The Higher Accuracy Mixed Spectral Element Method for Computing Graphene Plasmonic Waveguide Modes

Na Liu[1], *Xuanying Hou*[1], *and Qing Huo Liu**[2]
[1] *Institute of Electromagnetics and Acoustics, and Department of Electronic Science, University of Xiamen, Xiamen, Fujian, P. R. China, 361005*
liuna@xmu.edu.cn;
[2] *Department of Electrical and Computer Engineering, Duke University, Durham, NC, USA, 27708*
qhliu@duke.edu

Graphene a truly two-dimensional material consisting of a single carbon-atom layer, has attracted tremendous interests in recent years. Due to its unique electrical and optical properties, graphene plasmonic waveguides have been studied since it can not only confine electromagnetic fields into much smaller lateral spreading than metallic plasmons, but also be easily tuned by electrostatic gating or chemical doping over a broad frequency range. Since graphene is about 0.5 nm thick, an extremely fine mesh and numerous unknowns are need to obtain the accuracy numerical results. Therefore, advanced numerical methods with high efficiency and accuracy are required to determine propagation modes and to optimize geometrical and material parameters.

The higher accuracy mixed spectral element method (mixed SEM) with the equivalent boundary condition is proposed here for computing the optical waveguide modes. In order to suppress the zero spurious modes, the proposed method incorporates the Gauss' law into the vectorial Helmholtz wave equation. Furthermore, to avoid the very fine spatial discretization of the graphene thin sheets, impedance transmission boundary condition is considered to save CPU time and memory cost. The new contributions of this work include: (a) the mixed SEM with the equivalent boundary condition is proposed for the first time to remove all spurious modes and get the higher accuracy results (b) The ITBC is first implemented in the new mixed SEM formulation to speed up the computational time. Finally, numerical results on the graphene plasmonic waveguide and hybrid plasmonic waveguide clearly demonstrate that the proposed mixed SEM is an efficient alternative method to determine the optical waveguide modes.