Nonreciprocal transmission through 2D magneto-photonic crystal

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A combination of unique magneto-optic (MO) non-reciprocity and photonic band gap in periodic structures is promising for efficient enhancement of optical isolation [1,2]. One very interesting concept that appears by combining magneto-optics and photonic crystal (PhC) effects is the possibility to obtain one-way band gaps [3]. We have recently theoretically proven the existence of such unidirectional regimes for TE modes in 2D integrated uniformly transversely magnetized magneto-optic photonic crystals [1].

In this paper we model and optimize rectangular magnetophotonic crystal structure shown on Fig. 1. This precise motif symmetry with its purely rectangular features is perfectly adapted for RCWA modelling. Its Brillouin zone along with its irreducible part is given in Fig. 1. The right pane shows the impact of the symmetry reduction on the resulting isofrequency contours in the Brillouin zone. These have been calculated using a standard plane wave expansion technique taking into account the anisotropic nonreciprocal character of the permittivity [4]. The model uses transparent magneto-optic material in transverse geometry (Bismuth iron garnet (ε_{xx} = 6.25 and ε_{yz} = 0.1 i) at wavelength λ = 1300 nm). We have plotted a single isofrequency contour (reduced frequency f^* = 0.4545) of the second photonic band at a frequency halfway those of the now non-degenerate K and K points. As expected from the symmetry arguments elaborated in the left panel of the Figure, a local interior gap without inversion symmetry in the reciprocal space opens up. This makes for an extremely compact one-way mirror that can be used as for instance a novel integrated isolator.

Transmission through the finite magneto-photonic crystal was modeled using Rigorous Coupled Wave Analysis (RCWA). Optical field in the anisotropic structures containing a periodic grating can be on the basis of Bloch theorem expressed using a Fourier expansion into plane waves [5-7]. In the following we consider the structure with the period of Λ = 590.85 nm (f^* = Λ/λ = 0.4545), the angle of incidence φ = 17.94 ($N_y = n \sin \varphi$ = 0.693), and the filling factor of the air holes f = 0.4. In backward direction the transmission rapidly decreases (reach value 10^{-5} for 22 double periods of air holes), which corresponds to exponential decay of optical field and photonic bandgap behavior. However in forward transmission we obtain value of 30%, which can be more optimized. Figure 2 shows calculated field (the x-component of the magnetic field H_x) inside the structure. Left subplot shows the complete structure of 22 double-periods of air holes in forward and backward regime. Note that the color scale is logarithmic to visualize strong decrease of the field in backward direction. In the forward direction (structure is illuminated from the top) the optical field is amplified in the structure and the structure is partially transparent (orange color on the bottom). However, in backward direction (illumination from the bottom) the field is exponentially decreasing and the photonic structure block the transmission (blue color on the top). Right subplot shows a detail of the field distribution in the central area of the structure. It is clearly visible that the field is concentrated in between air holes.

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Figures

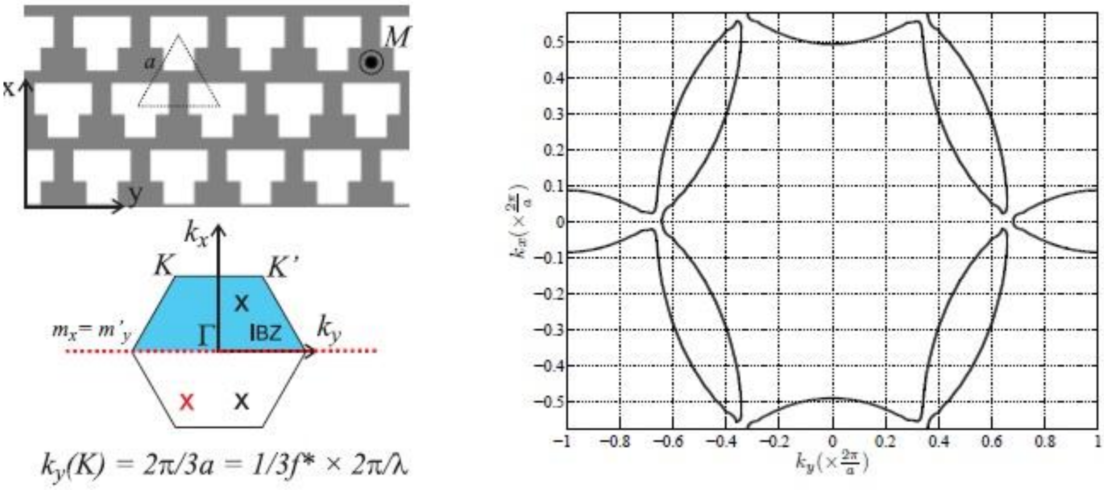

Figure 1. Scheme of photonics crystal structure in real and reciprocal space (left panel). The isofrequency contour at a reduced frequency of $f^* = \lambda = 0.4545$ of the uniformly magnetized MO PhC.

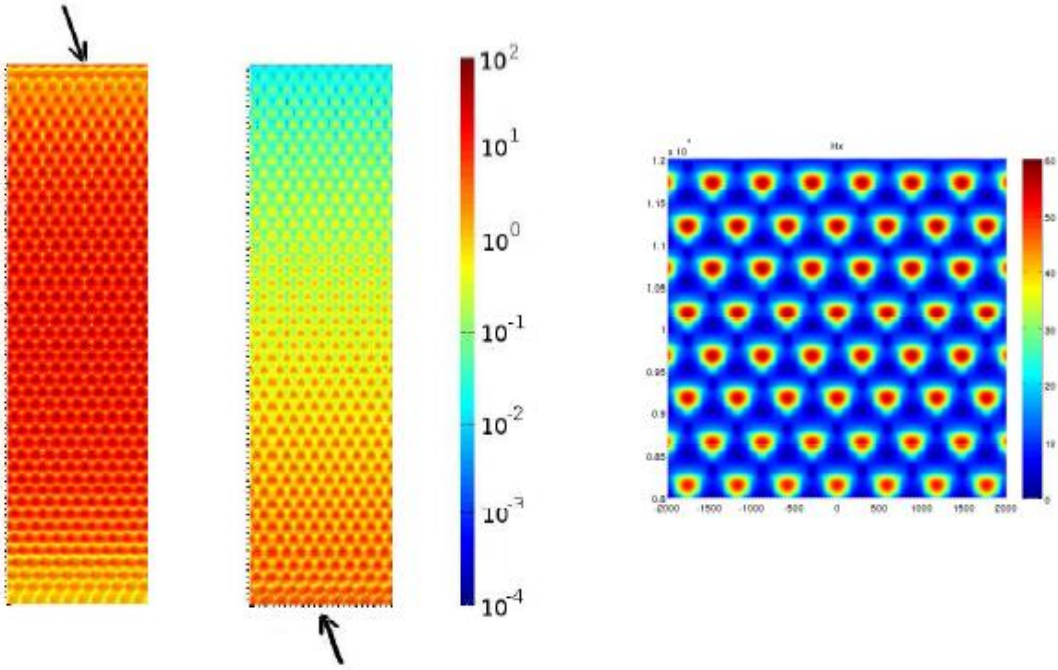

Figure 2. Field in the photonic-crystal structure