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The CID Number appears on each page of the manuscript. The complete citation is used on the first page, and an abbreviated version on subsequent pages.

Contents

- v *Authors*
- vii *Conference Committee*
- ix *A new approach to hyperbolic metamaterials (Invited Presentation Summary)*

DIELECTRIC AND TUNABLE METAMATERIALS

- 9883 06 **Extended Malus Law with metallic linear polarizers in terahertz and microwave domains** [9883-5]
- 9883 07 **Voltage-tunable optical transmission of subwavelength metal gratings filled with liquid crystals** [9883-6]
- 9883 09 **CMOS-compatible metamaterial-based wideband mid-infrared absorber for microspectrometer applications** [9883-9]

ACTIVE METAMATERIALS II

- 9883 0E **Plasmonic hole arrays with extreme optical chirality in linear and nonlinear regimes (Invited Paper)** [9883-13]

NANOSTRUCTURED PATHWAYS

- 9883 0G **Design of an optical sensor based on plasmonic nanostructures** [9883-15]
- 9883 0H **Plasmonic rack-and-pinion gear with chiral metasurface** [9883-16]
- 9883 0L **Structural Raman enhancement in graphite nano-discs** [9883-20]
- 9883 0M **A broadband highly efficient plasmonic polarization beam splitter** [9883-21]

SENSORS AND SPECIAL EFFECTS

- 9883 0O **Conjugate-impedance matched metamaterials for super-Planckian radiative heat transfer (Invited Paper)** [9883-23]

HYPERBOLIC AND MODERN METAMATERIALS

- 9883 0T **Dark-field hyperlens for high-contrast sub-wavelength imaging** [9883-28]

9883 0U **Enhancement of light extraction based on nanowire hyperbolic metamaterials in a grating structure** [9883-29]

9883 0W **Multispectral inhomogeneous metasurface for emissivity control (Best Student Paper Award)** [9883-32]

ADVANCES IN METAMATERIALS DESIGN

9883 0Y **Engineering optical properties of semiconductor metafilm superabsorbers (Invited Paper)** [9883-34]

9883 0Z **Homogenization of spatially dispersive 1D fractal metamaterials** [9883-35]

9883 12 **3D-stacked Ag nanowires for efficient plasmonic light absorbers and SERS sensors** [9883-38]

NONLINEAR AND SPECIAL EFFECTS IN METAMATERIALS

9883 17 **Effective medium approximation for deeply subwavelength all-dielectric multilayers: when does it break down? (Invited Paper)** [9883-43]

9883 1B **Transformation optics approach for Goos-Hänchen shift enhancement at metamaterial interfaces** [9883-47]

9883 1C **Gold asymmetric-split ring resonators (A-SRRs) for proteins sensing** [9883-48]

NOVEL CONFIGURATIONS AND PHENOMENA

9883 1E **Optical fiber meta-tips (Invited Paper)** [9883-50]

9883 1F **Transforming guided waves with metamaterial waveguide cores (Invited Paper)** [9883-51]

9883 1I **Improved optical amplification using metamaterial based split ring structures in optical fibres** [9883-55]

POSTER SESSION

9883 1M **Analysis of 2D hyperbolic metamaterial dispersion by elementary excitation coupling** [9883-58]

9883 1N **Varying the periodicity to achieve high quality factor on asymmetrical H-Shaped resonators** [9883-59]

Authors

Numbers in the index correspond to the last two digits of the six-digit citation identifier (CID) article numbering system used in Proceedings of SPIE. The first four digits reflect the volume number. Base 36 numbering is employed for the last two digits and indicates the order of articles within the volume. Numbers start with 00, 01, 02, 03, 04, 05, 06, 07, 08, 09, 0A, 0B...0Z, followed by 10-1Z, 20-2Z, etc.

Alberucci, A., ix	Lambrechts, Lieve, 1B
Alshabani, Haifaa, 0G	Lavrinenko, Andrei V., 0T, 17
AlSharif, Haya, 0G	Lee, MinKyoung, 12
Andryieuski, Andrei, 17	Maes, Bjorn, 1M
Artemov, Vladimir V., 07, 0E	Makhsiyan, Mathilde, 0W
Assanto, G., ix	Malureanu, Radu, 17
Ayerden, N. Pelin, 09	Maslovski, Stanislav I., 0O
Baida, Fadi, 06	Mbomson, Ifeoma G., 1N
Barnik, Mikhail I., 07	McCall, M., ix
Boardmann, A. D., ix	Micco, Alberto, 1E
Bouchon, Patrick, 0W	Moeini, Samaneh, 0Z
Boyer, Philippe, 06	Mohamad Ali Nasri, Ili F., 1N
Brongersma, Mark L., 0Y	Mun, ChaeWon, 12
Cardenas, J. F., 0L	Nefedov, I. S., ix
Castaldi, Giuseppe, 1E	Nigam, Raaghvam, 1I
Chakarov, D., 0L	Palto, Serguei P., 07
Chellappa, Sharath, 1I	Park, Sung-Gyu, 12
Consales, Marco, 1E	Paul, Jharna, 1C
Crescitelli, Alessio, 1E	Pelouard, Jean-Luc, 0W
Cusano, Andrea, 1E	Prakash, Geetha, 1I
Danckaert, Jan, 1B, 1F	Principe, Maria, 1E
Darinskii, Alexander N., 0E	Qadi, Eilaf, 0G
Das, Sovan, 1I	Rapoport, Y., ix
de Graaf, Ger, 09	Repän, Taavi, 0T
De La Rue, Richard M., 1C, 1N	Rogov, Oleg Y., 0E
Espósito, Emanuela, 1E	Romain, Xavier, 06
Fan, Pengyu, 0Y	Shkondin, Evgeniy, 17
Gainutdinov, Radmir V., 0E	Shtykov, Nikolay M., 07
Galdi, Vincenzo, 1E	Simovski, Constantin R., 0O
Geivandov, Artur R., 07	Sultan, Maha, 0G
Ghaderi, Mohammadamir, 09	Takayama, Osamu, 17
Ginis, Vincent, 1B, 1F	Tassin, Philippe, 1B, 1F
Gorkunov, Maxim V., 07, 0E	Tharwat, Marwa M., 0G
Gorodetski, Yuri, 0H	Tretyakov, Sergei A., 0O
Haïdar, Riad, 0W	Vadjed-Samiei, Mohammad Hashem, 0M
Hung, Yu-Chueh, 0U	Vahdat-Ahar, Amin, 0M
Jaeck, Julien, 0W	Vaianella, Fabio, 1M
Jensen, Flemming, 17	Viaene, S., 1F
Johnson, Nigel P., 1C, 1N	Willatzen, Morten, 0T
Kang, Ju-Hyung, 0Y	Wolfenbuttel, Reinoud F., 09
Kao, Tzu-Hung, 0U	Yudin, Sergey G., 07
Karabchevsky, Alina, 0H	Zhukovsky, Sergei V., 0T, 17
Karimi Shahmarvandi, Ehsan, 09	
Kasemo, B., 0L	
Kasyanova, Irina V., 07	
Kim, Dong-Ho, 12	
Kim, Soo Jin, 0Y	
Kondratov, Alexei V., 0E	
La Ferrara, Vera, 1E	

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Active Metamaterials I
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Nigel P. Johnson, University of Glasgow (United Kingdom)

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Kevin F. MacDonald, University of Southampton (United Kingdom)

Nanostructured Pathways

Martin W. McCall, Imperial College London (United Kingdom)

Sensors and Special Effects

Anatoly V. Zayats, King's College London (United Kingdom)

Hyperbolic and Modern Metamaterials

Nigel P. Johnson, University of Glasgow (United Kingdom)

Advances in Metamaterials Design

Kevin F. MacDonald, University of Southampton (United Kingdom)

Nonlinear and Special Effects in Metamaterials

Martin W. McCall, Imperial College London (United Kingdom)

Novel Configurations and Phenomena

Allan D. Boardman, University of Salford (United Kingdom)

Nigel P. Johnson, University of Glasgow (United Kingdom)

A new approach to hyperbolic metamaterials

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The theoretical aspects concerning the propagation of homogeneous, inhomogeneous and leaky electromagnetic waves in uniaxial, dielectric waveguides have been of interest for some considerable time.^{1,2} The current metamaterial world, however, is still only partially served by investigations that set out to incorporate some form of general asymmetry into the behavior of hyperbolic metamaterials^{3,4}. Stimulated by this situation, a dramatic change will be presented here by formulating a completely general approach to the constructive, and often unusual, positions that the optic axis position can adopt in such vital media. In the context of this work, it is acknowledged that an inspiration towards the dramatic development of the new pathways exposed here was reported some years ago⁵.

In order to sustain an investigation of how the orientation of the optic axis of a hyperbolic metamaterial affects guided waves, a thin film device will be examined and the optic axis will be permitted to adopt a wide range of interesting, and practical positions. The role of loss will also be estimated but this type of metamaterial is non-resonant, so loss will often not be competitive with the criticality of the optic axis orientation.

Clearly, the full control of light propagating in complex waveguides is an immensely important global topic so nonlinearity is a critically important tool for device creation. Indeed, in a nonlinear context, the use of metamaterials is seminal to the development of new devices. An initial nonlinear model will be developed and it will be shown that changes to the boundary conditions, due to the presence of effective media, permit even modest amounts of power to initiate elegant control of the effective group velocity. These outcomes will be strongly coupled to the optic axis-control in a manner that substantially modifies the dramatic linear investigations presented earlier on.

It will be emphasized that full control of solitonic metamaterial waveguides will need to be established through external influences, like a magnetic field, under the general heading of magnetophotonics. An outline of such a general optic-axis driven theory will be given. Finally, some pointers towards vortex formation in this new optic-axis driven environment will be critically commented upon because enhancing the addition of angular momentum to special light beams in this novel manner will also point to new, and important, devices, in the medical world for example..

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