Multiphysics Modeling of Plasmonic Photoconductive Antennas using Time-Domain Discontinuous Galerkin Method

Liang Chen*(1), Kostyantyn Sirenko(1,2), and Hakan Bagci(1)
(1) King Abdullah University of Science and Technology (KAUST), Thuwal, Saudi Arabia
(2) O. Usikov Institute for Radiophysics and Electronics of National Academy of Sciences of Ukraine (IRE NASU), Kharkiv, Ukraine

In the last two decades, terahertz (THz)-wave devices have become indispensable components of electromagnetic (EM) systems in applications ranging from wireless communication to non-destructive testing. The main obstacle in the way of widespread industrial use of THz technologies is the difficulty of the implementing compact, efficient, frequency-stable and tunable THz source generators capable of operating at room temperatures. Plasmonic photoconductive antennas (PCAs) have become one of the most promising candidates for THz source generation because of their dramatically increased optical-to-THz conversion efficiency and polarization insensitivity (C. W. Berry et. al, *Nat. Commun.,* 4, 1622, 2013). While the experimental research on plasmonic PCAs has made rather significant progress, there is still room for improvement in rigorous numerical modeling of EM/electronic interactions on this type of antennas.

The simulation tool developed for this purpose has to be capable of multiphysics and multiscale modeling. The optical-to-THz conversion consists of several processes running simultaneously: electromagnetic wave scattering on plasmonic structures, carrier generation and recombination, carrier motion driven by electric fields and diffusion. Due to the nonlinear nature of the carrier-EM field interactions, simulation has to be carried out in time domain. Characteristic scales of electromagnetic waves and carriers have several orders of magnitude difference in both time and space. Additionally, plasmonic nanostructures make spatial discretization even more challenging. Most of the simulation tools developed so far use finite difference time domain (FDTD) method and therefore are limited in their geometry modeling capabilities.

This work reports on a multiphysics simulation tool, which makes use of discontinuous Galerkin time domain (DGTD) framework (J. Hesthaven and T. Warburton, *Nodal Discontinuous Galerkin Methods*, Springer, 2008; K. Sirenko, M. Liu, and H. Bagci, *IEEE Trans. Antennas Propag.*, 61, 472–477, 2013). The proposed approach uses Maxwell equations and a bipolar drift-diffusion (DD) model to describe behavior of electromagnetic fields and photoconductive carriers, respectively. The photocurrent induced by carriers' movements is coupled with electromagnetic fields through the current term in Maxwell equations. Electromagnetic fields and the biased electric field are coupled with carriers through the drift term and the particle generation in the DD equations. The coupling is done explicitly at every time step while both sets of equations are solved using DGTD method.

The proposed method is validated via comparison with one- and two-dimensional FDTD methods for simple structures. Numerical results, which demonstrate its applicability to three-dimensional and more realistic examples, will be presented at the talk.