A Special Issue on Functional Nanophotonics and Nanoelectromagnetics

Nanophotonics and, more generally, nanoelectromagnetics (including magnetism, and the spectral ranges around microwave and THz frequencies) have become an extremely active research field, encompassing new materials, new physical phenomena and new design concepts. In both areas, design scenarios typically attempt to confine optical/electromagnetic functionality into the smallest possible volume in order to meet specifications in terms of integration density and device performance unparalleled by state-of-the-art technologies. This approach is based on the fundamental assumption that proper functionality is viable at the nanoscale and accessible from an environment whose scale is larger by several orders of magnitude. Nano-photonic/electromagnetic scientists are actually faced with devices that are operated at their physical limit and therefore have to rely on holistic designs when exploiting new material properties to lift restrictions posed by conventional optical designs, and when addressing the aforementioned interfacing problem. The objective of this special issue is to address these conceptual challenges while highlighting novel trends in nanophotonics and nanoelectromagnetics, including recent progress in modeling and component development.

The first group of papers is mainly devoted to nanophotonics, starting with a comprehensive invited review on photonic nanodipoles given by Heifetz et al. Photonic nanodipoles are somehow paradigmatic with respect to the above discussion because they demonstrate the ability of a considerably large (several micron sized) dielectric sphere to provide highly confined light fields for local optical excitations for sensing, sizing, patterning, light manipulation and trapping at the nanoscale. The second contribution, by Pergande et al., addresses the interface problem between free space modes and a distinct set of Bloch modes within a compact, low-group velocity photonic crystal device. The coupling scheme relies on an anti-reflection layer at the crystal’s input interface where the energy transfer is mediated via corresponding surface states. A nanostructured electromagnetic metamaterial is presented in the paper of Spiegel et al. for the microwave frequency range. Randomly distributed ferromagnetic nanowires in a polymer membrane form a magnetic composite serving as a substrate for a corresponding microstrip line. The authors have developed several effective material models, which are then validated by microwave experiments. Such composites enable non-reciprocal or tunable planar devices for higher operation frequencies compared to classical ferrites.

The second group of papers concentrates on optical nanoantennas for visible operation wavelengths up to the THz range, starting with an invited paper by Alù et al. on the analysis of plasmonic nanodipole antennas in the visible. Here, the important issue of the antenna feed is addressed with full consideration of fundamental antenna concepts, such as input impedance, matching and radiation resistance in the exciting framework of optical nanocircuit theory. The authors show derive simple design criteria, which are fully explainable from the viewpoint of well-established radio engineering. The next a paper from Shuba et al. deals with the nano-scatterer itself while analyzing finite-length carbon and metallic nanotubes considering aspects from nanoelectromagnetics. Absorption cross-section and near-field enhancement are rigorously determined by solving the scattering problem within a very compact integral equation formalism that includes material dispersion as well as quantum effects in the material conductivity. Moving then to the emitter perspective, Mohammadi et al. discuss in their invited contribution how to functionalize single-molecule light emission. Using one or two metallic nano-spheroids as antenna arms allows tailoring the spontaneous emission dynamics and enables huge wavelength tuning ranging from the near-IR spectrum up to the UV. The underlying numerical analysis is based on a body-of-revolution finite-difference time-domain (FDTD) approach, which takes advantage of the rotational symmetry of the nanoantenna system. Another efficient FDTD version is proposed in the paper of Le et al., which is termed Multiple Unit Cell Method (MUC). This scheme allows a fast and accurate analysis of metallic nanoparticle arrays under oblique excitation. Such finite particle chains that support coupled localized plasmon modes can further act as building blocks for more complex antenna structures as well as for waveguiding.

The last two contributions of the issue (defining a third group of papers) are devoted to planar plasmonic waveguiding and multilayer structures. Within a numerical study, Berini et al. investigate convergence and accuracy issues of the eigenmode computation for surface plasmon waveguides using both, a domain method and a boundary method, namely the finite-element method (FEM) and the method of lines (MoL), respectively. Their invited paper...
A SPECIAL ISSUE
A Special Issue on Functional Nanophotonics and Nanoelectromagnetics
Erni and Caloz

actually marks an important and necessary step towards the proper benchmarking of well-known numerical codes in the challenging context of surface plasmon-polariton waveguiding. Finally, surface plasmon excitations in quasi-periodic metal-dielectric multilayers are described by Kim et al. Fibonacci sequences of alternating layers are analyzed using the invariant imbedding theory to provide surprising findings such as the evidence for anomalous absorption.

We would like to thank the authors and the reviewers for their precious contribution to the high-quality content of this special issue. We also thank the editorial staff of the Journal of Computational and Theoretical Nanoscience for their efficient and continuous support. Without all these commitments the special issue would not have been possible.

Guest Editors

Daniel Erni
University of Duisburg-Essen, Faculty of Engineering General and Theoretical Electrical Engineering (ATE)
D-47048 Duisburg, Germany

Christophe Caloz
École Polytechnique de Montréal Department of Electrical Engineering Poly-Grames Research Center Montréal, Quebec, H3T1J4, Canada

ABOUT THE GUEST EDITORS

Daniel Erni received a bachelor degree from the Applied University in Rapperswil (HSR), Switzerland, in 1986, and a diploma degree from ETH Zürich, Switzerland, in 1990, both in electrical engineering. Since 1990 he has been working at the Laboratory for Electromagnetic Fields and Microwave Electronics, ETH Zürich, where he got his Ph.D. degree in 1996. From 1995–2006 he has been the founder and head of the Communication Photonics Group at ETH Zürich. Since October 2006 he is a full professor for General and Theoretical Electrical Engineering at the University of Duisburg-Essen, Germany (http://www.ate.unic.de/). His current research includes advanced data transmission schemes (i.e., O-MIMO) in board-level optical interconnects, optical on-chip interconnects, ultra-dense integrated optics, nanophotonics, plasmonics, electromagnetic and optical metamaterials, and quantum optics. On the system level Daniel Erni has pioneered the introduction of numerical structural optimization into dense integrated optics device design. Further research interests include science and technology studies (STS) as well as the history and philosophy of science with a distinct focus on the epistemology in engineering sciences. He has authored and co-authored over 300 publications and is a Fellow of the Electromagnetics Academy, as well as a member of the Swiss Physical Society (SPS), of the German Physical Society (DPG), of the Optical Society of America (OSA), and of the IEEE.

Christophe Caloz received the Diplôme d’Ingénieur en Électricité and the Ph.D. degree from École Polytechnique Fédérale de Lausanne (EPFL), Switzerland, in 1995 and 2000, respectively. From 2001 to 2004, he was a Postdoctoral Research Engineer at the Microwave Electronics Laboratory of University of California at Los Angeles (UCLA). In June 2004, Dr. Caloz joined École Polytechnique de Montréal, where he is now an Associate Professor, a member of the Microwave Research Center Poly-Grames, and the holder of a Canada Research Chair (CRC). He has authored and co-authored around 300 technical conference, letter and journal papers, 6 book and book chapters, and he holds several patents. He is a Senior Member of the IEEE, a Member of the Microwave Theory and Techniques Society (MTT-S) Technical Coordinating Committee (TCC) MTT-15, a Speaker of the MTT-15 Speaker Bureau, and the Chair of the Commission D (Electronics and Photonics) of the Canadian Union de Radio Science Internationale (URSI). He received the UCLA Chancellor’s Award for Post-doctoral Research in 2004 and the MTT-S Outstanding Young Engineer Award in 2007. His research interests include all fields of theoretical, computational and technological electromagnetics engineering, with strong emphasis on emergent and multidisciplinary topics.