Complex K-Bands Calculation for Plasmonic Crystal Slabs By Means of Weak Formulation of Helmholtz's Eigenvalue Equation

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Abstract

We present a Finite Element Method (FEM) to calculate the complex valued k(ω) dispersion curves of a photonic crystal slab in presence of both dispersive and lossy materials. In particular the method can be exploited to study plasmonic crystal slabs. We adopt Perfectly Matched Layers (PMLs) in order to truncate the open boundaries of the model, including their related anisotropic permittivity and permeability tensors in the weak form of Helmholtz's eigenvalue equation [1,2]. The method is applied to the complex case of periodic arrays of holes in a silver metal film (Figure 1, left), enabling to investigate the role that plasmonic Bloch modes play in the extraordinary optical transmission phenomenon presented by the structure. Results are compared to scattering FEM simulation in order to test the accuracy and reliability of the method once the PMLs parameters are properly set thus proving that PML implementation allows to effectively study leaky modes, characteristic features of photonic crystal slabs, and thus enabling the reconstruction of the correct radiative eigenmode profile. By comparing Bloch-modes dispersions to transmittance maps, indeed, it is possible to clarify the relationship between optical response of the structure and periodicity induced resonant modes (Figure 1, a, b, c, and d).

Reference

[1] M. Davanco, G. Shvets et al. “The complex Bloch bands of a 2D plasmonic crystal displaying isotropic negative refraction,” Opt. Express 15, 9681–9691 (2007).
[2] C. Fietz, G. Shvets et al. “Complex k band diagrams of 3D metamaterials/photonic crystals,” Opt. Express, 19, 19027-19041 (2011).

Figures used in the abstract

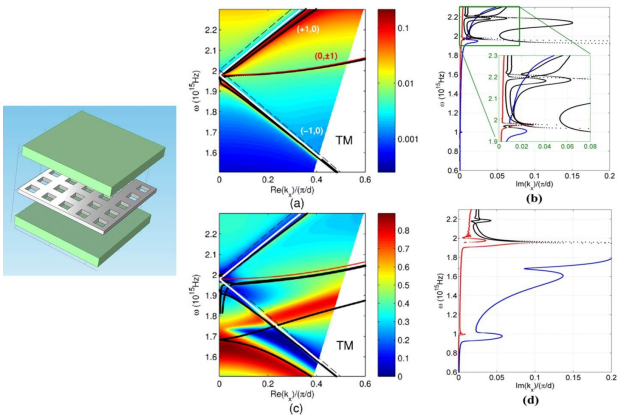

Figure 1: Figure 1. Left: Scheme of plasmonic crystal slab (gray silver) with PMLs (green) truncating the cladding domains. Right: Transmittance maps compared with the calculated dispersion curves (black lines). (a) and (b) refer to a 250nm holes array, (c) and (d) to a 500nm holes array. The black dashed line marks the light line, white and red solid lines mark the flat SPP dispersions, (±1,0) and (0,±1) respectively for all maps.