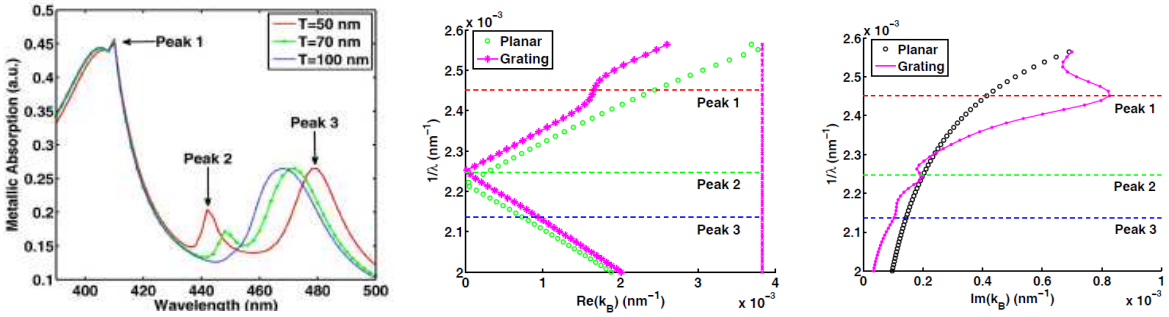
Universal Eigenvalue Analysis for 2D Periodic Plasmonic Nanostructures

Wei E. I. Sha[1], **Hui Wang**[2], **Wallace C. H. Choy**[1], **and Weng Cho Chew**[3]

[1]Department of Electrical and Electronic Engineering
The University of Hong Kong, Pokfulam Road, Hong Kong, China
[2]The Key Laboratory of Intelligent Computing and Signal Processing
Anhui University, Ministry of Education, Hefei, China
[3]Department of Electrical and Computer Engineering
University of Illinois, Urbana-Champaign, Illinois, USA

Abstract— We developed a universal eigenvalue analysis for 2D arbitrary nanostructures comprising dispersive and lossy materials. The complex Bloch band structures (BS) of plasmonic crystals and gratings are rigorously calculated by the finite-difference discretization of wave equation. Given a frequency of interest, the eigenvalue algorithm solves one Bloch wavenumber as the eigenvalue via fixing another. (1) For plasmonic crystals, the influence of ohmic (metallic) loss on the complex BS and eigenmodes is investigated. Regarding a TE polarization with H_z field, the ohmic loss strongly affects the BS and eigenmodes at plasmonic resonance frequencies. Both the fast oscillation of dispersion curve and strong field confinement of eigenmodes are damped due to the high ohmic loss. Regarding a TM polarization with E_z field, the introduction of ohmic loss twists the vertical dispersion curve at the bandgap and breaks the symmetry of eigenmodes. Regarding both polarizations, the high ohmic loss lowers the quality factor of eigenmodes. (2) For plasmonic gratings, the abnormally large group velocity is observed at a plasmonic band edge with a large attenuation constant. Interestingly, we found the abnormal group velocity is caused by the leaky (radiation) loss, not by metallic absorption (ohmic) loss. The periodically modulated surface of the grating significantly modifies the original BS of the semi-infinite dielectric-metal structure and induces the extraordinarily large group velocity, which is different from the near-zero group velocity at photonic band edge. The work is fundamentally important to the design of plasmonic nanostructures.



(a) (b) (c)

Figure 1: The plasmonic band gap (PBG) and plasmonic band edge (PBE) effects. (a) The absorbance as a function of grating thickness T. Peak 1 and 3 relate to PBEs. Peak 2 relates to PBG. (b), (c) Plasmonic BS of the grating. The anomalous group velocity is found at a PBE (peak 1 in (b)) with a large attenuation (peak 1 in (c)). The original BS of planar air-metal structure is strongly perturbed.