CONSOLIDER project CSD2008-00066 presentation [Oral]

Ramon Paniagua Dominguez, *Instituto de Estructura de la Materia (Consejo Superior de Investigaciones Científicas), Spain*
Fernando Lopez Tejeira, *Instituto de Estructura de la Materia (Consejo Superior de Investigaciones Científicas), Spain*
Ricardo Marques, *Universidad de Sevilla, Spain*
Jose Antonio Sanchez Gil, *Instituto de Estructura de la Materia (Consejo Superior de Investigaciones Científicas), Spain*



Here we propose a fully 3D, isotropic metamaterial with strong electric and magnetic responses in the optical regime, based on metallo-dielectric core-shell nanospheres. The magnetic response stems from the lowest, magnetic-dipole resonance of the dielectric shell with high refractive index, and can be tuned to coincide with the plasmon resonance of the metal core, responsible for the electric response. Since the response does not originate from coupling between structures, no particular periodic arrangement needs to be imposed. Moreover, due to the geometry of the constituents, the metamaterial is intrinsically isotropic and polarization independent.

12:00 – 13:30 Lunch — Restaurant

Oral sessions (Wednesday afternoon I)

13:30 – 15:00	Optical Metamaterials I	Kremlyovsky hall
13:30 – 15:00	THz and Microwave Metamaterials IV	Tverskoy hall
13:30 – 15:00	Transformation Optics III	Nevsky hall

13:30 – 15:00 Optical Metamaterials I — Kremlyovsky hall

Session chairperson(s): Sebastien Guenneau

13:30 – 14:00

Controlling electric, magnetic and magneto–electric dipole coupling in split ring clusters Invited oral

Femius Koenderink, *FOM Institute AMOLF, Netherlands*
Ivana Sersic, *FOM Institute AMOLF, Netherlands*
Felipe Bernal Arango, *FOM Institute AMOLF, Netherlands*

We present experiments and microscopic calculations that quantify the polarizability tensor of many planar metamaterial scatterers. Surprisingly, we find that a strong cross-polarizability is common to all the metamaterial scatterers, implying huge and robust optical activity for chiral and achiral scatterers. We discuss possible uses as magnetoelectric plasmonic antennas for single molecule microscopy, plasmon hybridization and extraordinary grating phenomena.

14:00 – 14:15

Power emitted by a transverse dipole located above hyperbolic medium–vacuum interface Oral

Caner Guclu, *University of California, Irvine, USA*
Salvatore Campione, *University of California, Irvine, USA*
Seyed Hassan Sedighy, *University of California, Irvine, USA*
Filippo Capolino, *University of California, Irvine, USA*

We investigate the power emitted by a transverse dipole at optical frequencies placed at a given distance from the interface between vacuum and a periodic bi-layered hyperbolic metamaterial (HM). We adopt the transmission line formalism for transverse electric (TE) and magnetic (TM) waves to determine the power spectrum emitted by the dipole towards the HM and the fraction of the power directed towards the isotropic half space, at various dipole distances from the interface. For small distances most of the power is directed into the HM, and we investigate the importance of layers' thickness. These results are compared to similar ones in which a transverse dipole is placed above bulk silica-vacuum or bulk silver-vacuum interfaces.

14:15 – 14:30 **Optical field enhancement in composite plasmonic nanostruc–tures: gold dots with graphene and dye R6G** Oral

Vasyl Kravets, *School of Physics and Astronomy, University of Manchester, United Kingdom*
F. Schedin, *School of Physics and Astronomy, University of Manchester, United Kingdom*
R. Jalil, *School of Physics and Astronomy, University of Manchester, United Kingdom*
L. Britnell, *School of Physics and Astronomy, University of Manchester, United Kingdom*
K. S. Novoselov, *School of Physics and Astronomy, University of Manchester, United Kingdom*
A. N. Grigorenko, *School of Physics and Astronomy, University of Manchester, United Kingdom*

We present composite plasmonic nanostructures designed to achieve cascaded enhancement of electromagnetic fields at optical frequencies. Our structures are made with the help of electron beam lithography and comprise a set of self-similar metallic nano-discs placed one above another. The optical properties of reproducible arrays of these structures are studied using scanning confocal Raman spectroscopy. We observe significant (up to 1000 times) enhancements of resonant Raman scattering from a graphene layer generated by near-fields of a plasmonic nanoarray. This enhancement is quantitatively explained by the electromagnetic mechanism.

14:30 – 15:00 **Polarization analyzer for the magnetic vector of light** Invited oral

D. S. Kim, *Seoul National University, Korea (South)*

We here report about subwavelength metallic aperture on infinite plane acting as polarization analyzers for magnetic field following Bethe's circular aperture diffraction, analogous to conventional polarizers determining the electric field direction.

13:30 – 15:00 THz and Microwave Metamaterials IV — Tverskoy hall

Session chairperson(s): Silvio Hrabar

13:30 – 13:45 **2D isotropic metamaterial with equal permittivity and permeability in THz range** Oral

Igor Semchenko, *Francisk Skorina Gomel State University, Belarus*
Sergei Khakhomov, *Francisk Skorina Gomel State University, Belarus*
Victor Prinz, *Institute of Semiconductor Physics, Russia*
Elena Naumova, *Institute of Semiconductor Physics, Russia*
Sergey Golod, *Institute of Semiconductor Physics, Russia*
Anatoly Buldygin, *Institute of Semiconductor Physics, Russia*

Valentin Seyfi, *Institute of Semiconductor Physics, Russia*

2D isotropic metamaterial with equal permittivity and permeability and compensated chirality was created by the original method of 3D nanostructure formation. Metamaterial consists of optimal helical elements. It is shown that this artificial structure can have the advantage over other metamaterials, for example, the ones based on straight wires and split-ring resonators.

13:45 – 14:00 **Challenges of metamaterial homogenization in dispersive cloaking shells** Oral

Fang Chen, *Michigan Technological University, USA*
Arash Hosseinzadeh, *Michigan Technological University, USA*
Elena Semouchkina, *Michigan Technological University, USA*
George Semouchkin, *Michigan Technological University, USA*

The problem of metamaterial homogenization is complicated by coupling and splitting phenomena in finite arrays of close-packed resonators, which form, in particular, invisibility cloaks. The presented results demonstrate an opportunity to provide coherent responses at superluminal wave propagation in the cloaking media comprised of dielectric resonators.

14:00 – 14:30 **Mesoscopic surface effects in finite metamaterial samples** Extended oral

Mikhail Lapine, *University of Sydney, Australia*
Lukas Jelinek, *Czech Tech. University in Prague, Czech Republic*
Ricardo Marques, *Universidad de Sevilla, Spain*

We report on mesoscopic effects associated with the boundaries of finite discrete metamaterial samples, which can invalidate an effective medium description. We make a proposal in order to avoid such effects by a proper choice of the boundary configuration.

14:30 – 14:45 **Coupling effect of dielectric metamaterial dimer** Oral

Fuli Zhang, *School of Science, Northwestern Polytechnical University, China*
Veronique Sadaune, *University of Lille 1, France*
Lei Kang, *University of Lille 1, France*
Qian Zhao, *Tsinghua University, China*
Ji Zhou, *Tsinghua University, China*
Didier Lippens, *University of Lille 1, France*

In this paper we report on coupling effects of dielectric metamaterial dimer experimentally and numerically. With various configurations and alignment of dimer resonator, magnetic and electric resonance shows a red/blue shift, resulting from longitudinal or transverse coupling effects of dipoles. Beside, the emergences of quasi bound states between tightly stacked dielectric cubes are pointed out for the electric Mie resonance, which shows an unexpected frequency shift with a re-verse variation.

14:45 – 15:00 **Spatial filtering by metasurfaces made of chains of interconnected SRRs and CSRRs** Oral

Juan D. Baena, *Universidad Nacional de Colombia, Colombia*
Julián D. Ortiz, *Universidad Nacional de Colombia, Colombia*
Vicente Losada, *Universidad de Sevilla, Spain*
Francisco Medina, *Universidad de Sevilla, Spain*

Here we study two metasurfaces made of 1D chains of Interconnected Split Ring Resonators (I-SRRs) or Interconnected Complementary Split Ring Resonators (I-CSRRs). The main result was that the central frequencies of the stopband and passband can be tuned by controlling the incidence angle, while it is constant for SRR/CSRR metasurfaces.

13:30 – 15:00 Transformation Optics III — Nevsky hall

Session chairperson(s): Tie Jun Cui

13:30 – 13:45 **Transformation media: space and time, curvature and carpets** Oral

Paul Kinsler, *Imperial College London, United Kingdom*
Martin McCall, *Imperial College London, United Kingdom*

We present our state of the art unification of Transformation Optics with other transformation-based wave theories (such as acoustics). This formalism allows quite naturally for spacetime devices, as well as for curvature, so we present applications in curved cloaks and spacetime carpets.

13:45 – 14:00 **Optically large three-dimensional directional cloaks: off-normal incidence performance study** Oral

Yaroslav Urzhumov, *Duke University, USA*
Nathan Landy, *Duke University, USA*
David Smith, *Duke University, USA*

We study a generalization of directional, optically large eikonal-limit cloaks based on conformal maps, to three dimensions. The cloak is a spherical shell filled with a graded isotropic dielectric whose distribution is cylindrically symmetric. Due to lack of spherical symmetry, the structure has low visibility only for a limited range of incidence angles. We employ a 2.5D full-wave modelling technique to estimate visibility of a cloak with respect to a monochromatic plane wave incident at various angles.

14:00 – 14:30 **Alternative material parameters for transformation optics designs** Invited oral

Anthony Grbic, *Dept. of EECS, University of Michigan, USA*

We present a method to find alternative/simplified material parameters for 2-D transformation optics (TO) devices that operate under a fixed illumination. The alternative material parameters support the same field pattern as the original material parameters of the TO device. Analytical calculations of the alternative parameters are shown and the results are verified through the full-wave simulations of a TO device: an electromagnetic field rotator. Although the TO devices possessing alternative material parameters only work for a particular illumination, the method presented will application in antennas and beam forming networks.

14:30 – 15:00 **New transmission-line unit cells for building transformation electromagnetics devices** Invited oral

Michael Selvanayagam, *University of Toronto, Canada*
George V. Eleftheriades, *University of Toronto, Canada*

Transformation electromagnetics requires anisotropic metamaterials which work for multiple polarizations. These can be very difficult to realize using currently existing metamaterials. In this paper, two new metamaterial unit cells are introduced. One

which can implement an anisotropic medium with a full tensor and another which supports two-polarizations. These unit cells can be quite useful for implementing various devices designed using transformation electromagnetics.

15:00 – 15:30 Coffee break — Poster area

Plenary sessions

15:30 – 17:00 **Plenary session I** — Kremlyovsky hall

Session chairperson(s): Martin Wegener

15:30 – 16:15 **Plasmonic metamaterials: Looking beyond gold and silver**

Alexandra Boltasseva, *Purdue University, USA*

Conventional plasmonic devices have always used silver and gold as metallic components. Other areas of research such as metamaterials and transformation optics that rely on the plasmonic properties of materials also use noble metals as their metallic building blocks. However, these metals are not well-suited for many of the proposed device applications in the optical frequencies because of various problems, including large losses and nanofabrication issues. We show that alternative plasmonic materials such as transparent conducting oxides and transition metal nitrides overcome many of these challenges for metamaterial and plasmonic applications in the near-infrared and visible ranges.

16:15 – 17:00 **Active non-Foster Metamaterials: From intriguing background physics to real-world applications**

Silvio Hrabar, *University of Zagreb, Croatia*

This plenary talk reviews the basic concepts, counter-intuitive background physics and foreseen applications of recently introduced active dispersionless non-Foster metamaterials.

17:00 – 17:30 Coffee break — Poster area

17:30 – 18:15 **Plenary session II** — Kremlyovsky hall

Session chairperson(s): Martin Wegener

17:30 – 18:15 **Beam shaping and wavefront engineering with phase discontinuities**

Federico Capasso, Robert Wallace *Professor of Applied Physics at Harvard University, USA*

18:15 – 20:00 Evening break

20:00 – 23:00 Conference banquet — Restaurant

St. Petersburg, **Russia**

Thursday, 20th September

Oral sessions (Thursday morning I)

08:30 – 10:00	Plasmonic Metamaterials	Kremlyovsky hall
08:30 – 10:00	Chiral Metamaterials II	Tverskoy hall
08:30 – 10:00	Unconventional Metamaterials	Nevsky hall

08:30 – 10:00 Plasmonic Metamaterials — Kremlyovsky hall

Session chairperson(s): Femius Koenderink

08:30 – 09:00 **Exotic plasmonic crystals** Invited oral

Anatoly Zayats, *King's College London, United Kingdom*

We will overview optical properties of plasmonic crystals, periodically nanostructured metal films, with complex crystal lattices. We will discuss their advantages and applications for spectral and polarization multiplexing/demultiplexing, extraction of light from LEDs and biosensing. Active functionalities and tuneability of their photonic properties using electronic, magnetic and optical controls will also be discussed.

09:00 – 09:15 **Bandgap tuning in plasmonic gratings** Oral

Jens Ehlermann, *University of Hamburg, Germany*
Hoan Vu, *University of Hamburg, Germany*
Markus Broell, *University of Hamburg, Germany*
Detlef Heitmann, *University of Hamburg, Germany*
Stefan Mendach, *University of Hamburg, Germany*

We investigate plasmon excitations on thin gold films coated with PMMA grating structures both, in the near field, using a scanning near field optical microscope (SNOM) and in the far field. The dependence of the size and energetic position of a bandgap on structural parameters like grating height and filling factor f is examined. With far field reflection measurements we discover a shift of the bandgap to lower energies with increasing f and we noticed a significant change in the bandgap's size delta E which can be tuned with structural parameters.

09:15 – 09:30 **Interference of Airy surface plasmons** Oral

Angela Klein, *Friedrich-Schiller-University Jena, Germany*
Alexander Minovich, *Australian National University, Australia*
Norik Janunts, *Friedrich-Schiller-University Jena, Germany*
Dragomir Neshev, *Australian National University, Australia*
Andreas Tünnermann, *Friedrich-Schiller-University Jena, Germany*
Yuri Kivshar, *Australian National University, Australia*
Thomas Pertsch, *Friedrich-Schiller-University Jena, Germany*

We study theoretically and experimentally the interference of Airy surface plasmons. We investigate the variation of the focal spot for different separation distance between the beams. We show that the focal spot location can be controlled by the tilt of the incident beam. Unique properties of Airy surface plasmons can find an application in plasmonic circuitry and optical surface tweezers.

09:30 – 09:45 **Transmission efficiency of optical signals through linear chains of metal nanoparticles** Oral

Jasper Compaijen, *University of Groningen, Netherlands*
Victor Malyshev, *University of Groningen, Netherlands*
Jasper Knoester, *University of Groningen, Netherlands*

We show that the transmission efficiency of optical signals through a linear chain of spherical silver metal nanoparticles can be substantially changed by placing the array close to a reflecting interface. We discuss the polarization and spectral dependence of the transmission efficiency in the presence of different reflectors. The role of «dark» plasmon modes in the transmission is highlighted.

08:30 – 10:00 Chiral Metamaterials II — Tverskoy hall

Session chairperson(s): Na Liu

08:30 – 08:45 **Hybridisation in coupled-dipole chiral meta-atoms** Oral

Mingkai Liu, *Australian National University, Australia*
David Powell, *Australian National University, Australia*
Ilya Shadrivov, *Australian National University, Australia*
Yuri Kivshar, *Australian National University, Australia*

We analyse the optical activity in twisted dimers, the meta-atoms of a chiral metamaterial, by introducing a simple yet accurate model for the coupling between them. The near-field interaction coefficients are derived from a Lagrangian model and include the effects of retardation, whereas the far-field radiation is based on a multipole expansion. Our approach is accurate over a wide frequency range, including the resonant regions with the highest optical activity. In contrast to other models of near-field interaction, it requires no fitted parameters or homogenization procedure and is directly applicable to a wide variety of resonant particles.

08:45 – 09:15 **Metallic helix array as a broadband wave plate** Invited oral

Hongqiang Li, *Physics Department, Tongji University, China*

This study demonstrates theoretically and experimentally that a metallic helix array can operate as a highly transparent broadband wave plate in propagation directions perpendicular to the axis of helices. The functionality arises from a special property of the helix array, namely, that two branches of elliptically right-handed and left-handed polarized states are nearly rigidly shifted in frequency and their dispersions are controlled by different mechanisms that can be independently tuned by structural parameters.

09:15 – 09:30 **Chiral meta-molecules composed of gold nanoparticles and tobacco mosaic virus** Oral

Satoshi Tomita, *Nara Institute of Science and Technology (NAIST), Japan*
Mime Kobayashi, *The Cancer Institute of the Japanese Foundation for Cancer Research, Japan*
Kei Sawada, *RIKEN SPring-8 Center, Japan*
Kiyotaka Shiba, *The Cancer Institute of the Japanese Foundation for Cancer Research, Japan*

Hisao Yanagi, *Nara Institute of Science and Technology (NAIST), Japan*
Ichiro Yamashita, *Nara Institute of Science and Technology (NAIST), Japan*
Yukiharu Uraoka, *Nara Institute of Science and Technology (NAIST), Japan*

We report a chiral meta-molecule in the ultraviolet and visible regions using a complex of Au nanoparticles and rod-shaped tobacco mosaic virus. Our results open a new avenue for the preparation of 3D chiral metamaterials in optical frequencies.

09:30 – 09:45 **Cross-polarization coupling – an abandoned property of 3-dimensional photonic crystals** Oral

Jens Küchenmeister, *Institut für Theoretische Festkörperphysik, Karlsruhe Institute of Technology, Germany*
Christian Wolff, *Institut für Theoretische Festkörperphysik, Karlsruhe Institute of Technology, Germany*
Kurt Busch, *Institut für Theoretische Festkörperphysik, Karlsruhe Institute of Technology, Germany*
Ulf Peschel, *Institute of Optics, Information and Photonics, University of Erlangen-Nuremberg, Germany*
Sergei Romanov, *Institute of Optics, Information and Photonics, University of Erlangen-Nuremberg, Germany*

In this paper we demonstrate experimentally and theoretically that the rotation of the polarization of incident light is intrinsic property of 3-dimensional photonic crystals. An opal crystal was used as an example. This effect should be taken into account when discussing polarization anisotropy of finite size photonic crystals because its magnitude is comparable to the transmission/reflectance in co-polarized light.

08:30 – 10:00 Unconventional Metamaterials — Nevsky hall

Session chairperson(s): Isabelle Staude

08:30 – 08:45 **Effective properties of a two-dimensional magnonic metamaterial** Oral

Roberto Zivieri, *Dipartimento di Fisica, Italy*

In this paper the metamaterial properties of a two-dimensional magnonic crystal are studied. The system is composed by holes embedded into a Permalloy ferromagnetic film. The collective mode dynamics in the microwave range is described in terms of an effective wavelength not necessarily equal to the Bloch wavelength.

08:45 – 09:00 **Multi-layer fishnet metamaterials as magnetic hyperbolic media** Oral

Sergey Kruk, *The Australian National University, Australia*
David Powell, *The Australian National University, Australia*
Alexander Minovich, *The Australian National University, Australia*
Dragomir Neshev, *The Australian National University, Australia*
Yuri Kivshar, *The Australian National University, Australia*

We study the anisotropic properties of multilayer fishnet metamaterials and reveal that such structures allow the realization of generalized indefinite media with hyperbolic dispersion. In contrast to other hyperbolic media, multilayer fishnet metamaterials may have not only effective permittivity tensor ε but also effective permeability tensor μ with negative components.

09:00 – 09:15

Magnonic and phononic properties of inverse opal structures Oral

Andrey Stashkevich, *Université Paris 13, LSPM, France*

In this paper we report on both magnonic and phononic properties of a Ni-based inverse ferromagnetic opal film with the fcc structure via ferromagnetic resonance measurements and “pump-probe” acousto-optical technique.

09:15 – 09:30

Frequency control of spin torque oscillation in magnetic metamaterials for microwave generator Oral

Chiharu Mitsumata, *Tohoku University, Japan*
Satoshi Tomita, *NAIST, Japan*

The combination of magnetic metamaterials and spintronics devices has been theoretically investigated. The magnetic metamaterials consisting of magnetic nano-dots realize a microwave generator, in which the oscillation frequency can be controlled by an external applied field and the magnetic interaction among dots, using spin torque oscillation (STO). The oscillation frequency is calculated by an analytic equation of a forced oscillation, that is transformed from the Landau-Lifshitz-Gilbert (LLG) equation. As a result, it is shown that the reduction of the effective Gilbert damping and the increase of oscillation frequency can be achieved independently in the microwave generator with STO.

09:30 – 10:00

Multipolar transitions in quantum emitters: beyond the electric dipole approximation Invited oral

Rashid Zia, *Brown University, USA*

In this presentation, we will investigate the multipolar optical transitions in quantum emitters, including rare earth ions, semiconductor quantum dots, and organic molecules. We will examine the electric dipole approximation and discuss naturally occurring systems that exhibit higher-order magnetic dipole and electric quadrupole emission. Then, we will illustrate how these quantum transitions can provide both a new way to probe magnetic light-matter interactions and a new degree of design freedom for active photonic devices. Specifically, we will demonstrate how the different symmetries of multipolar transitions can be exploited to identify, quantify, and control light emission, even at sub-lifetime scales.

Poster session III + Student paper competition

Coffee break

10:00 – 11:30

Towards Applications

Poster area

~~1. Optical properties of layered metamaterials with Sierpinski carpet structure~~

Dmitry Kharitonov, *Ural Federal University, Russia*
Ilya Weinstein, *Ural Federal University, Russia*

Planar negative-index fishnet-like metamaterial with Sierpinski carpet geometry of unit cell were studi[This paper was not presented at the conference ("no-show").]ters including refractive index, electric perm[This paper was not presented at the conference ("no-show").]e analyzed. Red shift of spectral features [This paper was not presented at the conference ("no-show").]on order of fractal unit cell. The possible applications of metamaterials under simulation in optical devices were discussed.

~~2. Development of glass nanocomposites with silver nanoparticles for biosensor applications~~

Petr Obraztsov, *Ioffe Physical-Technical Institute, Russia*
Alexey Nashchekin, *Ioffe Physical-Technical Institute, Russia*
Alexandr Sidorov, *State University of Information Technologies, Mechanics and Optics, Russia*
Vladimir Nevedomskiy, *Ioffe Physical-Technical Institute, Russia*

Presented paper concerns the development of biosensor platform based on silver nanoparticles, synthes[This paper was not presented at the conference ("no-show").]adiated photo-thermo-refractive glasses and[This paper was not presented at the conference ("no-show").]in water atmosphere. Two methods of opti[This paper was not presented at the conference ("no-show").]by thermal diffusion and ion-exchange. The configuration of localized surface plasmon resonance based biosensor is presented and discussed.

3. Hyperbolic metamaterials realized with two-dimensional transmission lines

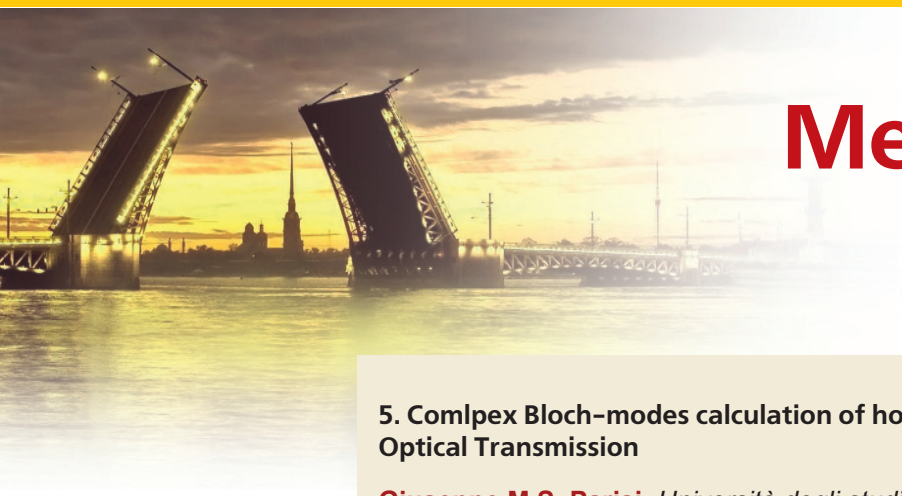
Alyona Chshelokova, *Laboratory Metamaterials, National Research University of Information Technologies, Mechanics and Optics, Russia*
Polina Kapitanova, *Laboratory Metamaterials, National Research University of Information Technologies, Mechanics and Optics, Russia*
Alexander Poddubny, *Laboratory Metamaterials, National Research University of Information Technologies, Mechanics and Optics, Russia*
Pavel Belov, *Laboratory Metamaterials, National Research University of Information Technologies, Mechanics and Optics, Russia*
Yuri Kivshar, *Nonlinear Physics Centre, Research School of Physics and Engineering, Australian National University, Australia*

We demonstrate the realization of a metamaterial medium with the hyperbolic isofrequency surfaces in the wavevector space as a two-dimensional grid of transmission lines. The peculiar character of wave propagation in such a hyperbolic medium is visualized by the study of the cross-like emission pattern of a current source. Our results are supported by the direct solution of the Kirchhoff equations and an analytical theory.

4. Exotic reflection of plane waves by anisotropic structures

Konstantin Vytovtov, *Dnepropetrovsk National University, Ukraine*
Said Zouhdi, *Laboratoire de Genie Electrique de Paris, Universite Pierre et Marie Curie, Paris, France*

An uniaxial anisotropic semi-infinite medium with arbitrary orientation of the anisotropy axis under tangential wave incidence is considered. A possibility of exotic normal reflection of a plane wave is studied. The mathematical model describing such a possibility is presented and the results of numerical calculations are given and analyzed.



5. Comlpex Bloch-modes calculation of holey metal film for Extraordinary Optical Transmission

Giuseppe M.S. Parisi, *Università degli studi di Padova, Italy*
Pierfrancesco Zilio, *University of Padova, Italy*
Filippo Romanato, *University of Padova, Italy*

We adopt a Finite Element Method (FEM) for calculating the complex valued k(ω) dispersion curves of a holey metal slab. In particular the method allows retrieving the imaginary part of the dispersion curve even in presence of strong leakage radiation. Transmittance maps of the structure are compared to the Bloch bands clarifying the relationship between optical response of the structure and periodicity induced resonant modes.

6. Surface impedance and coupled-wave model for extraordinary optical transmission through realistic metallic screens

Transfered to oral, Monday 11:30, Extraordinary Transmission

Vicente Delgado, *University of Seville, Spain*
Ricardo Marqués, *University of Seville, Spain*
Lukas Jelinek, *Czech Technical University in Prague, Czech Republic*

The paper proposes an analytical theory for extraordinary optical transmission (EOT) in metallic screens perforated by a periodic array of subwavelength holes. The theory is based on coupled-wave analysis and on the surface impedance concept. The analytical model allows for a considerable reduction of CPU time in the analysis of EOT.

7. On the nature of transmission in resonant metamaterial transmission lines

Transfered to oral, Monday 12:00, Extraordinary Transmission

Vesna Crnojevic-Bengin, *University of Novi Sad, Serbia*
Riana Geschke, *Stellenbosch University, South Africa*
Nikolina Jankovic, *University of Novi Sad, Serbia*
Norbert Cselyuszka, *University of Novi Sad, Serbia*

A detailed analysis of the transmission that occurs in various scenarios of a host medium with a capacitive gap and complementary split-ring resonator (CSRR) combination is presented. This is a typical situation where it is expected that left-handed propagation will occur in a certain band of frequencies. We now show that Epsilon-Near-Zero (ENZ) transmission may be obtained by tailoring the host structure geometry.

8. Double negative metamaterial inclusions in photonic crystal based resonant cavities

Rosa Letizia, *Lancaster University, United Kingdom*
Domenico Pinto, *Lancaster University, United Kingdom*

The inclusion of metamaterial (MTM) to form the defect region of a photonic crystal (PhC) cavity is investigated. Numerical results show that the MTM inclusion gives rise to a single resonant mode with enhanced localization effect and increased quality factor. This may result in improved PhC cavities for sensing applications.

~~9. Electrodynamic coupling in ordered arrays of finite-size cylinders~~

Viktoryia Koutun-Kuzha*lno, Belarus*

This paper was not presented at the conference ("no-show").

10. Numerical analysis of absorption enhancement in solar cells with Si nanoconical–frustum arrays

Gumin Kang, *School of Mechanical Engineering, Yonsei University, Korea (South)*
Haesung Park, *School of Mechanical Engineering, Yonsei University, Korea (South)*
Kyoungsik Kim, *School of Mechanical Engineering, Yonsei University, Korea(South)*

To investigate the enhancement of absorption in solar cells with antireflective Si nanoconical-frustum (NCF) arrays, we used finite-difference time-domain (FDTD) method for the analysis over the range of 300~900nm. The short circuit current density (Jsc) of the solar cell with Si NCF arrays increases about 46% compared to the solar cell without Si NCF arrays.

11. Study of photonic quantum well structures containing negative–index materials

Lixiang Liu, *Shanxi Datong University, China*
Lijuan Dong, *Shanxi Datong University, China*
Yanhong Liu, *Shanxi Datong University, China*
Yunlong Shi, *Shanxi Datong University, China*

The properties of photonic quantum well structures composed of the photonic crystals containing positive/negative-index materials and the defect of negative-index materials are experimentally studied. It is found that the number of the tunneling modes can be tuned by adjusting the thickness of negative-index materials in the well. Simultaneously, we also analyze the variance of the frequency for tunneling modes when the capacitance and inductance of negative-index materials are changed.

12. Study and optimization of fishnet metamaterial structures

Jan Fiala, *Czech Technical University in Prague, Faculty of Nuclear Sciences and Physical Engineering, Department of Physical Electronics, Czech Republic*
Pavel Kwiecien, *Czech Technical University in Prague, Faculty of Nuclear Sciences and Physical Engineering, Department of Physical Electronics, Czech Republic*
Ivan Richter, *Czech Technical University in Prague, Faculty of Nuclear Sciences and Physical Engineering, Department of Physical Electronics, Czech Republic*

The full-wave numerical simulations of plane-wave excitation of the multilayered nano-fishnets are performed using the in-house made RCWA based software and FDTD MEEP as well as commercial Photon Design tool. The reflection and transmission coefficients are calculated and the material parameters are consequently extracted from the obtained data. Furthermore, the frequency dependence of the effective negative index of refraction is predicted using the semi-analytical approach, describing the wave coupling processes within the fishnet structure, and hence providing more physical insight into these perspective metamaterial structures.

13. Optical dynamics of a bistable semiconductor quantum dot–metal nanoparticle heterodymer

Bintoro S. Nugroho, *Theory of Condensed Matter, Zernike Institute for Advanced Materials, the Netherlands*
Alexander A. Iskandar, *Faculty of Mathematics and Natural Science, Bandung Institute of Technology, Indonesia*

Victor A. Malyshev, *Theory of Condensed Matter, Zernike Institute for Advanced Materials, the Netherlands*
Jasper Knoester, *Theory of Condensed Matter, Zernike Institute for Advanced Materials, the Netherlands*

We perform a theoretical study of the optical dynamics of a hybrid system comprised of a closely spaced semiconductor quantum dot (SQD) and a metal nanoparticle (MNP). We show that, depending on the strength of the SQD-MNP coupling, the system can manifest bistability in the optical response. The SQD population demonstrate a hysteresis behavior upon sweeping adiabatically up and down the input intensity. We calculate the relaxation time required for the SQD population to reach its steady-state value and show that close to a critical intensity of the input, at which the SQD population switches from a lower to a higher value, the relaxation time is slowing down dramatically.

14. Reversed radiation pressure effect on electrons under plasmonic resonance in a magnetic metamaterial

Hiroyuki Kurosawa, *Tohoku University, Japan*
Teruya Ishihara, *Tohoku University, Japan*

We numerically studied optical radiation pressure effect on metallic thin film in a magnetic metamaterial under oblique incidence. The model system consists of an aluminum nanowire and a spatially separated homogeneous gold thin film. We found that for localized SPPs coupling electrons in the metallic film are pulled and pushed depending on the detuning of the resonance.

15. Cascaded field enhancement in plasmonic nanostructures

Benjamin Thackray, *University of Manchester, United Kingdom*
Fred Schedin, *University of Manchester, United Kingdom*
Vasyl Kravets, *University of Manchester, United Kingdom*
Alexander Grigorenko, *University of Manchester, United Kingdom*

Composite plasmonic nanostructures designed to enhance electromagnetic fields in a cascaded manner have been fabricated using electron beam lithography. The structures consist of three stacked metallic nanodiscs separated by dielectric spacers. We have optimized the fabrication process and performed initial characterization of the structures. Cascaded enhancement of electromagnetic fields in these nanostructures will be used for single molecule Raman studies.

16. 3D analysis of grating plasmonic coupler

Guido Gentili, *Politecnico di Milano, Italy*
Silvia Pietralunga, *CNR-IFN, Italy*
Marco Bolzoni, *Politecnico di Milano, Italy*

A 3D analysis of a plasmonic coupler has been carried out with a full wave FEM software. The coupler is realized with a 1D grating that is excited by a Gaussian beam. A comparison with the usual 2D approximated analysis available in the literature is shown and some interesting features of the 3D coupler are pointed out.

17. Duality in 2D optical nanocircuits

Juan D. Baena, *Universidad Nacional de Colombia, Colombia*
Julián D. Ortiz, *Universidad Nacional de Colombia, Colombia*
Ricardo Marqués, *Universidad de Sevilla, Sevilla*
Vicente Delgado, *Universidad de Sevilla, Spain*

A duality relation between the impedances of a single original element and its complementary element is deduced. It is also demonstrated that this duality property holds also for parallel or series associations of several circuit elements. This work can help to design 2D optical circuits with dual properties.

18. Large area array of split ring resonators for sensing applications

Valentina Giorgis, *Istituto Officina dei Materiali, Consiglio Nazionale delle Ricerche (IOM CNR), Italy*
Massari Michele, *Laboratory for Nanofabrication of Nanodevices (LaNN), Italy*
Pierfrancesco Zilio, Laboratory for Nanofabrication of Nanodevices (LaNN), Italy
Giuseppe Parisi, *Laboratory for Nanofabrication of Nanodevices (LaNN), Italy*
Gianluca Ruffato, *Laboratory for Nanofabrication of Nanodevices (LaNN), Italy*
Gianluca Grenci, *Istituto Officina dei Materiali, Consiglio Nazionale delle Ricerche (IOM CNR), Italy*
Filippo Romanato, *Laboratory for Nanofabrication of Nanodevices (LaNN), IOM CNR, Italy*

In this paper we present design, fabrication and characterization of golden Split Ring Resonators; the aim is to obtain large area samples for sensing purposes. SRR are fabricated using X-ray lithography and characterizated by ellipsometry. We propose to use the resonant response of an array of SRR, and in particular the features in the visible, to detect bio-chemical quantities.

19. Coherent control of a qubit for a rotation gate operation in photonic crystals

Hiroyuki Nihei, *Health Sciences University of Hokkaido, Japan*

We have developed a method of controlling the quantum state of an impurity atom embedded in photonic crystals that can be used as a single-qubit rotation gate, one of the universal quantum logic gates, using the coherent control of spontaneous emission from the embedded atom.

20. Directional plasmonic nano–antennas

Javier Munárriz, *Universidad Complutense, Spain*
Andrey Malyshev, *Universidad Complutense / A. F. Ioffe Physico-Technical Institute, Spain / Russia*

We address 2D arrays of metallic nano-particles arranged in a honeycomb lattice in the proximity of a hetero-interface of two media with high dielectric contrast. These systems can function as antennas in the visible range of the spectrum. We demonstrate that their radiation patterns can be made very directional by appropriate choice of the system geometry and materials. We show also that if such an antenna is excited by evanescent waves, the direction of the main radiation lobe can be switched abruptly by changing the polarization of the incident light. Within the proposed excitation scheme the device converts an incident plane wave into a narrow beam, operating as a nanoscopic source of light with tunable directionality.

~~21. Two-dimensional plasmonic eigenmode nanolocalization in an inhomogeneous metal-dielectric-metal slot waveguide~~

Daria Smirnova, *Institute for Physics of Microstructures, Russian Academy of Sciences, Russia*
Alexander Zharov, *Institute for Physics of Microstructures, Russian Academy of Sciences, Russia*

We show that transverse, with respect to the propagation direction, local narrowing of a metal-dielectric[illegible]s to a two-dimensional surface plasmon na[illegible]asmon eigenmode into a spot with a diameter size of about several tens of nanometers.

This paper was not presented at the conference ("no-show").

22. Demonstration of flat band for terahertz coupled plasmon in metamaterials with kagome symmetry

Yosuke Nakata, *Graduate School of Engineering, Kyoto university, Japan*
Takanori Okada, *Pioneering Research Unit for Next Generation, Kyoto University, Japan*
Toshihiro Nakanishi, *Graduate School of Engineering, Kyoto university, Japan*
Masao Kitano, *Graduate School of Engineering, Kyoto university, Japan*

In this paper, we demonstrate the flat band for a coupled plasmon. A metamaterial composed of metallic discs and bars arranged to have kagome symmetry is used. We theoretically show that a plasmonic flat band for the metamaterial is formed by the topological nature of the kagome lattice. To confirm the flat-band formation, we make transmission measurements in the terahertz regime, and observe the flat band.

~~23. Negative refraction in the visible range in opal photonic crystals~~

Vladimir Shchavlev, *Department of Optics, Russia*
Vladimir Gorelik, *Department of Optics, Russia*

A negative refraction effect has been found in opal photonic crystals in the visible range. We have calculated the dispersion branches of a photonic crystal and determined the position of its photonic[illegible]en identified where the refractive index of the [illegible]ement is proposed for focusing a light beam by passing it through a plane-parallel opal photonic crystal and experimental evidence is presented in favor of negative refraction in the visible range. Design of the plane-concave lens and the plane-convex lens with negative refraction is presented.

This paper was not presented at the conference ("no-show").

~~24. Extraordinary transmission of thin absorbing films containing a densely-packed monolayer of nanospheres~~

Alina Ponyavina, *Institute of Physics, National Academy of Sciences of Belarus, Belarus*
Roman Dynich, *Institute of Physics, National Academy of Sciences of Belarus, Belarus*

We apply the statistic[illegible]s in order to simulate an electromagnetic wa[illegible]erical pores displaced into a thin absorbing f[illegible]ce of waves scattered towards in the extraordinary transmission effect.

This paper was not presented at the conference ("no-show").

St. Petersburg, **Russia**

Thursday, 20th September

Oral sessions (Thursday morning II)

11:30 – 13:00	Active and Low-Loss Metamaterials I	Kremlyovsky hall
11:30 – 13:00	Chiral Metamaterials III	Tverskoy hall
11:30 – 13:00	Novel Concepts II	Nevsky hall

11:30 – 13:00 Active and Low-Loss Metamaterials I — Kremlyovsky hall

Session chairperson(s): Michael Sinclair

11:30 – 12:00 **Loss in metamaterials and nano-plasmonics and potential means of its mitigation** Invited oral

Jacob Khurgin, *Johns Hopkins University , USA*

We consider the origin of the loss in the metamaterials, how it scales with size and wavelength and how it can be mitigated by gain, using dispersive dielectrics, or synthesizing novel materials on atomic level.

12:00 – 12:15 **Spaser chains** Oral

Eugene Andrianov, *ITAE RAS, Russia*

We show that depending on the values of the coupling constants, two different scenarios for the stationary behavior of a chain of interacting spasers may be realized: (1) all the spasers are synchronized and oscillate with a unique phase and (2) a nonlinear autowave travels along the chain. In the latter scenario, the traveling wave is harmonic, unlike excitations in other known nonlinear systems. Due to the nonlinear nature of the system, any initial distribution of spaser states evolves into one of these steady states.

12:15 – 12:30 **Electromagnetic model for the loss compensation and emission properties of a dye-coated core-shell nanoparticle** Oral

Vitaliy Pustovit, *University of Bordeaux and CNRS, France*
Filippo Capolino, *University of California Irvine, USA*
Ashod Aradian, *University of Bordeaux and CNRS, France*

We present a detailed electromagnetic model of the plasmonic response of a metal core-dielectric shell metallic nanoparticle covered with optically active dipoles (fluorescent molecules or quantum dots). We establish a complete description of the optical response based on Green's functions, which allows us to investigate high molecular coverages of the nanoparticle with either regular or random distribution of dye molecules, taking into account not only the interactions between nanoparticle (treated in a multipolar approach) and dye dipoles, but also between dyes molecules, either directly or via the nanoparticle. Our model shows a strong amplification and increase of quality of the plasmonic resonance, and provides a simple framework to explain the appearance of very sharp, «nanolaser»-type emissive states, based on an analysis of the collective optical modes of the dye-nanoparticle system.

12:30 – 12:45

Transmission enhancement in active rolled-up metamaterials utilizing Fabry–Perot resonances Oral

Stephan Schwaiger, *Institute of Applied Physics, Germany*
Jochen Kerbst, *Institute of Applied Physics, Germany*
Andrea Stemmann, *Institute of Applied Physics, Germany*
Wolfgang Hansen, *Institute of Applied Physics, Germany*
Detlef Heitmann, *Institute of Applied Physics, Germany*
Stefan Mendach, *Institute of Applied Physics, Germany*

Recently, we experimentally demonstrated that the transmission through a rolled-up metamaterial can be enhanced by optical excitation of an embedded quantum well. Here, we present transfer matrix method calculations on such materials modelling the quantum well gain with a Lorentz oscillator. We find that the transmission enhancement of the embedded quantum well is maximized when tuning its operation energy to a Fabry-Pérot resonance.

12:45 – 13:00

Analysis of the nanolaser linewidth using semiclassical laser model Oral

Arkadi Chipouline, *FSU Jena, Germany*

Stochastic characteristics (radiation linewidth) of the nanolasers (such as the spaser and the dipole nanolaser), are investigated analytically and numerically. In frame of the semiclassical model gain dynamics is treated quantum mechanically based on density matrix approach, while the plasmon dynamics and radiation are assumed to be classical. It is shown that direct application of Schawlow-Townes overestimates the linewidth and has to be avoided at the description of the nanolaser. Analytical results are compared with ones obtained from the direct numerical simulation of the dynamics of the laser equations. The features of the below-, near- and above-threshold operation regimes are considered.

11:30 – 13:00 Chiral Metamaterials III — Tverskoy hall

Session chairperson(s): Sergei Romanov

11:30 – 11:45

Depolarizers for space applications consisting of spatially distributed meander structures with random orientation Oral

Philipp Schau, *Institut für Technische Optik, Universität Stuttgart, Germany*

A polarization scrambler consisting of spatially distributed meander structures with random orientation is investigated numerically using Mueller matrices. The presented approach has the potential to replace conventional Cornu depolarizers currently used in space instruments such as ESA's MERLIN or OCLI.

11:45 – 12:00

Tri-helical model for nanoplasmonic gyroid metamaterials Oral

Sang Soon Oh, *Imperial College London, United Kingdom*
Angela Demetriadou, *Imperial College London, United Kingdom*
Sebastian Wuestner, *Imperial College London, United Kingdom*
Ortwin Hess, *Imperial College London, United Kingdom*

Metallic single gyroids are part of a novel class of self-assembled nanoplasmonic metamaterials exhibiting chiral behavior in the visible spectrum. To identify the physical origin of their chirality and quantify their electromagnetic properties, we develop

an analytical model for a tri-helical metamaterial. Our model provides valuable insight into the optical properties of single nanoplasmonic gyroids, and the results show that the metamaterial's chirality is limited due to the structural integration of opposing helices along the main cubic axes, their connection into a continuous network-allowing induced current to flow - and the network's material properties, that is the dispersion of the metal.

12:00 – 12:15

Broadband white-light interferometry reveals giant optical activity in metamaterials Oral

Matthias Falkner, *Institute of Applied Physics, Friedrich-Schiller-Universität Jena, Germany*
Christian Helgert, *Institute of Applied Physics, Friedrich-Schiller-Universität Jena, Germany*
Ekaterina Pshenay-Severin, *Institute of Applied Physics, Friedrich-Schiller-Universität Jena, Germany*
Christoph Menzel, *Institute of Condensed Matter Theory and Solid State Optics, Germany*
Carsten Rockstuhl, *Institute of Condensed Matter Theory and Solid State Optics, Germany*
Thomas Pertsch, *Institute of Applied Physics, Friedrich-Schiller-Universität Jena, Germany*

We introduce a novel experimental scheme to characterize the transmission characteristics of optical metamaterials in amplitude and phase. The approach reveals all properties of the respective Jones matrix entirely on experimental grounds and was verified to be highly accurate. The presented Jones matrix formalism lifts issues associated with the assignment of effective properties to heterogeneous metamaterials and provides a straightforward, yet accurate description. Thus it is not required to resort on numerical simulations to disclose properties of metamaterials, for which the geometrical details of the considered structures or their material properties are often known with insufficient precision. We show how to discuss the pertinent properties of optical metamaterials once the Jones matrix is determined, and exemplarily present measurements of giant optical activity in a chiral metamaterial. The proposed experimental scheme enables the complex far-field characterization of a very broad class of generally dispersive and/or optically active media.

12:15 – 12:30

Design of a dual-band monopole antenna enclosed in a 2D-chiral metamaterial shell Oral

Larissa Cristiane Paiva de Sousa Lima, *Department of Electrical Engineering, University of São Paulo, Brazil*
Leone Veiga Muniz, *Department of Electrical Engineering, University of São Paulo, Brazil*
Thiago Campos Vasconcelos, *Department of Electronics and Systems, Federal University of Pernambuco, Brazil*
Frederico Dias Nunes, *Department of Electronics and Systems, Federal University of Pernambuco, Brazil*
Ben-Hur Viana Borges, *Department of Electrical Engineering, University of São Paulo, Brazil*

The application of 2D-chiral metamaterial structure aiming at controlling the radiation parameters of a monopole antenna in the microwave region is investigated. We show that an alumina substrate shell covered with these cells can significantly improve the antenna response (gain and return loss), especially when they are rotated.

12:30 – 13:00 **Chiral metamaterials for ultrasensitive biodetection** Invited oral

Malcolm Kadodwala, *University of Glasgow, United Kingdom*

We discuss the effects of chiral molecular materials on the optical properties of plasmonic materials, and the subsequent application is biodetection, Specifically we demonstrate the the EM field in the vicinity of chiral nanostructures can be engineered for enhanced performance in biophysical measurements

11:30 – 13:00 Novel Concepts II — Nevsky hall

Session chairperson(s): Rashid Zia

11:45 – 12:15 **Strong local field increase in perfect plasmonic absorbers** Extended oral

Mohammad Albooyeh, *Department of Radio Science and Engineering / SMARAD Centre of Excellence, Aalto University, Finland*
Constantin Simovski, *Department of Radio Science and Engineering / SMARAD Centre of Excellence, Aalto University, Finland*

The possibility of a huge local field enhancement in subwavelength volumes combined with a total power absorption of light within a metasurface/metafilm is studied here. The presence of a magnetic mode simultaneously with an electric mode is a key prerequisite for a planar grid in order to absorb all incident power when there is only one reflecting interface. This regime can be implemented in the optical range with the help of the so-called substrate-induced bianistropy. The local field enhancement results in such a perfect absorber due to the nanoantenna-like effect when the field in the gap between every nanoparticle and the substrate is similar to that in a gap between two elements of some plasmonic nanoantennas.

12:15 – 12:30 **Complementarity and Babinet principle in optical nano-circuits and metamaterials** Oral

Ricardo Marqués Sillero, *University of Seville, Spain*
Vicente Jesús Delgado Pozo, *University of Seville, Spain*
Juan Domingo Baena Coello, *Universidad Nacional de Colombia, Colombia*
Julián David Ortiz Cárdenas, *Universidad Nacional de Colombia, Colombia*

Complementarity and Babinet principle are widely used concepts in optics and electronics. The extension of these concepts to the optical range, where metals must be characterized as negative permittivity dielectrics rather than as perfect conductors is not straightforward. Here we explore the generalization of these concepts to optical planar nano-circuits and metamaterials.

12:30 – 12:45 **Isotropic metamaterial perfect absorbers** Oral

Juan D. Baena, *Universidad Nacional de Colombia, Colombia*
Julián D. Ortiz, *Universidad Nacional de Colombia, Colombia*

Here we theoretically study a perfect absorbing surface which does not depend on the polarization state and the incidence angle. Electric and magnetic surface currents allow for the cancelation of the field at the back of the surface while no reflection is scattered into the front of the surface.

13:00 – 14:30 Lunch — Restaurant

St. Petersburg, **Russia**

Thursday, 20th September

Oral sessions (Thursday afternoon I)

14:30 – 16:00	Active and Low-Loss Metamaterials II	Kremlyovsky hall
14:30 – 16:00	Quantum and Chiral Metamaterials	Tverskoy hall
14:30 – 16:00	Complex Electromagnetic Materials	Nevsky hall

14:30 – 16:00 Active and Low-Loss Metamaterials II — Kremlyovsky hall

Session chairperson(s): Anatoly Zayats

14:30 – 14:45 **Tapered nanoantennas for efficient broadband unidirectional emission enhancement** Oral

Isabelle Staude, *Nonlinear Physics Centre, Research School of Physics and Engineering, The Australian National University, Australia*
Ivan S. Maksymov, *Nonlinear Physics Centre, Research School of Physics and Engineering, The Australian National University, Australia*
Manuel Decker, *Nonlinear Physics Centre, Research School of Physics and Engineering, The Australian National University, Australia*
Andrey E. Miroshnichenko, *Nonlinear Physics Centre, Research School of Physics and Engineering, The Australian National University, Australia*
Dragomir N. Neshev, *Nonlinear Physics Centre, Research School of Physics and Engineering, The Australian National University, Australia*
Chennupati Jagadish, *Department of Electronic Materials Engineering, Research School of Physics and Engineering, The Australian National University, Australia*
Yuri S. Kivshar, *Nonlinear Physics Centre, Research School of Physics and Engineering, The Australian National University, Australia*

We fabricate and characterize tapered nanoantennas for broadband unidirectional emission enhancement. Numerical simulations predict that this type of nanoantenna reaches an average efficiency of 20% and average front-to-back ratio of 20 over the entire operation bandwidth of 300 nm. Measured transmittance spectra show broad resonances reflecting the nanoantenna's broadband characteristics.

14:45 – 15:00 **All-dielectric optical nanoantennas** Oral

Alexandr Krasnok, *National Research University of Information Technologies, Mechanics and Optics (ITMO), Russia*
Andrey Miroshnichenko, *Nonlinear Physics Centre, Research School of Physics and Engineering, Australian National University, Canberra, Australia*
Dmitry Filonov, *National Research University of Information Technologies, Mechanics and Optics (ITMO), Russia*
Alexey Slobozhanyuk, *National Research University of Information Technologies, Mechanics and Optics (ITMO), Russia*
Polina Kapitanova, *National Research University of Information Technologies, Mechanics and Optics (ITMO), Russia*

Pavel Belov, *National Research University of Information Technologies, Mechanics and Optics (ITMO), Russia and Queen Mary University of London, UK*
Yuri Kivshar, *Nonlinear Physics Centre, Research School of Physics and Engineering, Australian National University, Canberra, Australia; National Research University of Information Technologies, Mechanics and Optics (ITMO), Russia*

We suggest and study in detail a novel type of optical nanoantennas made of high-permittivity low-loss dielectric spheres. In addition to the electric resonances, they exhibit very strong magnetic resonances at the nanoscale. By placing a point-like dipole source near a single dielectric particle driven at the magnetic resonance results the radiation pattern similar to that of a Huygens source with the enhanced forward and vanishing backward emission. This feature can be employed in the Yagi-Uda geometry for highly efficient optical nanoantennas. We suggest the concept of optical all-dielectric antennas and verify experimentally in the microwave frequency range.

15:00 – 15:15 **Superradiance in 2D spaser array** Oral

Alexander Dorofeenko, *ITAE RAS, Russia*

We demonstrate that a 2D array of spasers may be synchronized. Since in the sole spaser the joule losses exceed radiation ones it is the near fields of surface plasmons that are amplified. In the array of synchronized spasers due to superradiance the radiation of photons prevails over the joule losses and spasers start working as nanolasers. Since the synchronization is due to near field interaction the system size may be greater than the wavelength, opposite to the case of usual supperradiance. Thus, the aperture of the system may be chosen greater than wavelength that results in narrowing of the radiation pattern and in cubic dependence of the intensity on the number of spasers.

15:15 – 15:30 **Lasing in the photonic crystal** Oral

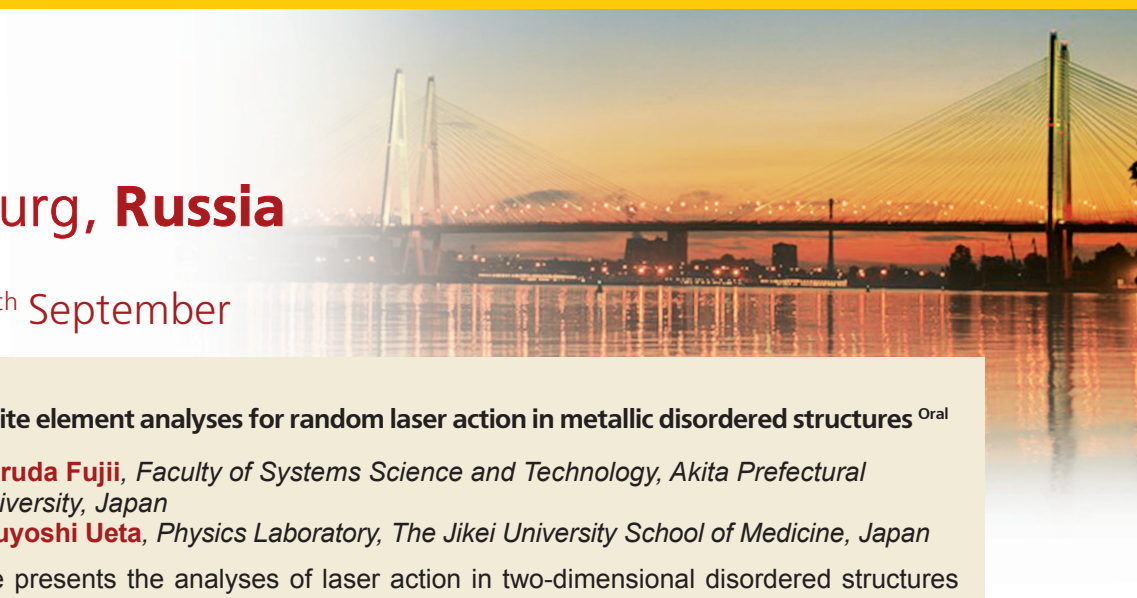
Alexander Zyablovsky, *Institute for Theoretical and Applied Electromagnetics RAS, Russia*
Alexander Dorofeenko, *Institute for Theoretical and Applied Electromagnetics RAS, Russia*
Alexey Vinogradov, *Institute for Theoretical and Applied Electromagnetics RAS, Russia*
Alexander Pukhov, *Institute for Theoretical and Applied Electromagnetics RAS, Russia*

In this paper we describe the lasing in a 1D photonic crystal containing gain layers. It is shown that the lasing threshold can be determined by linear (negative loss) approximation. Connecting the onset of lasing with the passage of the transfer function pole into the upper half-plane of the complex frequency.

15:30 – 15:45 **Spaser spectroscopy with subwavelength spatial resolution** Oral

Igor Nechepurenko, *ItaeRas, Russia*

The advances of nanotechnology open an opportunity of development of existent spectroscopy methods. We suggest a novel method that combines the ideas of tip-enhanced optical spectroscopy and of laser spectroscopy. The latter, offering no spatial resolution, provides an extremely high sensitivity and reveals even prohibited (non-dipolar) transitions. The combination is enabled by invention of plasmonic laser (spaser), which generates plasmons due to nonradiative energy transfer from the gain medium (quantum dot) to SPP, localized at a nanoparticle. Recently we have suggested a spaser radiating 1D plasmons. The device suggested here is based on 1D spaser generating plasmons on a needle with narrow tip. We show that the sensitivity allows detection of some dozens of atoms with high (sub-wavelength) spatial resolution.



St. Petersburg, **Russia**

Thursday, 20th September

15:45 – 16:00 **Finite element analyses for random laser action in metallic disordered structures** Oral

Garuda Fujii, *Faculty of Systems Science and Technology, Akita Prefectural University, Japan*
Tsuyoshi Ueta, *Physics Laboratory, The Jikei University School of Medicine, Japan*

We presents the analyses of laser action in two-dimensional disordered structures consisting of metallic cylinders by means of a finite element method. Metallic cylinders reflect light waves completely on their surfaces, and then, random multiple scattering in the disordered structures is expected to become extremely intense. Hence, random lasers in the random systems of metallic cylinders are expected to be extremely low-threshold lasers. Metallic cylinders and optically active medium in the random systems are modeled by Drude model and negative value in imaginary part of relative permittivity, respectively. The lasing threshold in the random structures of metallic cylinders becomes much lower than those in random structures of dielectric cylinders.

14:30 – 16:00 **Quantum and Chiral Metamaterials** **Tverskoy hall**

Session chairperson(s): Dai Sik Kim

14:30 – 14:45 **Super-collimation of electron waves in semiconductor superlattices and the paradigm of transformation electronics** Oral

Mario Silveirinha, *University of Pennsylvania & University of Coimbra, USA & Portugal*
Nader Engheta, *University of Pennsylvania, USA*

The speed of integrated circuits is ultimately limited by the electron mobility, which depends on the effective mass of electrons in a semiconductor. Building on an analogy between electromag-netic media and semiconductors, we describe a new transport regime in a semiconductor superlat-tice characterized by extreme anisotropy of the ef-fective mass and a minute inertia to movement — with zero effective mass — along a preferred direction of space, such that electron waves are super-collimated along that direction. We envision that this effect may pave the way for faster electronic devices and detectors, and new functional materials with a strong electrical response in the infra-red regime.

14:45 – 15:00 **Electromagnetic phenomena in omega nihility media** Oral

Younes Radi, *Dept. of Radio Science and Engineering, School of Electrical Engineering, Aalto University, Finland*
Sergei Tretyakov, *Dept. of Radio Science and Engineering, School of Electrical Engineering, Aalto University, Finland*

Omega material is a reciprocal bi-anisotropic material with an antisymmetric magnetoelectric dyadic (e.g., a composite formed by conductive Ω-shaped particles). In this presentation we will discuss the extreme electromagnetic properties of omega materials in the limiting case of nihility, when both permittivity and permeability of the medium tend to zero, and the magnetoelectric parameter alone defines the material response. Among other effects, we show that the omega nihility material provides the extreme asymmetry in reflection from a material slab: The reflection coefficients from the two opposite sides differ by sign, while the transmission coefficient is symmetric as in any reciprocal material slab.

15:00 – 15:15 **Non-birefringent omega-like media** Oral

Sérgio Matos, *Instituto de Telecomunicações, ISCTE-IUL, Portugal*
Filipa Prudêncio, *Instituto de Telecomunicações, IST, Portugal*
Carlos Paiva, *Instituto de Telecomunicações, IST, Portugal*

Non birefringent media (NBM) have attracted some attention in the literature. In this paper we show that omega media can be non birefringent. Moreover a new type of omega-like NBM was found (2D-NBM). NBM have a single isofrequency surface, whereas 2D-NBM have two isofrequency surfaces that intersect in a plane.

15:15 – 15:45 **Rolled-up metamaterials** Invited oral

Stephan Schwaiger, *IAP Hamburg, Germany*
Andreas Rottler, *IAP Hamburg, Germany*
Wolfgang Hansen, *IAP Hamburg, Germany*
Detlef Heitmann, *IAP Hamburg, Germany*
Stefan Mendach, *IAP Hamburg, Germany*

We briefly review the research of rolled-up metamaterials and present our latest results on rolled-up optical metamaterials with integrated semiconductor quantum structures.

15:45 – 16:00 **Field enhancement and harmonic generation in ε-near-zero substrates under oblique TM-polarized illumination** Oral

Salvatore Campione, *University of California Irvine, USA*
Maria Antonietta Vincenti, *Nanogenesis - AEgis Technologies Group Inc, USA*
Domenico de Ceglia, *Nanogenesis - AEgis Technologies Group Inc, USA*
Michael Scalora, *US Army Charles M. Bowden Research Center, RDECOM, USA*
Filippo Capolino, *University of California Irvine, USA*

We investigate local field enhancement phenomena using epsilon-near-zero (ENZ) substrates for incident TM-polarized fields. When material losses are present a moderate field enhancement is achieved for a fairly wide frequency band and incident angles. In contrast, when material losses are partly compensated we observe much stronger field enhancement for narrower frequency band and incident angles. We show that the combination of low material losses, intended in the sense of small Im(ε), and ENZ condition may lead to even higher absorption. However, this feature may be used to trigger and enhance low-threshold nonlinear phenomena despite increased pump losses.

Complex Electromagnetic Materials

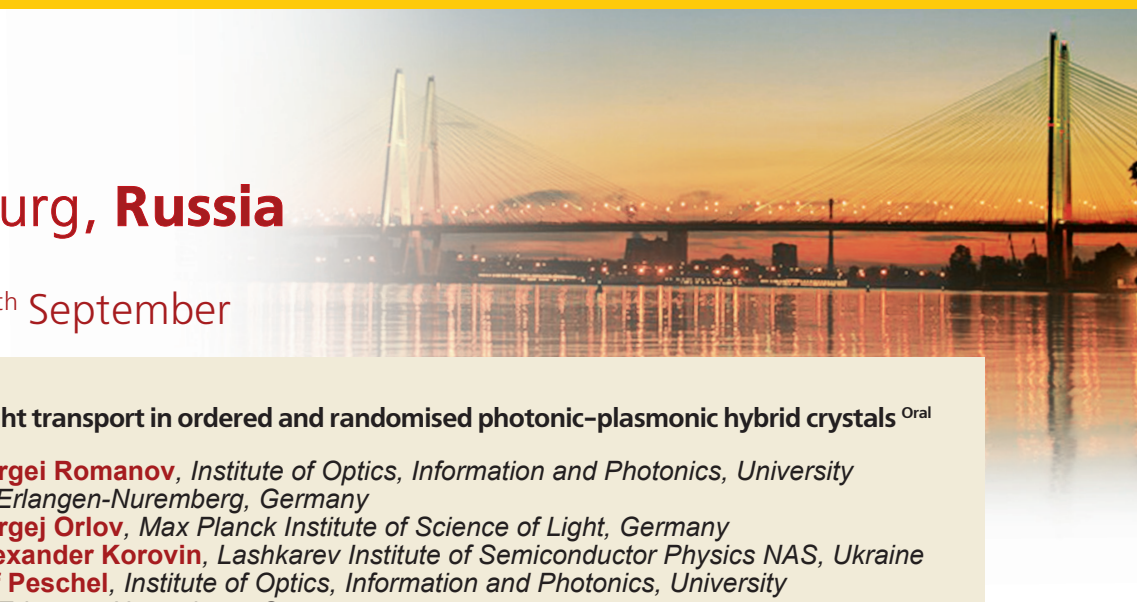
14:30 – 16:00 **Nevsky hall**

Session chairperson(s): Richard W. Ziolkowski

14:30 – 14:45 **Hybrid electromagnetic resonances coupling in all-dielectric double-negative metamaterials** Oral

Qian Zhao, *Department of Precision Instruments and Mechanology,Tsinghua University , China*
Chuwen Lan, *Advanced Materials Institute, Shenzhen Graduate School, Tsinghua University, China*
Fuli Zhang, *School of Science, Northwestern Polytechnical University, China Bo li, Advanced Materials Institute, Shenzhen Graduate School, Tsinghua University, China*
Yonggang Meng, *Department of Precision Instruments and Mechanology,Tsinghua University , China*
Ji Zhou, *Department of Materials Science and Engineering, Tsinghua University, China*
Didier Lippens, *Institut d'Electronique de Micro-électronique et de Nanotechnologie, University of Lille, France*

The electromagnetic couplings between two sizes of cubes with different arrangements in the E, H, and k directions are numerically studied by overlapping the magnetic-resonance of the smaller one and the electric-resonance of the bigger one. The results will make contribution to the design of novel isotropic three-dimension double-negative metamaterials.



St. Petersburg, **Russia**

Thursday, 20th September

14:45 – 15:00 **Light transport in ordered and randomised photonic–plasmonic hybrid crystals** Oral

Sergei Romanov, *Institute of Optics, Information and Photonics, University of Erlangen-Nuremberg, Germany*
Sergej Orlov, *Max Planck Institute of Science of Light, Germany*
Alexander Korovin, *Lashkarev Institute of Semiconductor Physics NAS, Ukraine*
Ulf Peschel, *Institute of Optics, Information and Photonics, University of Erlangen-Nuremberg, Germany*
Nicolas Vogel, *Max-Planck-Institute for Polymer Research, Germany*
Katharina Landfester, *Max-Planck-Institute for Polymer Research, Germany*
Clemens Weiss, *Max-Planck-Institute for Polymer Research, Germany*

In this paper we investigate the disorder-driven transition from collective transport by Bloch waves and SPPs to single particle scattering in 2D hybrid plasmonic-photonic crystals. Where reflection and transmission of ordered structures appear to be highly correlated such strict relation is lost in the disordered case due to changing the light transport regime.

15:00 – 15:30 **Dirac–cone physics and zero–refractive index medium** Invited oral

Che Ting Chan, *Hong Kong University of Science and Technology, Hong Kong*

Two dimensional (2D) photonic and acoustic/elastic crystals can be designed to exhibit Dirac cone dispersions at the centre of the Brillouin zone at a finite frequency by accidental degeneracy. Using effective medium theories, we can map a subset of these structures to a material with effective permittivity and permeability simultaneously equal to zero in photonic crystals, and with effective mass density and reciprocal of bulk modulus (1/ C44) simultaneously equal to zero in acoustic (elastic) crystals. The concept of 2D Dirac cone can be extended to three dimensions.

15:30 – 15:45 **Controlled by the permittivity transformation of energy bands of dielectric metamaterial arrays** Oral

Arash Hosseinzadeh, *Michigan Technological University, USA*
Elena Semouchkina, *Michigan Technological University, USA*
George Semouchkin, *Michigan Technological University, USA*

Band diagrams of 2D arrays of dielectric rods are simulated at TE wave incidence in dependence on dielectric permittivity of rod material. It is shown that permittivity defines the variety of propagation modes corresponding to extreme energies of the lowest transmission bands because of interplay between Bragg and Mie resonances.

15:45 – 16:00 **Nonlinear–transformation based cylindrical cloaks and their practical advantages**

Viktar Asadchy, *Gomel State University, Belarus*
Igar Faniayeu, *Gomel State University, Belarus*
Igor Semchenko, *Gomel State University, Belarus*
Sergei Khakhomov, *Gomel State University, Belarus*

Constitutive electromagnetic parameters of cloaks based on non-linear (quadratic and exponential)coordinate transformations are considered in this paper. The paper includes analysis and comparison of such parameters and parameters of cloaks based on the linear transformation found previously by other researchers. The shortcomings and advantages of found parameters are presented in this work. Also the results of numerical analysis of the cloak parameters done with COMSOL Multiphysics are shown.

16:00 – 16:30 **Coffee break** **Poster area**

Oral sessions (Thursday afternoon II)

16:30 – 18:00	Optical Metamaterials II	Kremlyovsky hall
16:30 – 18:00	Plasmonic Components and Devices	Tverskoy hall
16:30 – 18:00	Novel Concepts III	Nevsky hall

16:30 – 18:00 Optical Metamaterials II — Kremlyovsky hall

Session chairperson(s): Stefan Mendach

16:30 – 16:45

Diffractively induced transparency and extraordinary light emission at the plasmon band edge Oral

Said Rahimzadeh-Kalaleh Rodriguez, *FOM Institute AMOLF c/o Philips Research, Netherlands*

We demonstrate Electromagnetically Induced Transparency-like spectral line shapes for periodic arrays of optical antennas covered by a thin layer of quantum dots. The coupling of localized surface plasmons to diffraction orders radiating into the quantum dot layer leads to the opening of a plasmonic stop gap in the dispersion relation of the array. Standing waves with an enhanced density of optical states are formed at the band edge, leading to an extraordinary light emission enhancement across subwavelength apertures.

16:45 – 17:00

Small metal particles as resonators for microwave, terahertz and optical frequencies Oral

Yury Terekhov, *Lomonosov Moscow State University, Faculty of Physics, Russia*
Anton Zhuravlev, *Lomonosov Moscow State University, Faculty of Physics, Russia*
Gennady Belokopytov, *Lomonosov Moscow State University, Faculty of Physics, Russia*

In this paper we analyze resonance response of single split-ring and core-shell resonators whose sizes vary from few millimeters to tens of nanometers to external electromagnetic field in wide spectral range spanning from microwave to optics. Polarizability spectra, quality factors and resonance frequencies were obtained using numerical simulation. The limits of scaling were determined for parameters of dipole polarizability.

17:00 – 17:15

NIR multilayer hyperbolic metamaterial Oral

Alexander Petrov, *Hamburg University of Technology, Germany*
Michael Störmer, *Helmholtz-Zentrum Geesthacht, Germany*
Hooi Sing Lee, *Hamburg University of Technology, Germany*
Manfred Eich, *Hamburg University of Technology, Germany*

Hyperbolic metamaterials based on a 1D multilayer system with metal-dielectric combination are typically considered at the visible spectrum. The transition to the hyper-

bolic region at NIR is difficult to obtain due to a large negative dielectric constant of metals at these wavelengths. A possibility of compensating the large negative epsilon of metal with large positive epsilon of silicon at NIR is investigated. It is shown that a combination of silicon and gold in multilayers with a thickness ratio of 9 to 1 can shift the transition to the hyperbolic region to approximately 1.5μm. Transmission and reflection measurements at such medium confirm the hyperbolic transition at NIR.

17:15 – 17:30 **Metasurfaces with interwoven conductor patterns on dielectric substrates** Oral

Andrea Vallecchi, *University of Siena, Italy*
Alexander Schuchinsky, *Queen's University of Belfast, United Kingdom*

The properties of metasurfaces comprised of interwoven conductor patterns on dielectric substrates have been examined. The significant reduction of the fundamental resonance frequency and expanded fractional bandwidths (FBWs) offered by the intertwined spirals and Brigid's crosses extended beyond a single unit cell has been achieved with the aid of thin dielectric substrates. A qualitative model has been proposed and proved to adequately predict the main properties of entwined spiral arrays on dielectric substrates.

17:30 – 18:00 **Plasmonic laser antennas and infrared molecular sensors** Invited oral

Ertugrul Cubukcu, *University of Pennsylvania, USA*

In this paper we describe two potential applications for plasmonic nanoantennas. The first application we discuss relies on the ability of optical nanoantennas to confine light to subwavelength dimensions. This property is utilized by directly integrating a nanoantenna on the facet of a commercial semiconductor laser. As a second application, we capitalize on the large local field enhancements offered by optical antennas to significantly increase the detection sensitivity of infrared absorption spectroscopies.

16:30 – 18:00 Plasmonic Components and Devices — Tverskoy hall

Session chairperson(s): Pavel Belov

16:30 – 16:45 **Optical performance of clusters of plasmonic nanoantennas: Periodic, disordered and aperiodic arrays** Oral

Arash Rashidi, *Northeastern University, USA*
Hossein Mosallaei, *Northeastern University, USA*

The goal of this paper is to present a computational scheme to accurately and efficiently characterize the interactions between optical waves and clusters of metamaterials comprising of plasmonic nanorod antennas. The clusters studied herein are two-dimensional periodic arrays, disordered finite arrays, and Fibonacci quasi-lattices. To efficiently model the complex structure we take advantage of Characteristic Basis Function Method (CBFM) in conjunction with Macro Basis Functions. The proposed computational scheme achieves speed and memory performances that are considerably superior to that of the conventional approaches (orders of magnitude improvement). Novel physics are demonstrated.

16:45 – 17:00 **Course of nanophotonics in view of modernization of courses of electrodynamics: 4 years of experience** Oral

Arkadi Chipouline, *FSU Jena, Germany*

Education in area of electrodynamics of compound materials, especially electrodynamics of metamaterials (compound materials with magnetic response) requires deep review, modernization, and cooperation in order to follow the actual tendencies in science and technology. In this work I present my experience of giving/teaching my course, "Introduction to nanooptics", at Friedrich-Schiller University of Jena. I identify the main weak points in the education system in area of modern electrodynamics, and give my opinion about the optimum way of improving educational standards in this area.

17:00 – 17:30 **CMOS compatible plasmonic devices for nano–integrated circuits** Invited oral

Er-Ping Li, *A*STAR Institute of High Performance Computing, Singapore*

This paper presents a novel CMOS-compatible plasmonic waveguide building block, which is based on the metal-silica-silicon hybrid plasmonic waveguides. Study shows that the propagation loss of the waveguide can be as low as 0.4 dB/μm with a cross section of 100×340 nm2. The block can be used to build various plasmonic nano-devices. As an example, a ring resonator with the ring radius of 0.91μm is demonstrated. In addition, a novel nanoparticle-based Schottky barrier Si-waveguide photodetector is presented as well. The absorption in the photodetector is dramatically enhanced due to the localized surface plasmon resonance.

17:30 – 18:00 **Controlling light** Invited oral

Nikolay Zheludev, *University of Southampton, United Kingdom*
Jianfa Zhang, *University of Southampton, United Kingdom*
Kevin F. MacDonald, *University of Southampton, United Kingdom*

According to the fundamental Huygens superposition principle, light beams traveling in a linear medium will pass though one another without mutual disturbance. Indeed, the field of photonics is based on the premise that controlling light signals with light requires intense laser fields to facilitate beam interactions in nonlinear media, where the superposition principle can be broken. Here we challenge this wisdom and demonstrate that two coherent beams of light of arbitrarily low intensity can interact on a metamaterial layer of nanoscale thickness in such a way that one beam modulates the intensity of the other. We show that the interference of beams can eliminate the plasmonic Joule losses of light energy in the metamaterial or, in contrast, can lead to almost total absorption of light. Applications of this phenomenon may lie in ultrafast all-optical pulse-recovery devices, coherence filters and THz-bandwidth light-by-light modulators.

Novel Concepts III

16:30 – 18:00 Session chairperson(s): Richard Syms **Nevsky hall**

16:30 – 16:45 **Liquid crystal infiltrated optical magnetic metamaterials** Oral

Manuel Decker, *Nonlinear Physics Centre, Research School of Physics and Engineering, The Australian National University, Australia*
Alex Minovich, *Nonlinear Physics Centre, Research School of Physics and Engineering, The Australian National University, Australia*
Christian Kremer, *Institute of High-Frequency and Communication Technology, University of Wuppertal, Germany*

Andrey E. Miroshnichenko, *Nonlinear Physics Centre, Research School of Physics and Engineering, The Australian National University, Australia*
Hark Hoe Tan, *Department of Electronic Materials Engineering, Research School of Physics and Engineering, The Australian National University, Australia*
Dmitry Chigrin, *Institute of High-Frequency and Communication Technology, University of Wuppertal, Germany*
Dragomir N. Neshev, *Nonlinear Physics Centre, Research School of Physics and Engineering, The Australian National University, Australia*
Chennupati Jagadish, *Department of Electronic Materials Engineering, Research School of Physics and Engineering, The Australian National University, Australia*
Yuri S. Kivshar, *Nonlinear Physics Centre, Research School of Physics and Engineering, The Australian National University, Australia*

We infiltrate split-ring-resonator metamaterials with nematic liquid crystals in order to tune their optical response by reorientation of the liquid crystals. As predicted by our numerical simulations strong anchoring of the liquid crystals to the nano-structured surface significantly affects the tunability of the metamaterial's response.

16:45 – 17:00 **Active metamaterials to increase absorbing bandwidth** Oral

Thierry Lagutere, *CEA, France*

This paper describes circuits designed to improve the absorbing range of meta-materials connected to an active circuit. This circuit's purpose is to behave as a negative inductor. The instability of the previous architecture led us to design a new circuit providing a negative inductor on a wide frequency range. The encouraging simulated results will be verified by measurements by the end of 2012. Modifying the voltage applied on the circuit changes the metamaterial behaviour.

17:00 – 17:15 **Omnidirectional radiation by arbitary sources embedded in zero index metamaterials** Oral

Cheng Qiang, *State Key Laboratory of Millimeter Waves, Radio Department, Southeast University, China*
Tie Jun Cui, *State Key Laboratory of Millimeter Waves, Radio Department, Southeast University, China*
Wei Xiang Jiang, *State Key Laboratory of Millimeter Waves, Radio Department, Southeast University, China*

We have shown that the radially anisotropic metamaterials can be utilzed to realize ominidirectional radiation, independent of numbers and relative positions of the sources. When the radial component of the permeability tensor is approaching zero, and the wave impedance in the radial direction is designed equal to that of free space, the waves emitted from the sources will be transformed into perfect cylindrical waves without any reflection. Both the numerical and experimental results have validated our theoretical analysis.

17:15 – 17:30 **Novel way for constructing flexible metamaterials with chiral conformational nonlinearity** Oral

Alexey Slobozhanyuk, *Laboratory Metamaterials, NRU ITMO, Russia*
Mikhail Lapine, *Laboratory Metamaterials, NRU ITMO, Russia*
Ilya Shadrivov, *Nonlinear Physics Centre, Research School of Physics and Engineering, Australian National University, Australia*
Yuri Kivshar, *Nonlinear Physics Centre, Research School of Physics and Engineering, Australian National University, Australia*

Pavel Belov, *Laboratory Metamaterials, NRU ITMO, Russia*

We investigate nonlinear behavior of metamaterial, where responses of a different nature are intrinsically coupled within its spiral structural elements. We provide an experimental demonstration of the electromagnetically induced compression of the metamaterial, which leads to a remarkable shift of the resonance frequency.

17:30 – 17:45 **Nonlinear beams and field concentrators with hyperbolic metamaterials** Oral

Allan Boardman, *Joule Physics Lab., Inst. for Materials Res., University of Salford, UK*
Vladimir Grimalsky, *Autonomous University of Morelos, Cuernavaca, Mexico*
Yuriy Rapoport, *Physics Faculty, Taras Shevchenko National University, Ukraine*

The new method including matched complex geometrical optics and full-wave multimode nonlinear solution is developed for modelling beam propagation in non-linear hyperbolic meamaterial field concentrator. New effect is found: switching to highly nonlinear regime with strong focusing inside a nonlinear region, when amplitude of input beam(s) reaches some threshold value.

17:45 – 18:00 **Nonlinear effects in liquid-crystal-infiltrated fishnet metamaterials** Oral

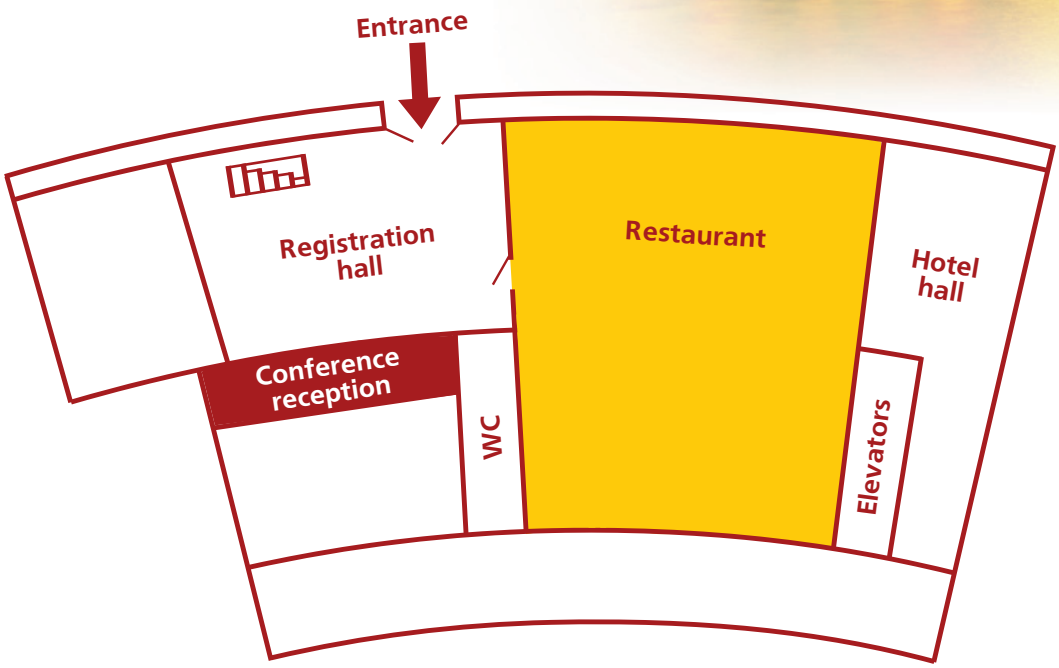
Alexander Minovich, *Australian National University, Australia*
James Farnell, *Australian National University, Australia*
Dragomir Neshev, *Australian National University, Australia*
Ian McKerracher, *Australian National University, Australia*
Fouad Karouta, *Australian National University, Australia*
Jie Tian, *Australian National University, Australia*
David Powell, *Australian National University, Australia*
Ilya Shadrivov, *Australian National University, Australia*
Hark Hoe Tan, *Australian National University, Australia*
Chennupati Jagadish, *Australian National University, Australia*
Yuri Kivshar, *Australian National University, Australia*

We present our experimental studies of nonlinear properties of fishnet structure infiltrated with nematic liquid crystals. We observe that moderate laser powers cause significant changes in the optical transmission of the composite structures, and demonstrate that the nonlinear response of the design can be further controlled with a bias electric field.

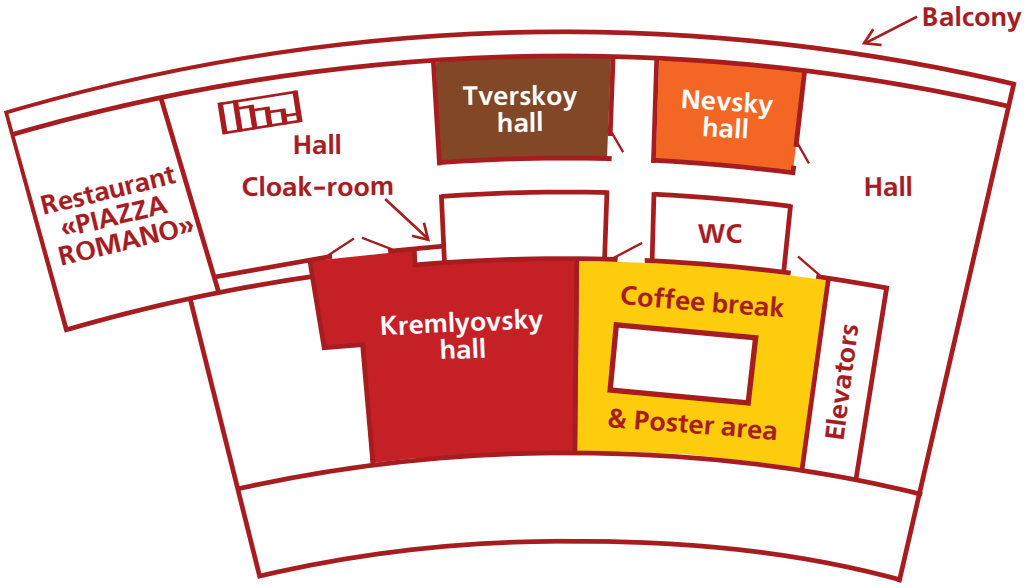
18:15 – 18:45 **Closing ceremony** **Kremlyovsky hall**

St. Petersburg, **Russia**

Venue Map, Ground floor



Venue Map, 1st floor



Metamaterials 2012

Session Matrix

Monday, 17th September

	Kremlyovsky	Tverskoy	Nevsky	Poster area	Restaurant
09:15 - 09:30	Opening Ceremony				
9:30 - 11:00	Optical and UV Metamaterials	Microwave Metamaterials	Acoustic Metamaterials I		
11:00 - 11:30				Coffee break	
11:30 - 13:00	Nonlinear Metamaterials I	Extraordinary Transmission	Acoustic Metamaterials II		
13:00 - 14:30					Lunch
14:30 - 16:00	Nonlinear Metamaterials II	Antenna Applications of Metamaterials	Acoustic and Other Metamaterials		
16:00 - 17:30				Coffee break + Poster session I	
17:30 - 19:00	Nonlinear and Tunable Metamaterials	RF and Microwave Metamaterials I	Transformation Optics I		

Tuesday, 18th September

	Kremlyovsky	Tverskoy	Nevsky	Poster area	Restaurant
08:30 - 10:00	Transformation Optics and Cloaking	Homogenization I	Tunable Metamaterials		
10:00 - 11:30				Coffee break + Poster session II	
11:30 - 13:00	Metamaterial Based Sensors I	RF and Microwave Metamaterials II	Quantum Aspects of Metamaterials I		
13:00 - 14:30					Lunch
14:30 - 16:00	Transformation Optics II	Homogenization II	Quantum Aspects of Metamaterials II		
16:00 - 16:30				Coffee break	
16:30 - 18:00	Metamaterial Based Sensors II	THz and Microwave Metamaterials I	Chiral Metamaterials I		

St. Petersburg, **Russia**

Session Matrix

Wednesday, 19th September

	Kremlyovsky	Tverskoy	Nevsky	Poster area	Restaurant
08:30 - 10:00	Imaging Using Metamaterials	THz and Microwave Metamaterials II	Novel Concepts I		
10:00 - 10:30				Coffee break	
10:30 - 12:00	Graphene-Based Metamaterials	THz and Microwave Metamaterials III	Slow Light and 3D Metamaterials		
12:00 - 13:30					Lunch
13:30 - 15:00	Optical Metamaterials I	THz and Microwave Metamaterials IV	Transformation Optics III		
15:00 - 15:30				Coffee break	
15:30 - 17:00	Plenary session I				
17:00 - 17:30				Coffee break	
17:30 - 18:15	Plenary Session II				
20:00 - 23:00					Conference Banquet

Thursday, 20th September

	Kremlyovsky	Tverskoy	Nevsky	Poster area	Restaurant
08:30 - 10:00	Plasmonic Metamaterials	Chiral Metamaterials II	Unconventional Metamaterials		
10:00 - 11:30				Coffee break + Poster session III + Student paper competition	
11:30 - 13:00	Active and Low-Loss Metamaterials I	Chiral Metamaterials III	Novel Concepts II		
13:00 - 14:30					Lunch
14:30 - 16:00	Active and Low-Loss Metamaterials II	Quantum and Chiral Metamaterials	Complex Electromagnetic Materials		
16:00 - 16:30				Coffee break	
16:30 - 18:00	Optical Metamaterials II	Plasmonic Components and Devices	Novel Concepts III		
18:15 - 18:45	Closing Ceremony				