Complex k-bands of plasmonic crystal slabs

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Introduction: We present a Finite Element Method (FEM) to calculate the complex valued **k**(ω) dispersion curves of a *plasmonic crystal slab* in presence of both dispersive and lossy materials. The method can be exploited to study plasmonic crystal slabs.

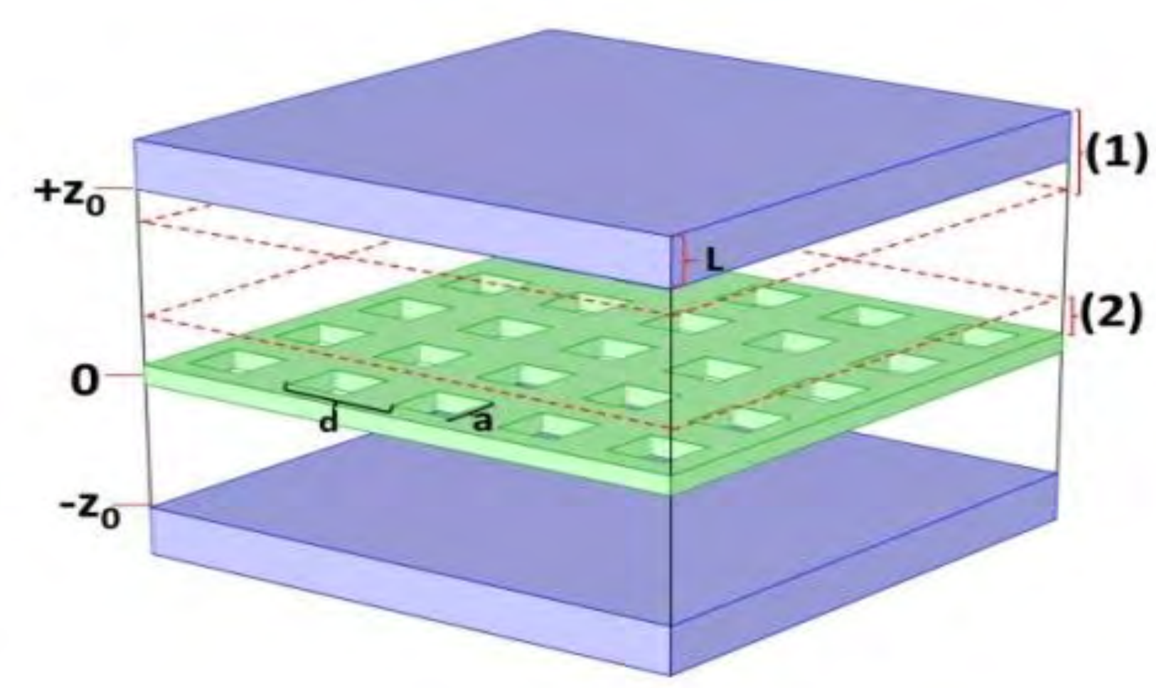

Figure 1. Unite cell

Computational Methods: The method relies on the *weak formulation* of the Helmholtz's eigenvalue equation [1,2,3]. :

$$\begin{cases} \nabla\times\left(\hat{p}\nabla\times\mathbf{H}\right)-\omega^2\hat{q}\mathbf{H}=0 \\ \mathbf{H}=e^{-i\mathbf{k}\cdot\mathbf{r}}\mathbf{u}(\mathbf{r}) \end{cases} \qquad \hat{p}=1/\hat{\mu}(\mathbf{r},\omega),\ \hat{q}=\hat{\varepsilon}(\mathbf{r},\omega)$$

u(r) Bloch function, **k** eigenvalue

$$\int_\Omega d^3\mathbf{r}\left(\hat{p}\left[k^2(\mathbf{v}\cdot\mathbf{u})-(\mathbf{k}\cdot\mathbf{v})(\mathbf{k}\cdot\mathbf{u})\right]-i\hat{p}\mathbf{v}\cdot\left[\mathbf{k}\times(\nabla\times\mathbf{u})\right]-i(\nabla\times\mathbf{v})\cdot\hat{p}(\mathbf{k}\times\mathbf{u})\right)+$$
$$+\int_\Omega d^3\mathbf{r}\left((\nabla\times\mathbf{v})\cdot\hat{p}(\nabla\times\mathbf{u})-\hat{q}\frac{\omega^2}{c^2}\mathbf{v}\cdot\mathbf{u}\right)+\int_{\partial\Omega}dA\mathbf{v}\cdot\left[\hat{\mathbf{n}}\times\hat{p}\left(-i\mathbf{k}\times\mathbf{u}+\nabla\times\mathbf{u}\right)\right]=0,$$

In order to deal with leaky modes and to simulate Perfect Matched Layers (PML) an anistropic tensor is required in the form of:

$$\hat{\varepsilon}=\varepsilon\hat{\Lambda},\ \hat{\mu}=\mu\hat{\Lambda}, \qquad \hat{\Lambda}=\begin{pmatrix} c & 0 & 0 \\ 0 & c & 0 \\ 0 & 0 & c^{-1} \end{pmatrix},$$

$$\begin{cases} c=\alpha-i\beta \\ \beta=\bar{\sigma}\dfrac{\left|\left(z\mp|z_0|\right)\right|^n}{L^n} \end{cases} . \qquad \kappa=\frac{\left\langle|\mathbf{H}|^2\right\rangle_{(1)}}{\left\langle|\mathbf{H}|^2\right\rangle_{(2)}}$$

Results: The figures below show the retrieved results: the TE and TM modes compared with Transmittance maps (Fig. 2 ,3 respectively), the H_y and |**E**| fields profiles (Fig.4) and the imaginary part of modes eigenvalues (Fig.5)

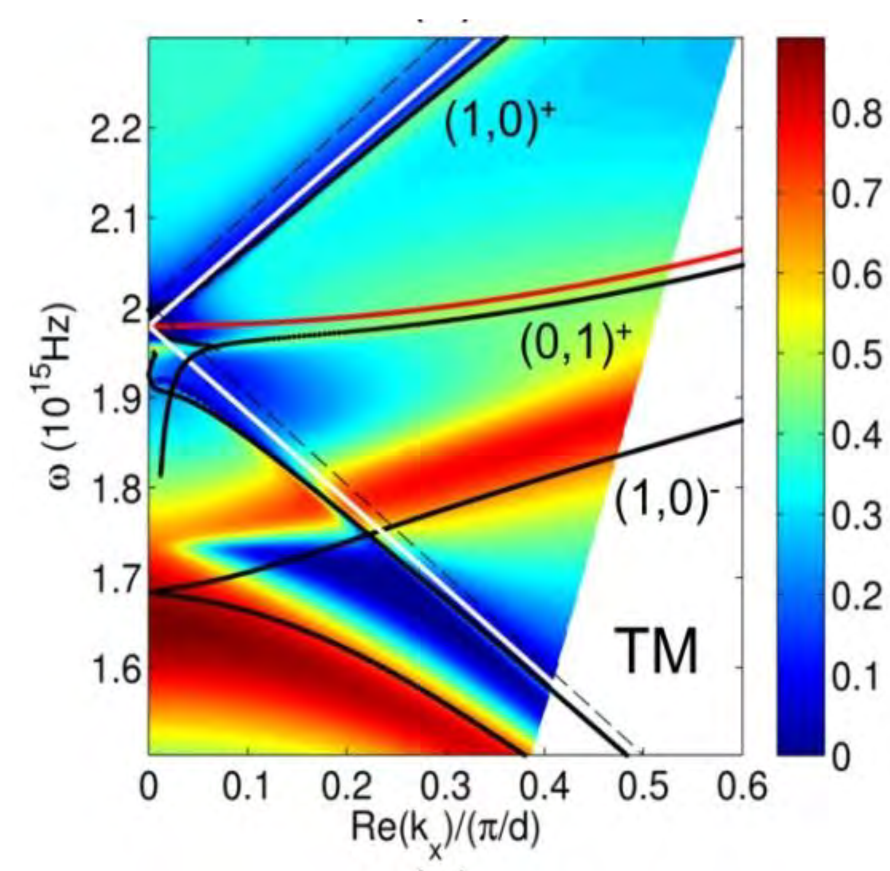

Figure 2. TM modes

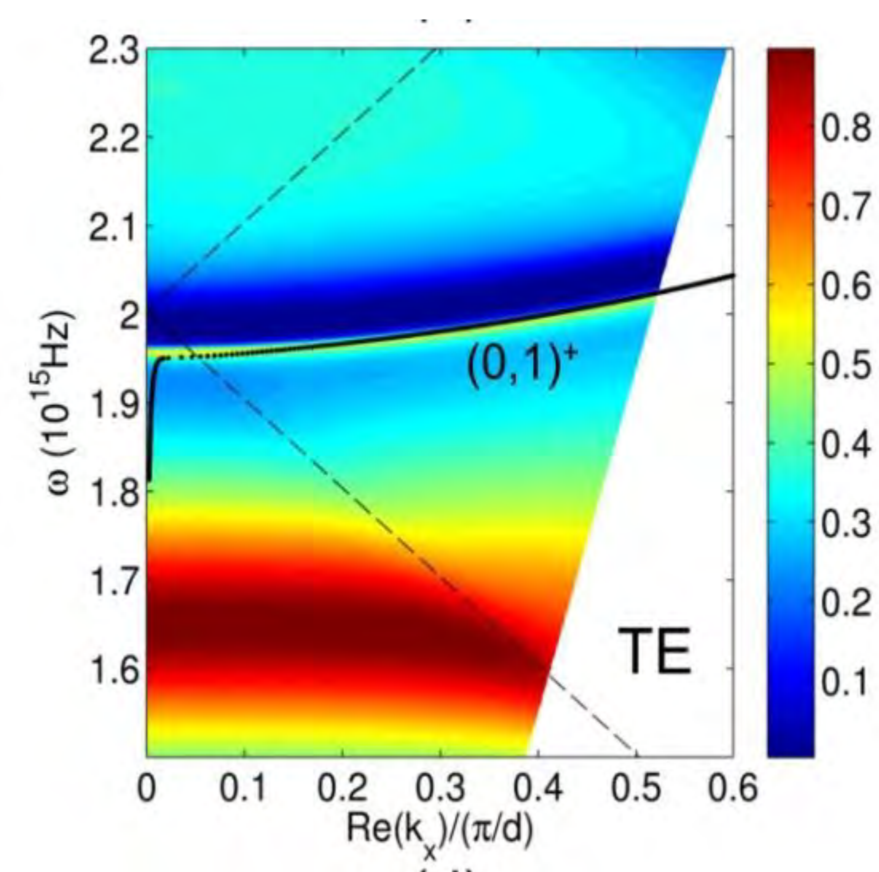

Figure 3. TE modes

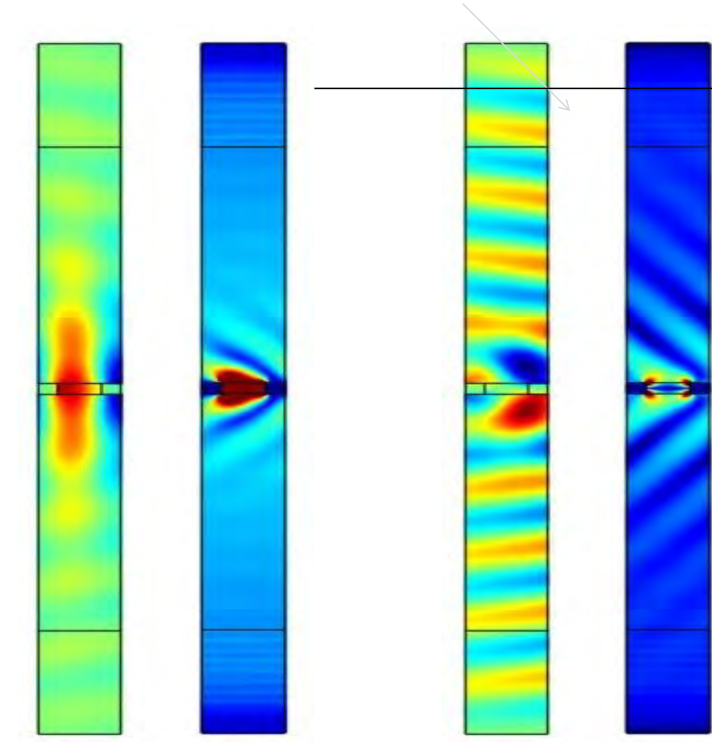

Figure 4. H_y and |**E**| fields

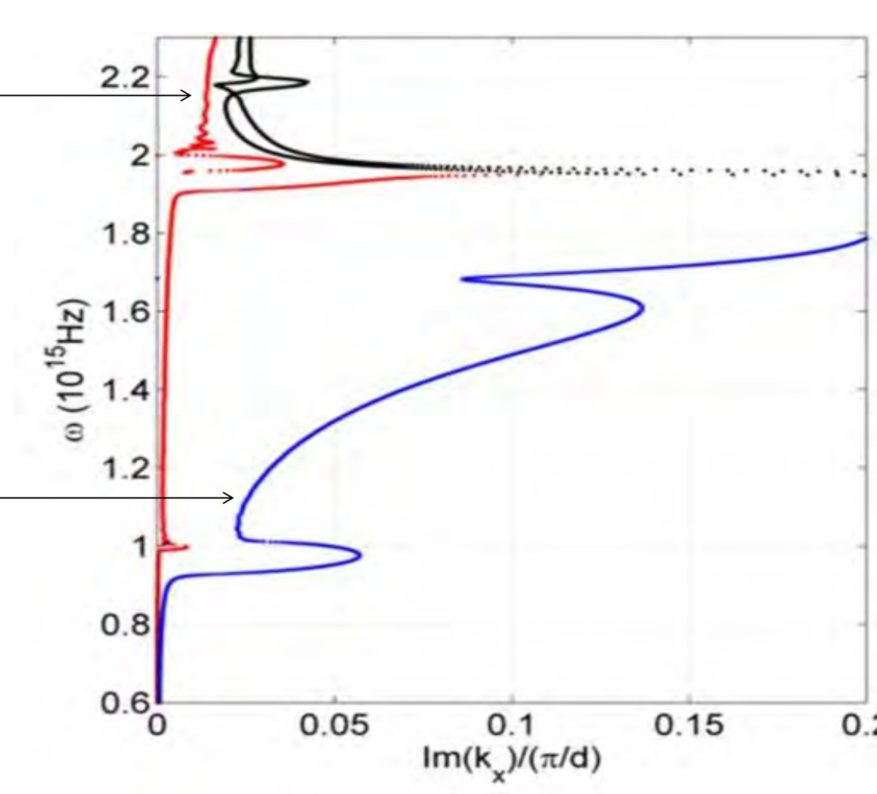

Figure 5. Imaginary k bands

Conclusions: Our results prove that PML implementation allows to effectively study leaky modes, characteristic features of photonic crystal slabs, thus enabling the reconstruction of the correct radiative eigenmode profile.

References:

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Excerpt from the Proceedings of the 2012 COMSOL Conference in Milan