Density of Modes for 2D finite photonic crystal structures

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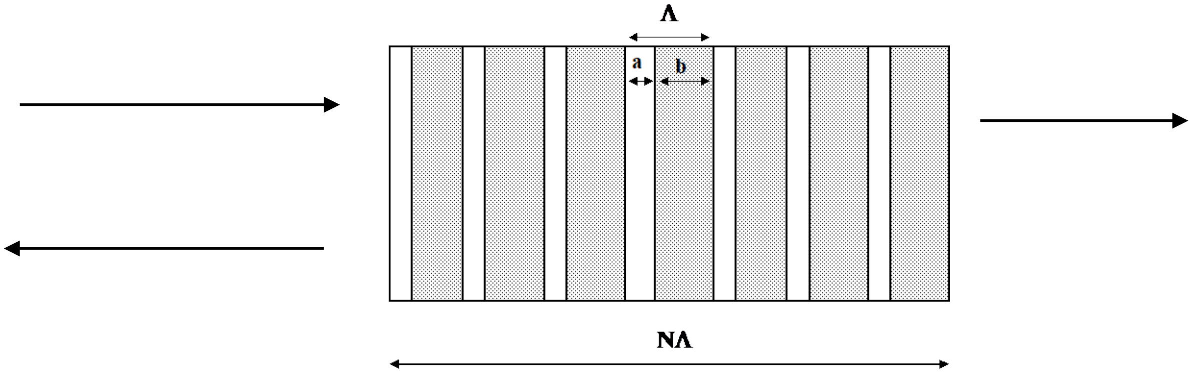
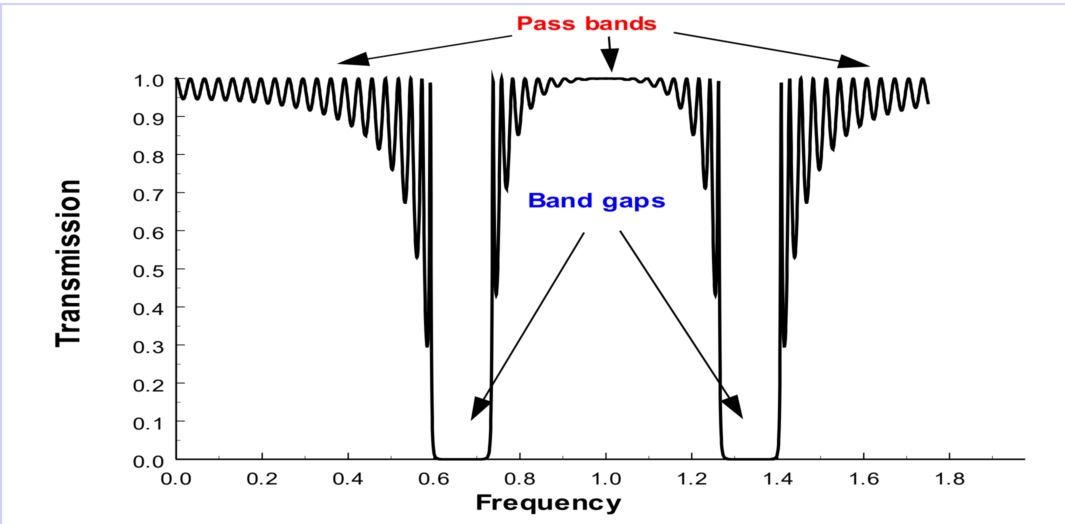
1D PBG : Layered disposition of materials with high contrast of refractive index





:Transmission function for the structure depicted in Fig.(1). Note the frequency pass bands and band gaps.

Outline:

•Finite, 1-D, PBG

•DOM -

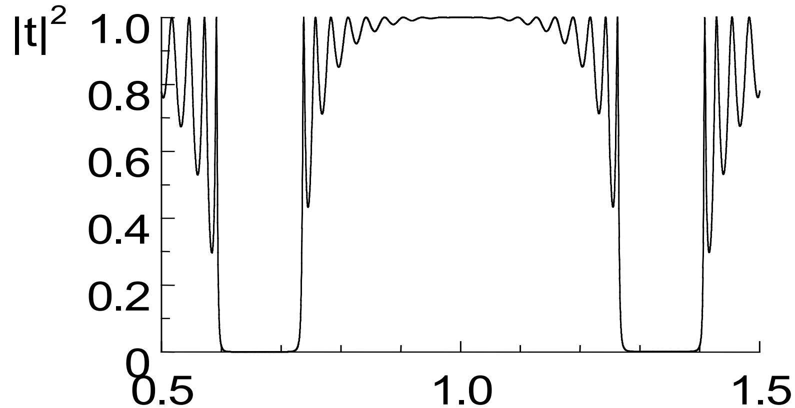
•Definitions for open cavities

•QNM theory

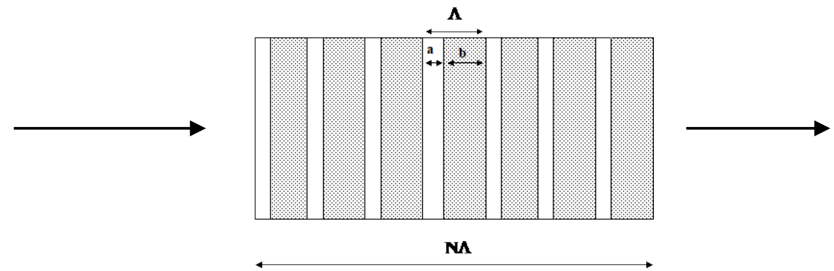
Finite 2D PC

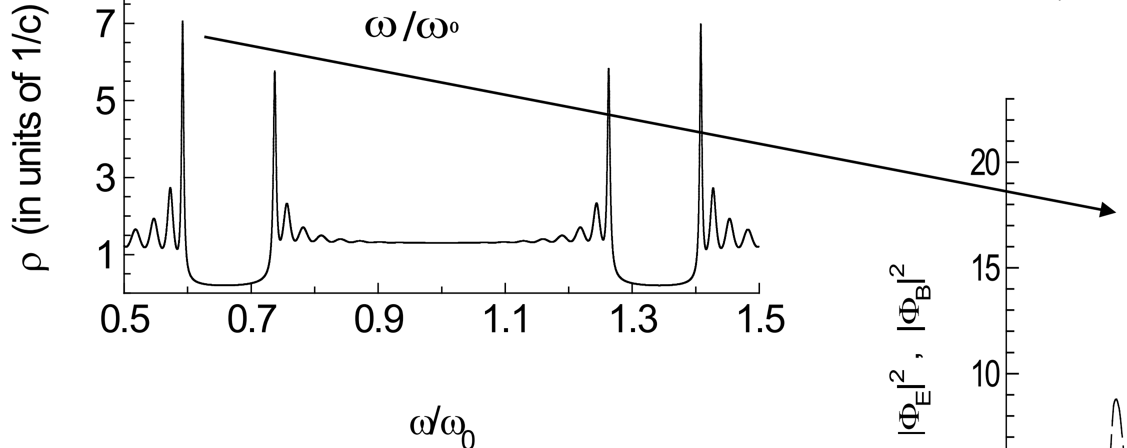
•QNM 2D

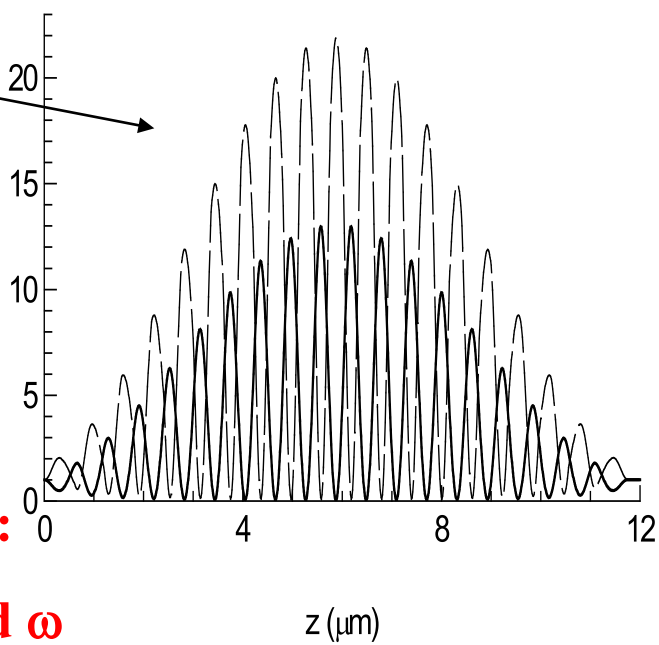
•Conclusions



1)DOM - 1D from t







$$t(\omega) = x(\omega) + i\,y(\omega) = \sqrt{T}\,e^{i\phi_t}$$

$$\phi_t = \tan^{-1}(y/x) \pm m\pi$$

$$\phi_t = k(\omega)D = \frac{\omega}{c} n_{eff}(\omega) D$$

Density of modes :

dφ/dω = (1/D)dk/d ω

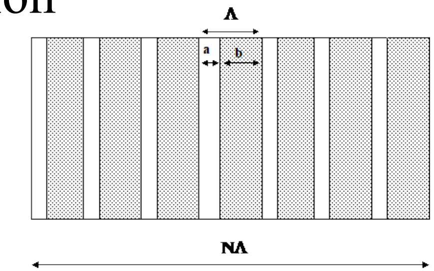
DOM = dk/dω=

(1/D)(y'x-x'y)/(x^2+y^2)

Bendickson at al

2) From the energy density

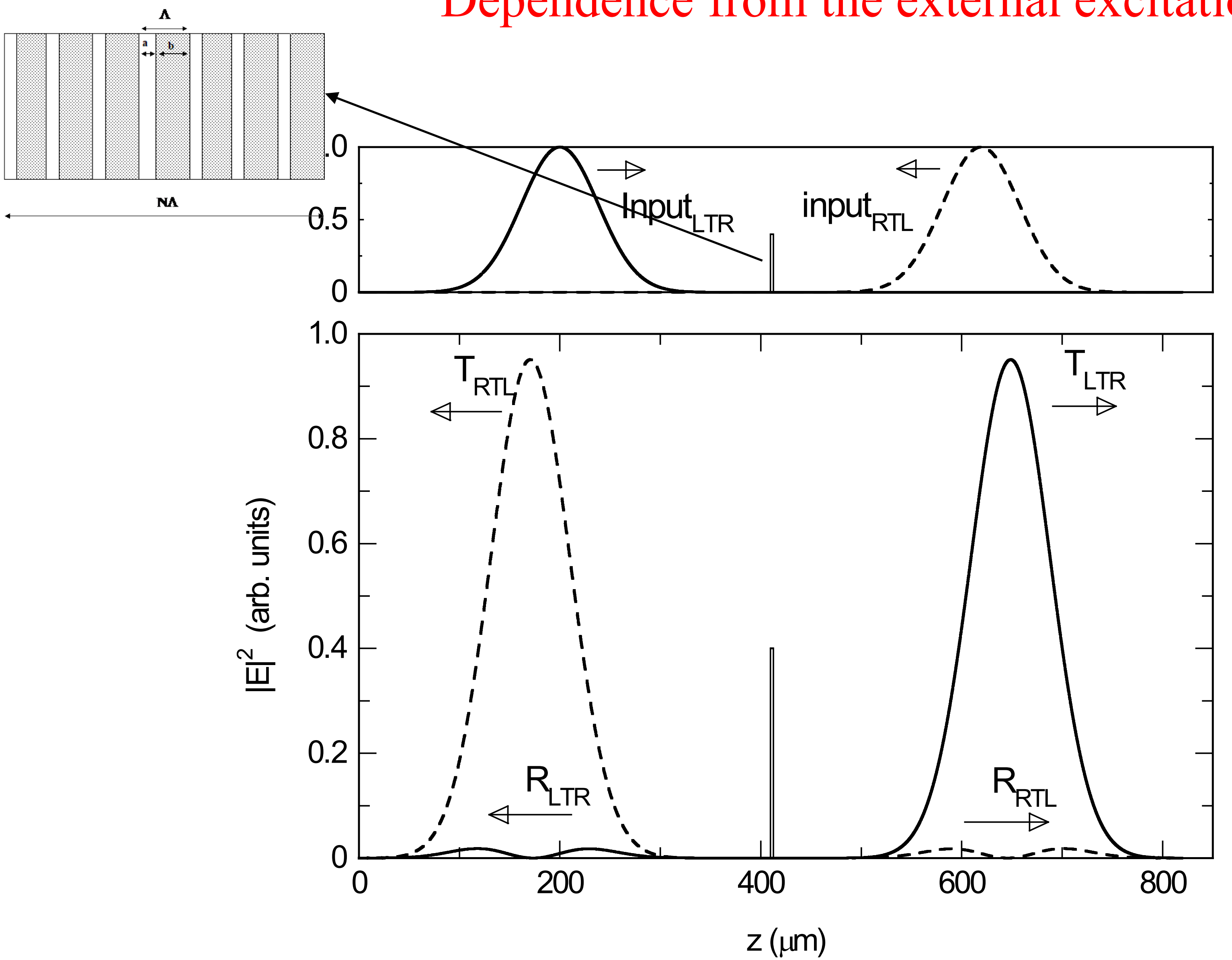
Because " density of modes" is synonymous of " field localization" at a given frequency we can adopt the following definition , as proposed by G.D'Aguanno et al



$$\rho = \frac{1}{2ncD}\int_0^D \varepsilon(z)\left(|\Phi|^2 + \frac{c^2}{\omega^2}\left|\frac{d\Phi}{dz}\right|^2\right)dz$$

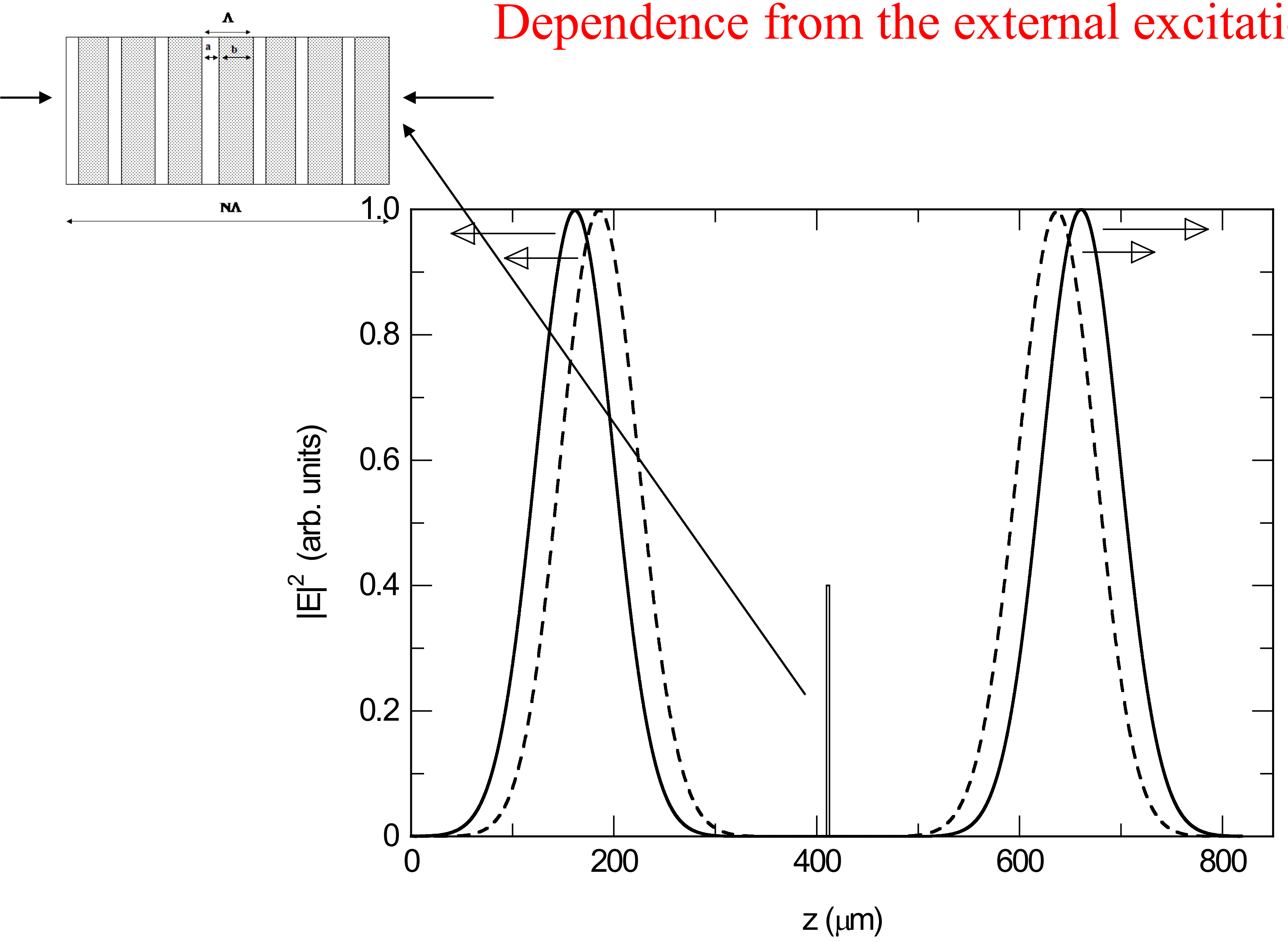
$$\tau_\omega = \frac{1}{2\left|\Phi_\omega^{(input)}\right|^2 c}\int_0^L \left[\varepsilon_\omega(z)\left|\Phi_\omega\right|^2 + \frac{c^2}{\omega^2}\left|\frac{d\Phi_\omega}{dz}\right|^2\right]dz$$

Dependence from the external excitation



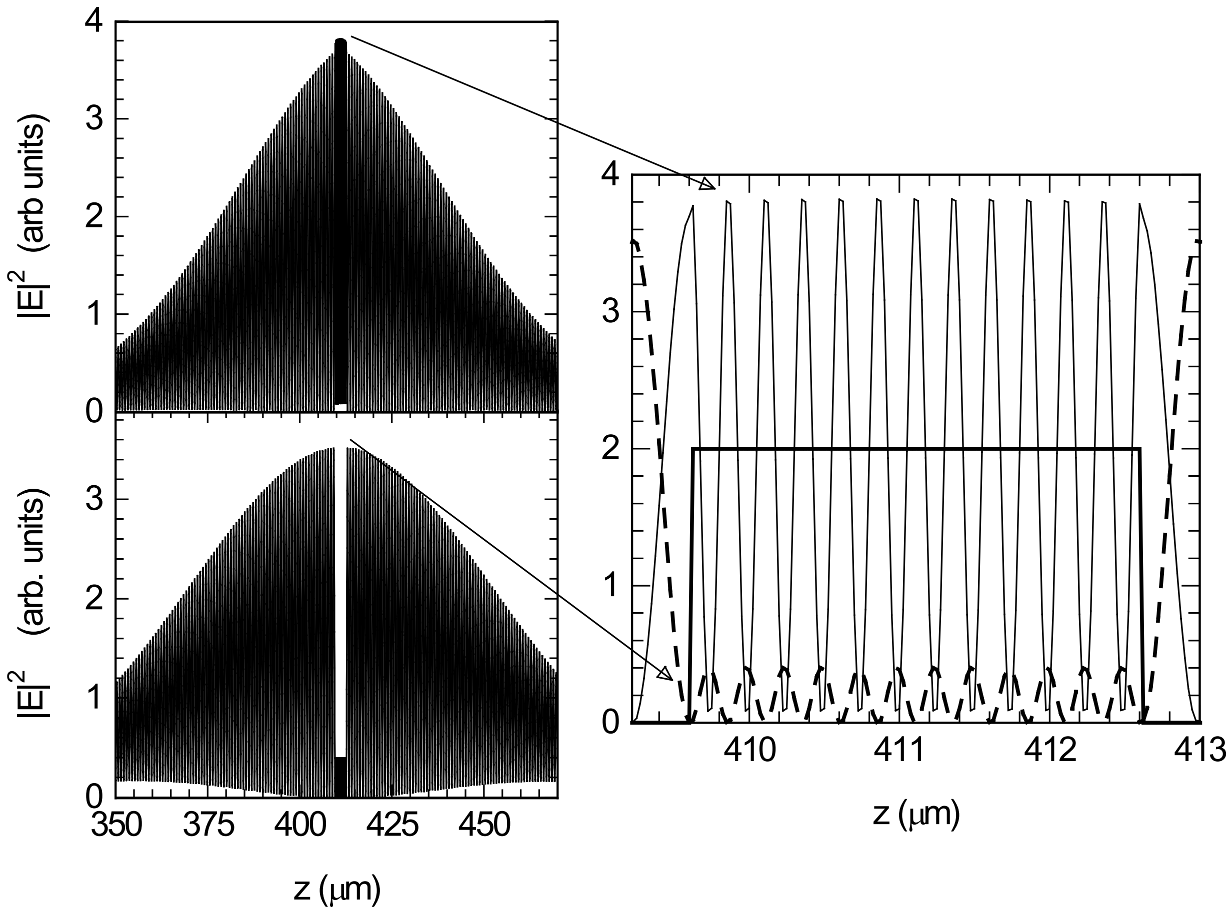
Normalized input (a) and transmitted pulse (b) propagating LTR (solid) and RTL (dashed). Pulse duration is 300fs

Dependence from the external excitation



Snapshots of outgoing pulses when input counterpropagating pulses have the relative phase difference
is $\Delta\varphi=0$ (solid) and $\Delta\varphi=\pi$ (dashed

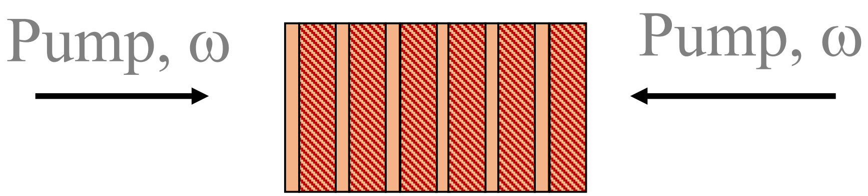
Dependence from the external excitation

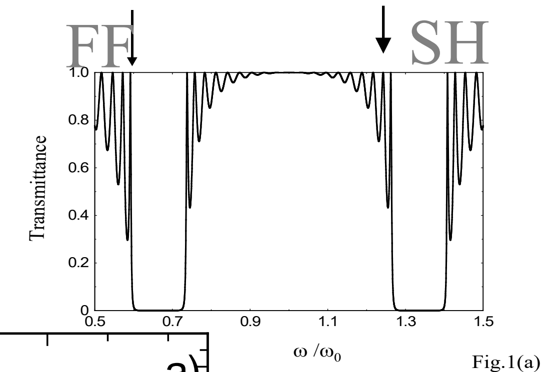


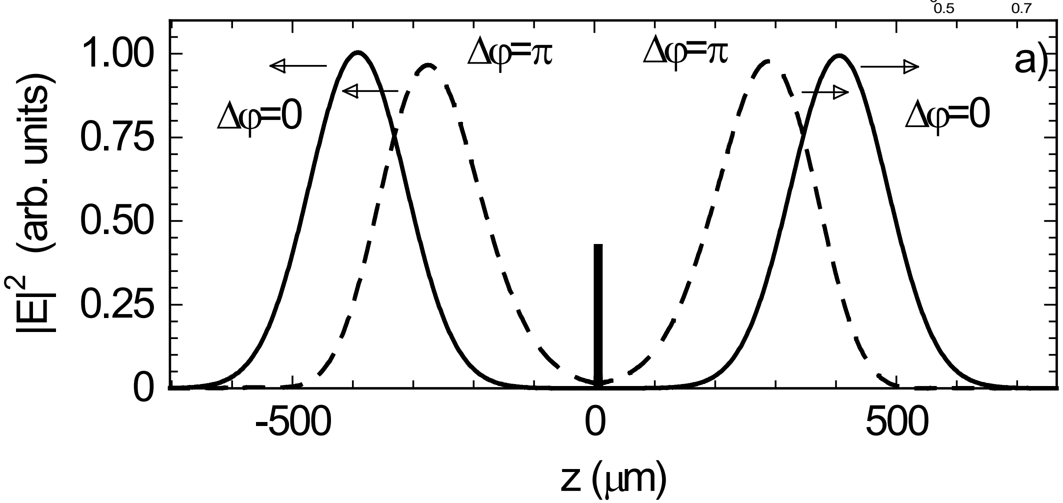
Snapshots taken when the peaks of both pulses are inside the structure for initial phase differenc is:

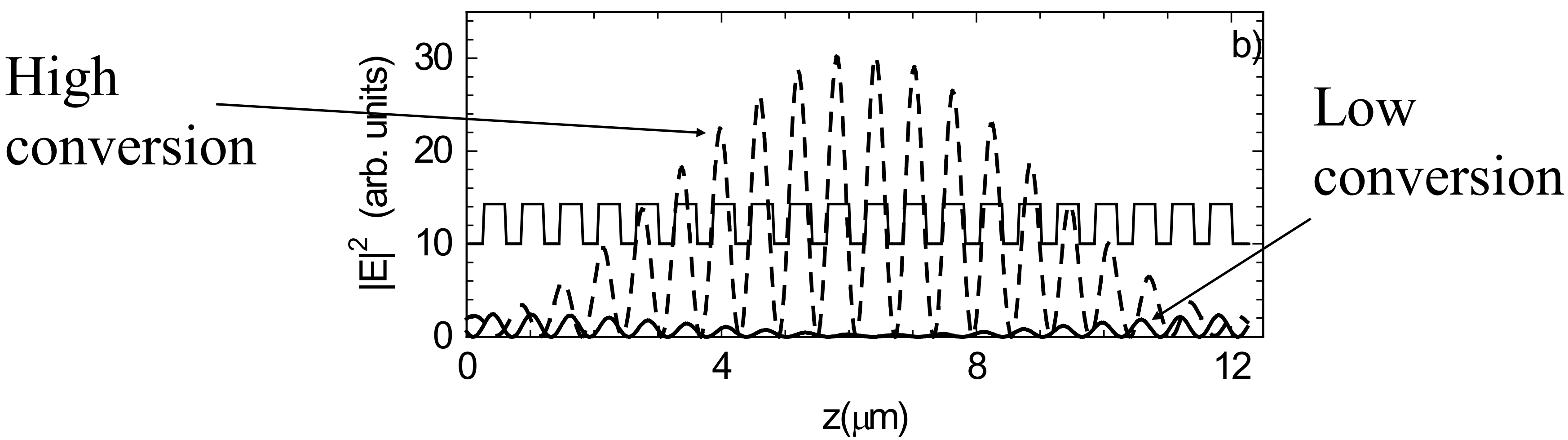
(a) $\Delta\varphi=\pi$; (b) $\Delta\varphi=0$. (c) Field intensity profile inside the etalon, for $\Delta\varphi=\pi$ (solid) and $\Delta\varphi=$ (dashed).

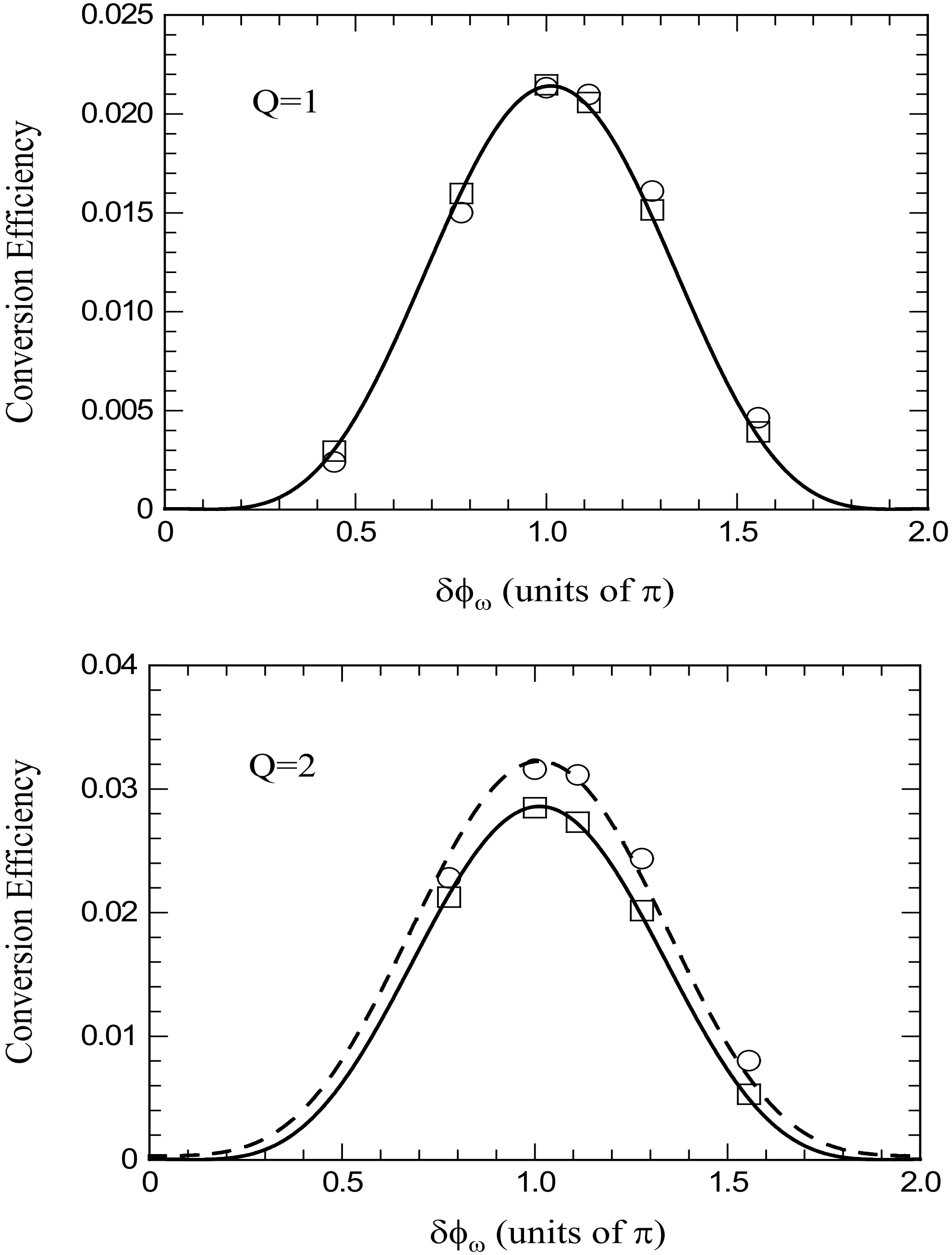
Enhancement and Suppression of the SH process











Enhancement and Suppression of the SH process

- - - - (dashed line)	backward SH	**Analytic calculation**
——— (solid line)	forward SH	
□	forward SH	**Numerical calculation**
○	backward SH	

$Q = I_{pump2}/I_{pump1}$

QNM- Quasi-Normal Mode

$$\omega_{m,0} = \mathrm{Re}(\omega_{m,0}) + j\,\mathrm{Im}(\omega_m)$$

We deal with an open cavity, however through the concept of QNM we can "look" inside the cavity and define the local density of "quasi-normal modes" so that the number of QNMs

$$\delta N_{QNM}(x,\omega) = \sigma_{loc}(x,\omega)\,dx\,d\omega$$

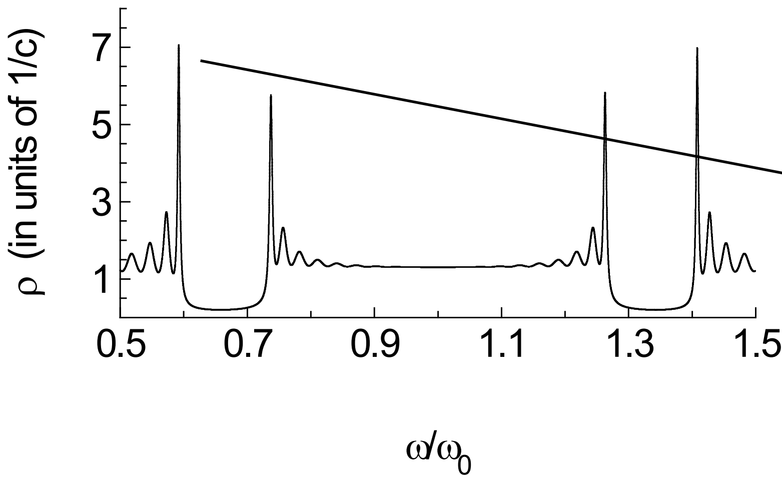
$$\sigma_{loc}(x,\omega) = K\frac{\rho_0}{\pi}\sum_{n,m}\frac{F_n(0)F_m(0)}{(\omega-\omega_n)(\omega+\omega_m)}F_n(x)F_m(x)$$

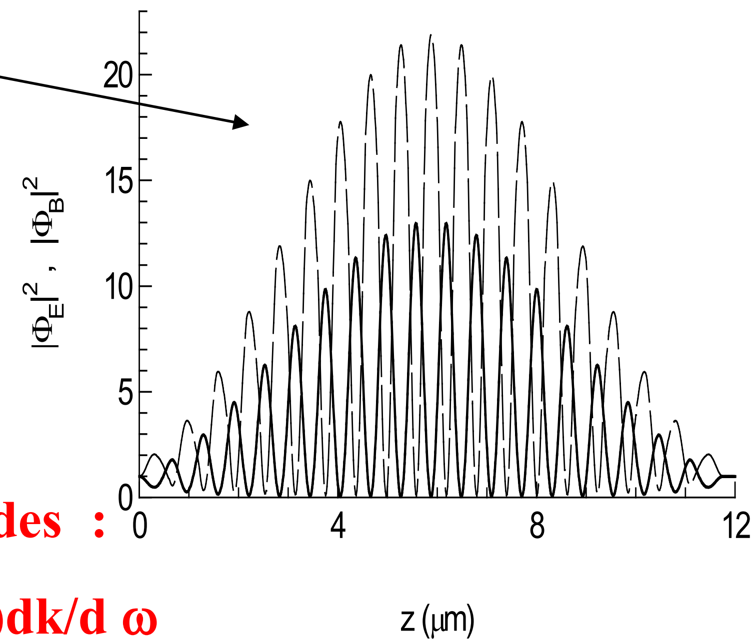
$$\sigma(\omega) = \frac{1}{L}\int_0^L n^2(x)\sigma_{loc}(x,\omega)\,dx$$

$$\sigma(\omega) = \frac{K_\sigma}{\pi}\sum_n\frac{|\mathrm{Im}\,\omega_n|}{(\omega-\mathrm{Re}\,\omega_n)^2+\mathrm{Im}^2\,\omega_n}$$

QNM- Quasi-Normal Mode 1D

Same results as from t





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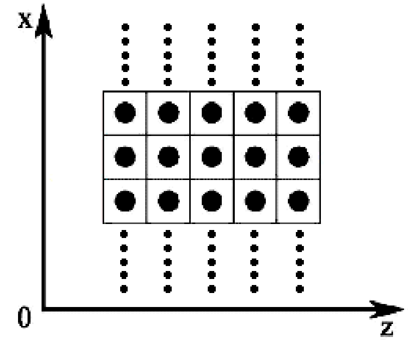
QNM- Quasi-Normal Mode 2D

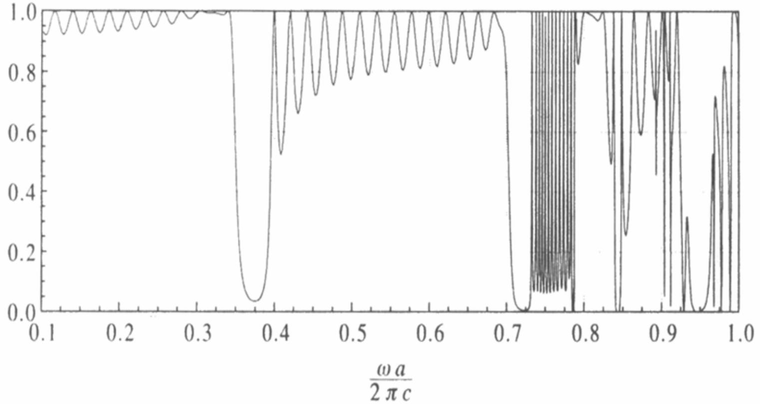


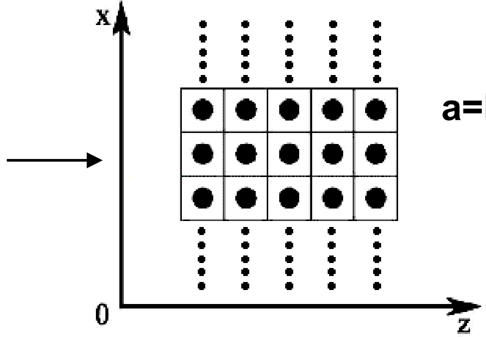
$$\varepsilon(x,z) = \varepsilon_X(x) + \varepsilon_Z(z)$$

$$DOM_X(x,\omega) = \frac{1}{L_Z}\int_0^{L_Z} \varepsilon_Z(z)\sigma_{loc}(x,z,\omega)dz$$

$$DOM_Z(z,\omega) = \frac{1}{L_X}\int_0^{L_X} \varepsilon_X(x)\sigma_{loc}(x,z,\omega)dx$$

$$\begin{cases} \sigma_{loc}^{(X)}(x,\omega) = -\dfrac{2\omega}{\pi}\mathrm{Im}[\tilde{G}_X(x,x,\omega)] \\ \sigma_{loc}^{(Z)}(z,\omega) = -\dfrac{2\omega}{\pi}\mathrm{Im}[\tilde{G}_Z(z,z,\omega)] \end{cases}$$





a=b r/a= 0,2 εr=1,5

Energy Density-Local DOM

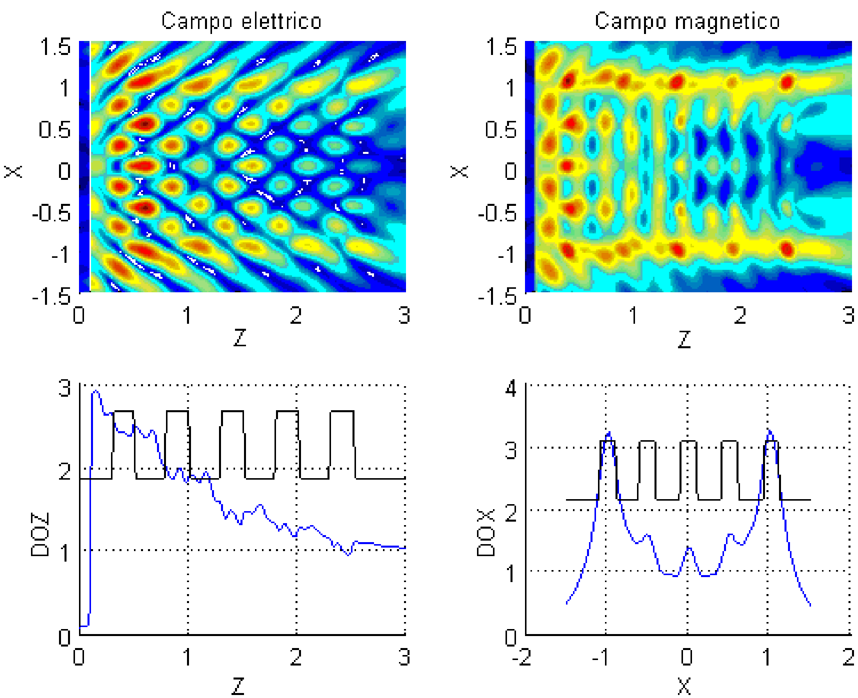
$$DOE = \frac{1}{A}\mathrm{Re}\left[-c^2\mu\int_0^{Lx}\int_0^{Lz} E_y^* H_x \, dxdz\right]$$

DOE (x) : $$DOX = \frac{1}{L_z}\mathrm{Re}\left[-c^2\mu\int_0^{Lz} E_y^* H_x \, dz\right]$$

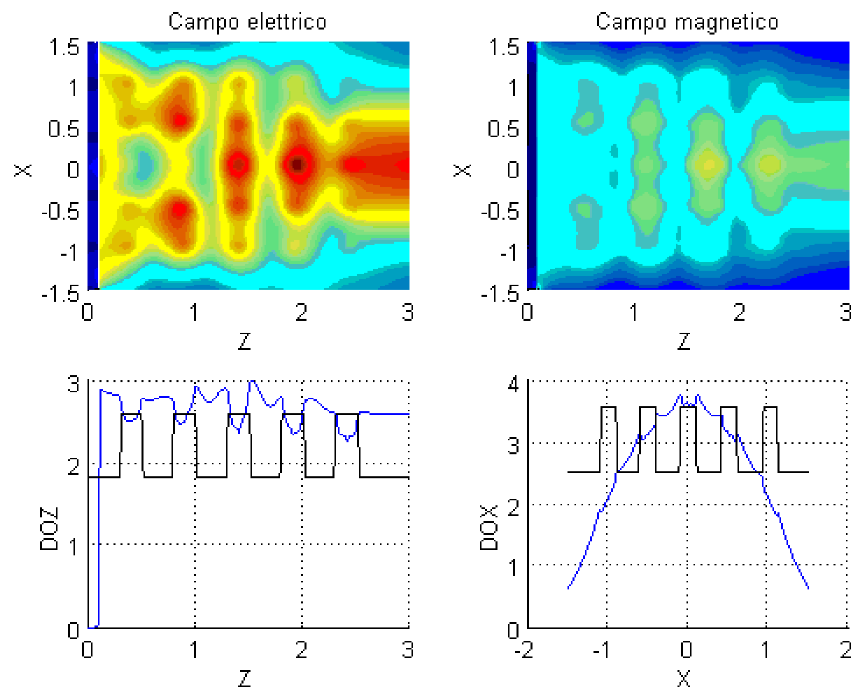
DOE (z) : $$DOZ = \frac{1}{L_x}\mathrm{Re}\left[-c^2\mu\int_0^{Lx} E_y^* H_x \, dx\right]$$

PC 5x5

λ=0.485 μm



λ=1.323 μm



Conclusions

- -Open cavities
  - -DOM from t , energy density ,
    QNM
  - -Depencence on the input excitation
  - -Extension to 2D