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# Optical transmission properties of an anisotropic defect cavity in one-dimensional photonic crystal

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## ABSTRACT

We investigate theoretically the possibility to control the optical transmission in the visible and infrared regions by a defective one dimensional photonic crystal formed by a combination of a finite isotropic superlattice and an anisotropic defect layer. The Green's function approach has been used to derive the reflection and the transmission coefficients, as well as the densities of states of the optical modes. We evaluate the delay times of the localized modes and we compare their behavior with the total densities of states. We show that the birefringence of an anisotropic defect layer has a significant impact on the behavior of the optical modes in the electromagnetic forbidden bands of the structure. The amplitudes of the defect modes in the transmission and the delay time spectrum, depend strongly on the position of the cavity layer within the photonic crystal. The anisotropic defect layer induces transmission zeros in one of the two components of the transmission as a consequence of a destructive interference of the two polarized waves within this layer, giving rise to negative delay times for some wavelengths in the visible and infrared light ranges. This property is a typical characteristic of the anisotropic photonic layer and is without analogue in their counterpart isotropic defect layers. This structure offers several possibilities for controlling the frequencies, transmitted intensities and the delay times of the optical modes in the visible and infrared regions. It can be a good candidate for realizing high-precision optical filters.

## 1. Introduction

Photonic Crystals (PCs) have attracted a great deal of attention during the last two decades [1–3] due to their potential applications in optoelectronic and optical communications [4–16]. They can be used in the fabrication of lasers [4,5], optical diodes [6,7], waveguides [8,9], filters [10], dielectric reflectors [11–14], sensors [15,16], etc. Research in PCs has known a tremendous expansion and covers a wide range of electromagnetic spectrum from microwaves to the visible. Several technological difficulties restrict the fabrication of three-dimensional (3D) PCs in the visible (VIS) and infrared (IR) regions, due to their small lattice constant, which should be comparable to the wavelength [17]. However, the complication associated with 3D PCs lead to the investigation of one-dimensional (1D) periodic structures, which can be easily produced for this range of wavelengths, by using thin-film deposition techniques.

For most applications, a defective PCs are more desired than the perfect ones. The physical properties of the localized or defect modes within the photonic band gaps (PBGs) has been increasingly studied. According to such combination, several materials are used as the defect layer in the design of the photonic devices. Several works have investigated the optical and microwave properties of defect modes in 1D isotropic dielectric PCs. Liu et al. [10] have studied a 1D PC structure consisting of alternate layers of $Ta_2O_5$ and $MgF_2$ films with a defect layer in the visible region. They have shown that the number and the frequencies of the defect modes can be controlled in the visible range by adjusting the thickness of the defect layer. This structure can be useful in the design of blue–

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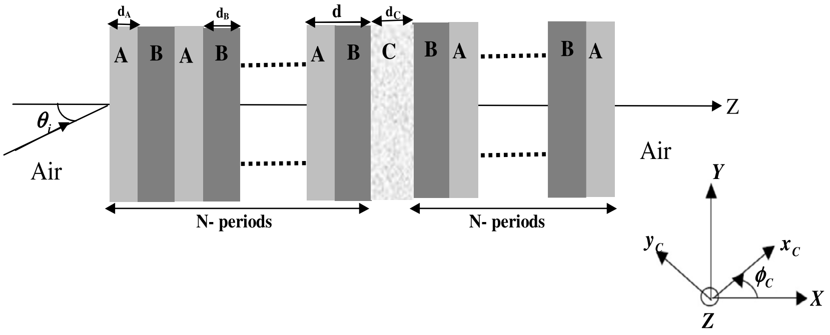

**Fig. 1.** Schematic representation of a finite 1D superlattice composed of 2N cells with an anisotropic defect cavity: $SbSI$ (layer $C$) in the middle of the structure. The unit cell of the perfect structure is composed by TiO$_2$ (layer $A$) and SiO$_2$ (layer $B$). The layers A, B and C are characterized by their thicknesses $d_A$, $d_B$ and $d_C$, respectively. The principal axes of the defect layer are oriented by the azimuthal angle $\phi_C$ with respect to the laboratory axes $(XYZ)$. $d = d_A + d_B$ is the period of the SL. The input and output isotropic media are air and the incident electromagnetic wave is launched with an angle $\theta_i$ with respect to the normal to the superlattice.

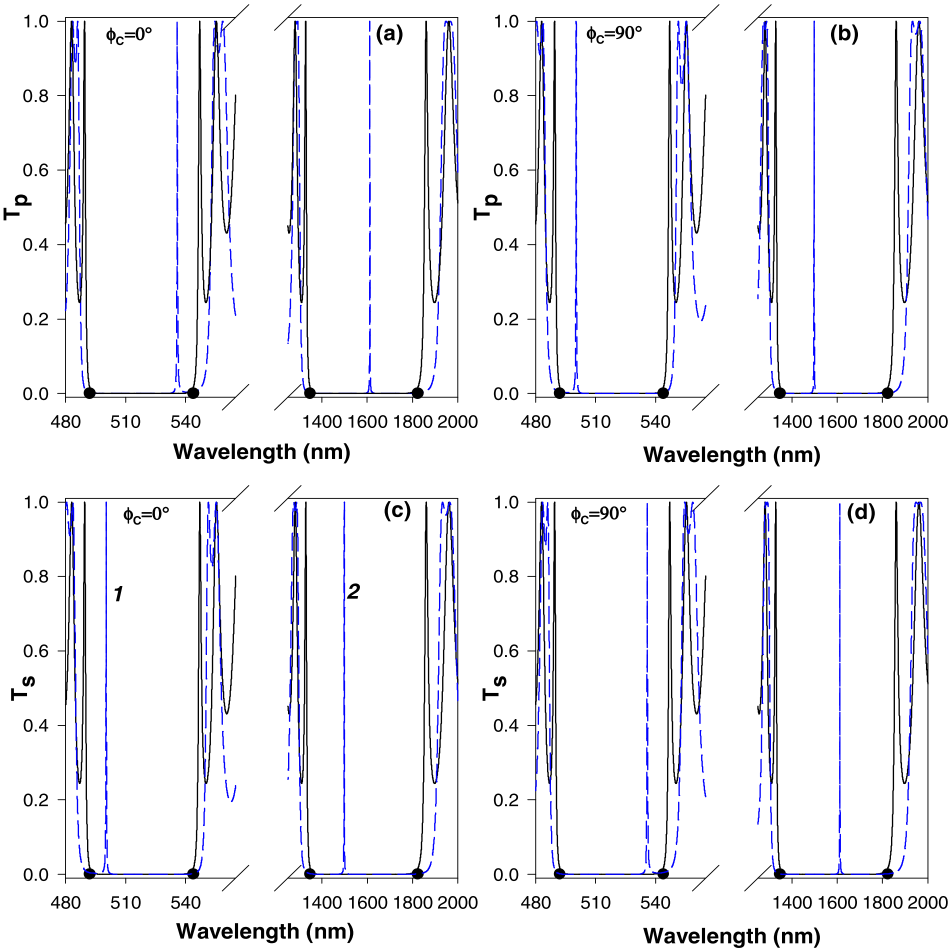

**Fig. 2.** Variation of the transmittances $T_P$ (a, b) and $T_S$ (c, d) as a function of the wavelength $\lambda$ for $\phi_C = 0°$ (a, c) and $\phi_C = 90°$ (b, d). The solid and dashed lines correspond to the perfect and defective structures, respectively. The black dots on the $\lambda$-axis represent the edges of the band gaps of the infinite isotropic SL. The incidence angle of the incoming light is $\theta_i = 0°$.

green color filters. The green and red color filters were studied by Xiang et al. [18].

Superconductor material and liquid crystal are among potential materials to serve as defect layers in tunable photonic devices, as their optical properties can be controlled by external excitation. Indeed, Wu and Gao [16] have studied the effect of the temperature on the defect modes in a 1D dielectric PC heterostructure with a superconducting defect. They have shown that this structure has very high temperature sensitivity. Dadoenkova et al. [19] have investigated PBG spectra of a 1D dielectric PC with a complex defect layer, consisting of ultrathin superconducting and dielectric sublayers. Recently, some research works [20–23] have investigated the effect of an electric field on the defect modes induced by a liquid crystal defect layer (anisotropic medium) or by an Ag/LiNbO$_3$/Ag sandwich structure into 1D PC [22,23]. Tang el al. [24] have explored the influence of the anisotropy of the single-negative material on photonic band gaps and tunneling modes of 1D PCs containing dispersive anisotropic single-negative metamaterials. Penninck et al. [25] have studied the emission of light in uniaxially anisotropic thin film devices. This emission is performed