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# Introduction to the Special Issue on Metamaterials

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# Introduction to the Special Issue on Metamaterials

**T**HE GUEST editors of the IEEE JOURNAL OF SELECTED TOPICS IN QUANTUM ELECTRONICS (JSTQE) are pleased to introduce this special issue on Metamaterials. This publication covers new research topics and state-of-the-art developments in the fundamentals and applications of metamaterials.

While a theoretical prediction of the possibility of having materials with negative index of refraction, now known as negative index metamaterials, was made by V. Veselago back in 1967, the first experimentally demonstrated metamaterial operating in the microwave frequency range only celebrates its 10th anniversary this year, and optical metamaterials are just five years old. Nevertheless, as this special issue attests, enormous progress has been made over this decade in both theoretical and experimental research directions, enabling a broad range of potential applications of these unusual structures.

The 13 papers in this special issue describe some of the most remarkable work in the field and outline a number of exciting future research directions. There are four invited papers written by leading researchers that comprehensively address a variety of topics ranging from novel bianisotropic photonic metamaterials described by Rill *et al.* and a detailed theoretical study of an important problem of coherent pulse amplification in metamaterials addressed by Kennedy *et al.*, to potential applications of transmission-line-based metamaterials in magnetic resonance imaging discussed by Syms *et al.*, or a fascinating study of non-Euclidean cloaking for light waves presented by Tyc *et al.* The remaining nine contributed papers are no less important in their discussion of important results in subtopics, including liquid crystal tunable metamaterials, applications of metamaterials for sensing, and others.

This special issue would not have been possible without the professionalism, dedication, and expertise of all the members of our publication team. First of all, the guest editors would like to thank the authors, both invited and contributed, for submitting their exciting and thought-provoking research to this special issue. We are grateful to the international peer reviewers who dedicated their time and expertise to maintain the technical quality of this special edition while also staying within tight deadlines. The editors would like to thank Dr. F. Bartoli, Editor-in-Chief of JSTQE, for inviting us to put together this special

issue. Finally, the guest editors are grateful to C. T. Lutz for all the hard work coordinating this special issue at all steps of the publication process.

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**Vladimir (Vlad) M. Shalaev** (M'04–SM'05–F'10) received the Master's degree in physics, with highest distinctions, in 1979, and the Doctoral degree in physics and mathematics in 1983, both from the Siberian Federal University (SFU), Krasnoyarsk, Russia.

He is currently the Robert and Anne Burnett Professor of Electrical and Computer Engineering and Professor of Biomedical Engineering at Purdue University (Purdue), West Lafayette, IN, where he has been engaged in research on nanophotonics, plasmonics, and optical metamaterials. He came to Purdue in 2001 after previously holding the position of the George W. Gardiner Professor of Physics at New Mexico State University. He also previously taught and conducted research at SFU and the University of Toronto. Before coming to Canada and then to the U.S., he was an Humboldt Foundation Fellow at the University of Heidelberg in Germany and Paris-Sud University in France. He made pioneering contributions to the optics of fractal and percolation composites, their applications for surface-enhanced Raman spectroscopy (SERS). At Purdue, his seminal research in the field of optical metamaterials and transformation optics resulted in several

important breakthroughs, including the first experimental observation of negative refractive index in the optical range, artificial magnetism across the entire visible range, and novel approaches for imaging with subwavelength resolution and optical cloaking. He is the author of three books, 21 invited book chapters, and more than 300 research publications, in total. According to the ISI database, out of all Optics papers published for the past five years (more than 80 000 papers, in total, published since January 1, 2005 in 72 optics journals), three papers from the Shalaev group have been ranked, in terms of the number of citations, as first, second, and fifth. He is the Editor for five books in the areas of nanophotonics.

Prof. Shalaev received several awards for his research in the field of nanophotonics and metamaterials, including the Willie Lamb Award. He is a Fellow of the, American Physical Society, International Society for Optical Engineering (SPIE), and Optical Society of America. He is the Program Chair for a number of international symposia and conferences, including Chair of the 2009 CLEO/IQEC conference, Co-Editor and/or an Editorial Board Member for eight research journals.



**Natalia M. Litchinitser** received the Master's degree in physics from Moscow State University, Moscow, Russia, in 1993, and the Ph.D. degree in electrical engineering from the Illinois Institute of Technology, Chicago, in 1997.

She was involved in research at the University of Michigan, Ann Arbor. She was a Member of Technical Staff at Bell Laboratories, Lucent Technologies, where she was engaged in the development of a tunable dispersion compensator. She was also a Senior Member of Technical Staff at Tyco Submarine Systems. Since 2008, she has been in the Department of Electrical Engineering, The State University of New York, Buffalo. Her research interests include linear and nonlinear optics in metamaterials, photonic devices, and optical communications. She is the author of five invited book chapters, more than 70 journal and conference research papers, and more than 20 invited conference talks. She also served as a Guest Editor for a Special Issue of the *Optics Communications Journal* on "Nonlinear Metamaterials." She is also a member of the advisory board of the *Optics Communications Journal*.

Dr. Litchinitser was the recipient of the R&D 100 Award (team award) from the Bell Laboratories, Lucent Technologies for the development of a tunable dispersion compensator. She was a co-organizer of a special session on "Nonlinear Metamaterials" at the 3rd International Congress on Advanced Electromagnetic Materials in Microwaves and Optics in 2009.

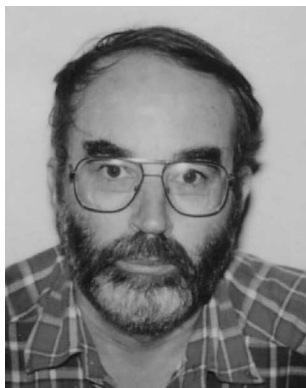


**Nader Engheta** (S'80–M'82–SM'89–F'96) received the B.S. degree from the University of Tehran, Tehran, Iran, and the M.S. and Ph.D. degrees from the California Institute of Technology (Caltech), Pasadena, all in electrical engineering.

He was a Postdoctoral Research Fellow at Caltech for one year and a Senior Research Scientist at Kaman Sciences Corporation's Dikewood Division, Santa Monica, CA, for four years before he joined the faculty of the University of Pennsylvania (UPenn), Philadelphia, where he is currently the Ramsey Professor. He is also a member of the Mahoney Institute of Neurological Sciences, Philadelphia, PA, and holds an appointment in the Bioengineering Department, University of Pennsylvania. He was the Graduate Group Chair of electrical engineering from July 1993 to June 1997. His research interests include metamaterials and plasmonics, nano-optics and nanophotonics, nanocircuits and nanostructures modeling, bio-inspired/biomimetic polarization imaging and reverse engineering of polarization vision, miniaturized antennas and nanoantennas, hyperspectral sensing, biologically based visualization and physics of sensing and display of

polarization imagery, through-wall microwave imaging, fractional operators and fractional paradigm in electrodynamics. He has published numerous journal papers, book chapters, and conference articles in his field of research. He has organized and chaired various special sessions in international symposia and conferences, and has guest edited/coedited several special issues, namely, the special issue of the *Journal of Electromagnetic Waves and Applications* on the topic of "Wave Interaction with Chiral and Complex Media" in 1992, part special issue of the *Journal of the Franklin Institute* on the topic of "Antennas and Microwaves (from the 13th Annual Benjamin Franklin Symposium) in 1995, special issue of the journal *Wave Motion* on the topic of "Electrodynamics in Complex Environments" (with L. B. Felsen) in 2001, special issue of the IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION on the topic of "Metamaterials" (with R. W. Ziolkowski) in 2003, and special issue of *Solid State Communications* on the topic of "Negative Refraction and Metamaterials for Optical Science and Engineering" (with G. Shvets) in 2008. He is the coeditor of the book *Metamaterials: Physics and Engineering Explorations* (Wiley, 2006).

Dr. Engheta is a Guggenheim Fellow, an IEEE Third Millennium Medallist, a Fellow of the American Physical Society, Optical Society of America, and the American Association for the Advancement of Science, and the recipient of the 2008 George H. Heilmeier Award for Excellence in Research from UPenn, the Fulbright Naples Chair Award, the NSF Presidential Young Investigator Award, the UPS Foundation Distinguished Educator term Chair, and several teaching awards including the Christian F. and Mary R. Lindback Foundation Award, the W. M. Keck Foundation's 1995 Engineering Teaching Excellence Award, and two times recipient of S. Reid Warren, Jr. Award. He was selected as one of the Scientific American Magazine 50 Leaders in Science and Technology in 2006 for developing the concept of optical lumped nanocircuits. He was an Associate Editor of The IEEE ANTENNAS AND WIRELESS PROPAGATION LETTERS (2002–2007), of the IEEE TRANSACTIONS ON ANTENNA AND PROPAGATION (1996–2001), and of *Radio Science* (1991–1996). He was on the editorial board of the *Journal of Electromagnetic Waves and Applications*. He is on the editorial board of the journal *Metamaterials*, and on the editorial board of the journal *Waves in Random and Complex Media*. He served as an IEEE Antennas and Propagation Society Distinguished Lecturer for the period 1997–1999. He is a member of Sigma Xi, Commissions B, D, and K of the U.S. National Committee (USNC) of the International Union of Radio Science (URSI), and a member of the Electromagnetics Academy. He is the Chair of the Commission B of USNC-URSI for 2009–2011. He has been elected to be the Vice-Chair of the Gordon Research Conference on Plasmonics in 2010 and its Chair in 2012.



**Ross C. McPhedran** received the Doctoral degree in physics from the University of Tasmania, Tasmania, Australia, in 1973.

He is currently a Personal Chair in electromagnetism at the School of Physics, CUDOS (A28), University of Sydney, Sydney, Australia, and also an Australian Research Council Professorial Fellow. His research interests include the interaction of waves with periodic systems of scatterers, generally in electromagnetism, but also in elastodynamics. He is also involved in research on methods of mathematical physics, including Green's function techniques, and the properties of lattice sums. He was engaged with Prof. R. Petit's group on diffraction gratings, blazing, and Wood anomalies in Marseille. He received a Queen Elizabeth II fellowship, at the University of Sydney, in 1975, where he began influential work on the transport properties of composite materials, calculated using multipole methods, which has since become a common approach in his later work in a variety of contexts, including the application of cermet in photothermal systems for solar energy, and in the study of microstructured optical fibers. He has also engaged

in research on optical thin film systems, diffraction by doubly periodic surfaces (using a method which is an early example of that applied in transformation optics), properties of photonic crystals, and the theory of phononic crystals. He has published over 250 articles in refereed scientific journals, which have attracted over 5000 citations, and was the coauthor of the book *Electromagnetic Processes in Dispersive Media* (Cambridge University Press, 1991).

Prof. McPhedran is a Fellow of the Optical Society of America, the Institute of Physics (U.K.), and the Australian Institute of Physics. He is the President of the International ETOPIM Association, and was the Chief Organizer of its 7th International Conference, held in Sydney. He was Foundation Secretary of the Australian Optical Society (AOS). He was the recipient of the AOS Medal for distinguished service in the field of optics in Australia, in 2004.



**Ekaterina Shamonina** was born in Tver, Russia, in 1970. She graduated in physics from Moscow State University, Moscow, Russia, in 1993. She received the Ph.D. degree from the University of Osnabrueck, Osnabrueck, Germany, in 1998, and the Habilitation degree in theoretical physics from the same university, in 2006.

She is currently a Professor in the SAOT, Erlangen Graduate School in Advanced Optical Technologies, University of Erlangen-Nuremberg, Erlangen, Germany. She was a Visiting Scientist at the University of Campinas, Campinas, Brazil during 1996 and 1998. In 2000 she received a seven-year Emmy Noether fellowship from the German Research Council (Deutsche Forschungsgemeinschaft). She spent the first leg of the fellowship at the University of Oxford during 2000–2002. After further six months at Imperial College, London, she returned back to the University of Osnabrueck, where she built up a research group working on metamaterials. Her research interests apart from metamaterials include amorphous semiconductors, photorefractive materials, antennas, and plasmonics. She is the author or coauthor of one book, two book chapters,

and over 70 research papers.

Dr. Shamonina was the recipient of the Hertha-Sponer Prize 2006 from the German Physical Society.



**Thomas A. Klar** received the Diploma degree in physics from Ludwig-Maximilians-Universität München (LMU), München, Germany, in 1997, the Ph.D. degree from the Max-Planck-Institute for Biophysical Chemistry, Göttingen, Germany, in 2001, and the *venia legendi* degree from the School of Electrical and Computer Engineering, Purdue University, West Lafayette, IN, in 2007.

He was an Assistant at the Photonics and Optoelectronics Group, LMU for six years. Since 2007, he has been with the Technische Universität, Ilmenau, Germany, as an Associate Professor. His current research interests include spectroscopy of hybrid systems containing noble metal nanoparticles, colloidal semiconductor quantum dots, and/or organic fluorophores.

Dr. Klar is a member of the German Physical Society (DPG), the Materials Research Society, and the European Optical Society. In 2001, he received the Helmholtz Award together with S. Hell for their work on sub-Abbe resolution in far field microscopy.