Magneto-optical studies of nanopatterned periodic structures

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The optical properties of periodically arranged dielectric nanostructures is receiving much attention in recent years. These structures, fulfilling the proper conditions, present gaps in the frequency spectrum. For this property they receive the name of Photonic Crystals. Most of the experimental, as well as theoretical, investigations of these photonic crystals have been devoted to the analysis of geometrical alterations of the structure.

The control of the flow of light requires external fields such as electric fields (e.g. when liquid crystals are employed) or magnetic fields (e.g. magneto-optical active materials). Here we will concentrate in the case of magneto-optical materials. These materials posses a very interesting characteristic: their dielectric function can be tuned under the application of a magnetic field. From a theoretical point of view magneto-optically active materials present extra complications since their dielectric tensor is no longer diagonal.

In this work we study the transmission properties in the direction of the longitudinal axis of periodically arranged metallic nanowires embedded in an alumina matrix ($n = 1.75$) as depicted in the left panel of Fig. 1. Such a system present plasmon-like features and the magnetic field is used to control the coupling of light with localized plasmons. The metallic wires are modeled through a Drude model:

$$\epsilon = \begin{pmatrix} \epsilon_{xx} & \epsilon_{xy} & 0 \\ \epsilon_{yx} & \epsilon_{yy} & 0 \\ 0 & 0 & \epsilon_{zz} \end{pmatrix} ; \quad \begin{array}{c} \epsilon_{xx} = \epsilon_{yy} = \epsilon_{zz} = \left(1 + \frac{\mathrm{i}(1-\mathrm{i}\omega\tau)\omega_p^2\tau}{\omega[(1-\mathrm{i}\omega\tau)^2+\omega_c^2\tau^2]}\right)\epsilon_\infty \\ \epsilon_{xy} = -\epsilon_{yx} = \frac{\mathrm{i}\omega_c\omega_p^2\tau^2\epsilon_\infty}{\omega[(1-\mathrm{i}\omega\tau)^2+\omega_c^2\tau^2]} \end{array} \tag{1}$$

Where the magnetic field is applied along the wire axis and its magnitude is determined by ω_c. The parameters entering in Eq. 1 are taken to resemble Ag and the value of ω_c is such that the magneto-optical activity is similar to that of Co. In order to obtain the transmitted and reflected fields, we use a scattering matrix formalism, specially adapted to deal with non-diagonal dielectric tensors of the type of Eq. 1.

In the right panel of Fig. 1 we show the transmission amplitude of metallic wires (diameter $d = 10nm$) in a triangular arrangement (lattice parameter $a = 100nm$) in absence ($\omega_c = 0$) and in presence of a magnetic field ($\omega_c = 0.04eV$). As it can be seen in the low frequency range of the spectrum, the magnetic field controls the transmission of light through the structure allowing the coupling of the light to the infrared plasmon-like structures of the wires.

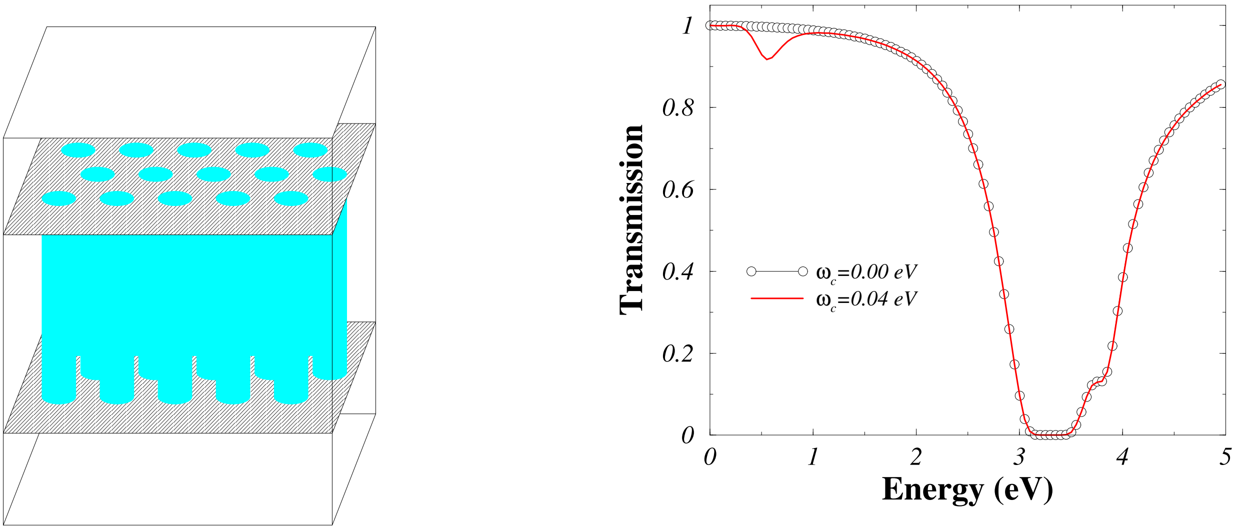

FIG. 1. Left: Schematic view of the system under consideration. Right: Transmission amplitude of a triangular array of $5\mu m$ long wires with $d = 10nm$, $a = 100nm$, $\omega_p = 3.85$, $\tau = 4eV^{-1}$ and $\epsilon_\infty = 6.25$

The method we present here can also be used to calculate Kerr and Faraday rotation induced by the presence of the off-diagonal term in the dielectric tensor. These quantities are of prime importance in the context of sensor devices. We will present results of the transmission as well as the magneto-optical activity (focused in the Faraday rotation) of wires and disks both in a triangular and square arrangement. We will vary the geometrical parameters to show the different couplings and interactions between the localized modes of the wires/disks.