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## PHD COURSE:

# On Light, Electrons, and Metamaterials

**Speaker**: **Prof. Nader Engheta**
*(University of Pennsylvania, Philadelphia, USA)*

**Dates**: 3-4-5 December 2013

**Location**: ICT International Doctoral School, University of Trento

**Duration**: 20 Hours

**Note**: The lessons will be held in English

**Contact**: Prof. Andrea Massa (andrea.massa@ing.unitn.it)

Metamaterials and Plasmonic optics provide mechanisms for controlling and taming electrons and electromagnetic waves in unprecedented ways. As the field of metamaterial reaches a certain level of development, new directions and novel vistas are appearing in the horizon. Modularization and parameterization of metamaterials may be exploited to provide new functionalities and possibilities stemming from such interesting platforms. These may include "meta-systems" that can be formed on the metamaterial paradigms, and new functionalities may result from proper combinations of meta-systems and metamaterials. In my group we have been exploring various features and characteristics of these concepts, topics, and directions in metamaterials, and we have been investigating new classes of applications such paradigms may provide. Some of the features of interest include nonlinearity, anisotropy, chirality, non-reciprocity, and non-locality. We have been developing the concept of "optical metatronics", i.e. metamaterial-inspired optical nanocircuitry, in which the three fields of "electronics", "photonics" and "magnetics" can be merged together. In such a paradigm, the concept of metamaterials and plasmonics optics can be exploited to bridge the gaps among these fields, to modularize, standardize, and parameterize some of the optical and electronic phenomena, and to transplant concepts from one field into another. In optical metatronics, the nanostructures with specific values of permittivity and permeability may act as the optical lumped circuit elements at the nanoscale, analogous to the circuit elements in RF electronics. Nonlinearity in metatronics can also provide us with novel optical nonlinear lumped elements. Optical nanoantennas can link the "macroworld" with such optical metatronics. We have also been exploring how metamaterials can be exploited to control the flow of photons, as possibly one-way flow of photons. The concept of metatronics has now been extended to other platforms such as graphene as a new paradigm for metatronic circuitry and also as one-atom-thick metamaterials and one-atom-thick transformation optical devices. Extreme-parameter metamaterials, such as epsilon-near-zero (ENZ) and mu-near-zero (MNZ) metamaterials have also offered unprecedented characteristics in electromagnetic wave propagation.

In this series of lectures, I will discuss various topics in the fields of electromagnetic metamaterials and plasmonic optics, will present recent research findings, and will forecast future directions and possibilities in these fields.

## • About the Speaker

**Prof. Nader Engheta** received the B.S. degree in electrical engineering from the University of Tehran, Tehran, Iran, and the M.S. and Ph.D. degrees in electrical engineering from the California Institute of Technology (Caltech), Pasadena, CA, USA. He is the H. Nedwill Ramsey Professor at the University of Pennsylvania, with affiliation in the departments of Electrical and Systems Engineering, Bioengineering, Materials Science and Engineering, and Physics and Astronomy. After spending one year as a Postdoctoral Research Fellow at Caltech and four years as a Senior Research Scientist at Kaman Sciences Corporation's Dikewood Division, he joined the faculty of the University of Pennsylvania. He is also a member of the Mahoney Institute of Neurological Sciences. He was the Graduate Group Chair of Electrical Engineering from 1993 to 1997. His current research interests and activities span over a broad range of areas including metamaterials and plasmonics, nanooptics and nanophotonics, nanocircuits and nanostructures modeling, graphene photonics, one-way flow of photons, 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, fields and waves phenomena, fractional operators and fractional paradigm in electrodynamics. He has guest edited/co-edited several special issues, including the Journal of Electromagnetic Waves and Applications Special Issue on Wave Interaction with Chiral and Complex Media in 1992, the Journal of the Franklin Institute Special Issue on Antennas and Microwaves in 1995, the Wave Motion Special Issue on Electrodynamics in Complex Environments in 2001, the IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION Special Issue on Metamaterials in 2003, the Solid State Communications Special Issue on Negative Refraction and Metamaterials for Optical Science and Engineering in 2008, the IEEE Journal of Selected Topics in Quantum Electronics Special Issue on Metamaterials in 2010, and the Proceedings of IEEE Special Issue on Metamaterials: Fundamentals and Applications in Microwaves and Optical Regimes in 2011. He co-edited the book Metamaterials: Physics and Engineering Explorations (Wiley-IEEE Press, 2006). Dr. Engheta is a Guggenheim Fellow, an IEEE Third Millennium Medalist, a Fellow of IEEE, American Physical Society (APS), Optical Society of America (OSA), American Association for the Advancement of Science (AAAS), and of the SPIE-International Society for Optical Engineering. 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 was the Chair of the Commission B of USNC-URSI for 2009–2011 and of the Gordon Research Conference on Plasmonics in 2012. 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, and was the recipient of the 2012 IEEE Electromagnetics Award, the 2008 George H. Heilmeier Award for Excellence in Research, the Fulbright Naples Chair Award, an NSF Presidential Young Investigator award, UPS Foundation Distinguished Educator term Chair, and several teaching awards. 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 Radio Science (1991–1996). He was on the Editorial Board of the Journal of Electromagnetic Waves and Applications. He is currently on the Editorial board of Waves in Random and Complex Media, Nanophotonics, Physical Review X (PRX), and of the Istituto Superiore Mario Boella Book Series in Radio Science. He served as an IEEE Antennas and Propagation Society Distinguished Lecturer for the period 1997–99.

## • References


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