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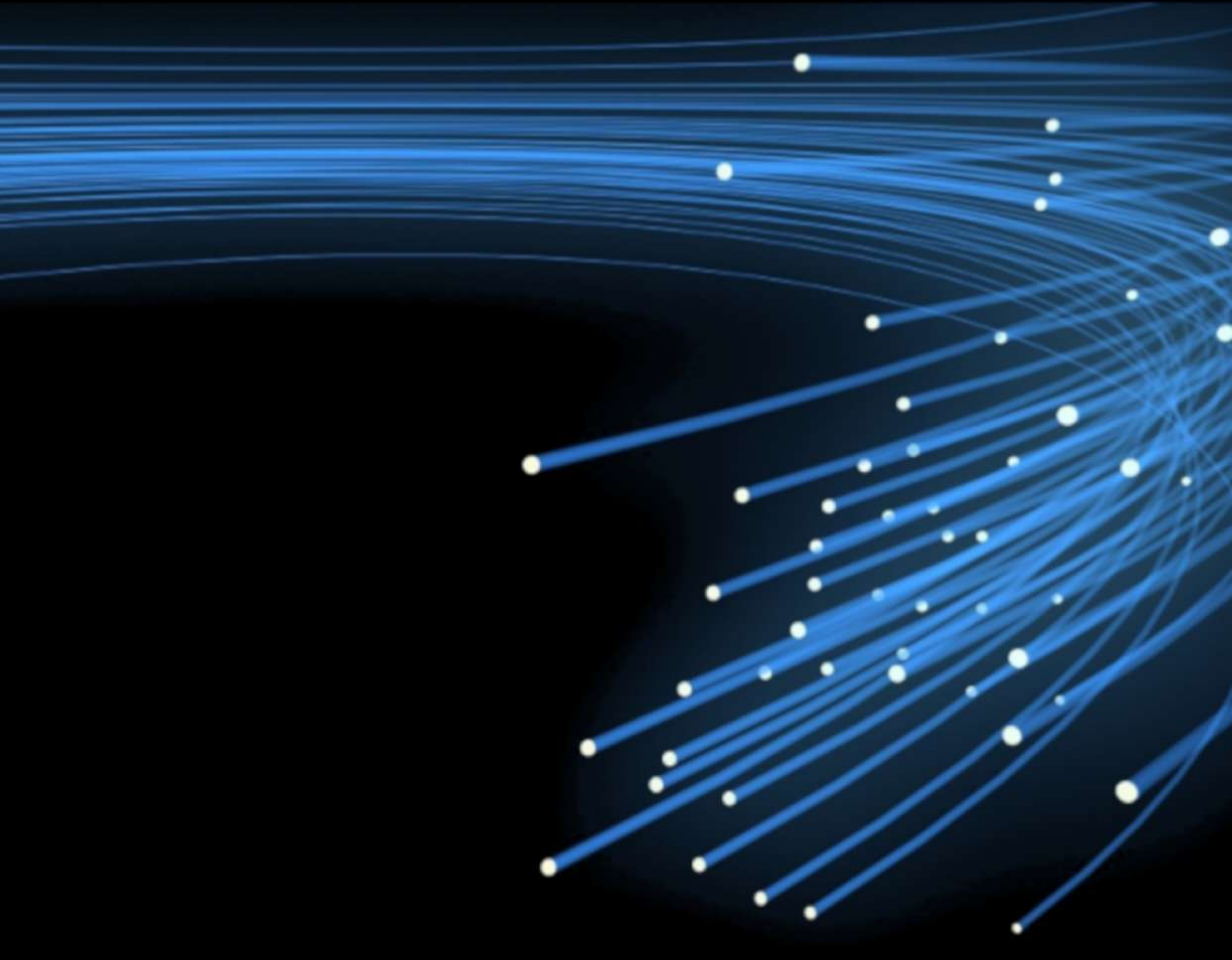

## Proceedings

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# Spin waves and electromagnetic waves in photonic-magnonic crystals

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## Abstract

In the periodic structures combining the ferromagnetic and dielectric elements, both the spin waves and electromagnetic waves can propagate characterized by the dispersion relations with magnonic and photonic band gaps (MBGs and PBGs), respectively. These hybrid structures called photonic-magnonic crystals (PMCs) can be used to enhance the magneto-optical interactions. We calculated the MBG and PBG structures in 1D PMC and discussed the enhancement of Faraday rotation and cross-polarized contribution to Goos-Hänchen shift resulting from the periodicity in the structure under consideration.

## 1. Introduction

In this paper, we are considering a new type of 1D structure of similar type in which the periodically arranged magnetic layers (constituting a magnonic crystal (MC)) are spaced by dielectric multilayers (finite-size dielectric photonic crystal (PC)). Thus, the whole system has a double periodicity, which generates complex PBGs and MBGs. Its multifunctional properties manifest themselves by the possibility of simultaneous propagation of both electromagnetic waves (EMWs) and spin waves (SWs) [1-3].

In the considered structures the EMWs can be highly localized in magnetic layers when their frequencies correspond to the frequencies from the stop band of the finite-size PC. For such modes we can observe enhancement of magneto-optical (MO) interaction (resulting e.g. in the increase of Faraday rotation) and we expect to find the noticeable interaction between the SWs and the EMWs.

## 2. Photonic-magnonic crystal

The exemplary structure of 1D PMC is presented in Fig.1. We considered the structure where the dielectric ferrimagnetic layers (made of yttrium iron garnet (YIG)) are separated by nonmagnetic $SiO_2/TiO_2$ multilayers. The dielectric multilayers $SiO_2/TiO_2$ are thin enough to couple dipolar SWs in YIG layers. We investigated the case when the magnetization is saturated and oriented in the plane of the YIG layers which are, on the other hand, transparent for EMWs.

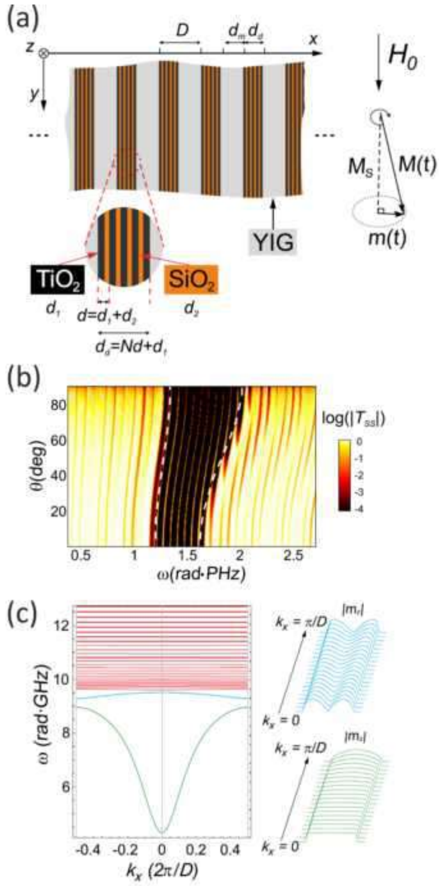


Figure 1: (a) The considered 1D PMC acting as magnonic and photonic crystal. The parameters $d_m$, $d_d$, and $D=d_m+d_d$ denote the thicknesses of the magnetic, or complex non-magnetic layers, and the period of the whole structure, respectively. (b) The transmittivity spectra $\log|T_{SS}|$ of a PMC with dielectric composite layers of structure $(TiO_2/SiO_2)^N$ with $N=5$ subperiods as a function of the incidence angle and frequency of the EMW. The dotted lines denote the PBG edges for the infinite dielectric PC with the unit cell ($TiO_2/SiO_2$) (for the details see [1, 2]). (c) The SW dispersion and profiles in YIG layer.

For the structure presented in Fig.1 we found the dispersion relations of dipolar SWs in simple 1D layered MC and the dispersion relations of the EMWs for complex PMC where the double periodicity is manifested in the splitting of the bands of $SiO_2/TiO_2$ PC into minibands and in the presence of weakly dispersive bands of the modes in the PBG of $SiO_2/TiO_2$ PC [1]. We call these modes as inside-PBG modes. The similar problem was investigated for a PMC with complex unit cell which contains two magnetic layers with different thicknesses [4].

## 3. Faraday rotation and Goose-Hänchen effects in photonic-magnonic crystal

We analyzed theoretically the Faraday rotation (FR) and the Goose-Hänchen (GH) effect (lateral shift of the transmitted Gaussian wave packet) for the near-infrared electromagnetic beams in PMC. These effects can be enhanced for inside-PBG modes which are confined in the magnetic layers. The presence of the linear magnetoelectric coupling in the magnetic layers can result in a significant increase of the FR (see Fig.2c) and in a vanishing of the positive maxima of the cross-polarized contribution to the GH shift (see Fig.3b).

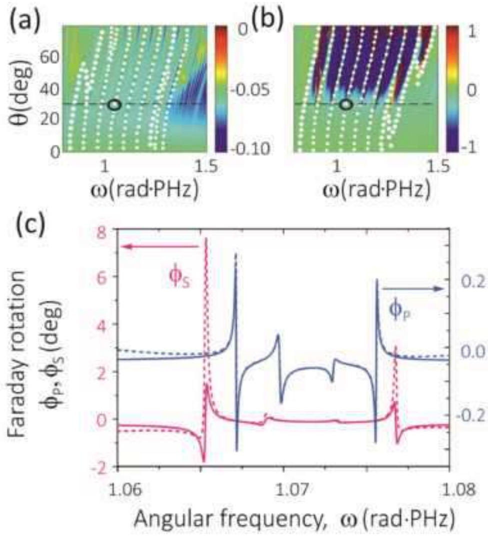


Figure 2: The evolution of the FR angles of (a) *p*-polarized and (b) *s*-polarized incident light, respectively, with frequency $\omega$ and incidence angle $\theta$ for the photonic structure $[M(AB)^4A]^5M$ (where M is YIG layer and A,B are $SiO_2$, $TiO_2$ layers.) The white dots depict the positions of the PBG edges and the inside-PBG modes. (c) Fine structure of the FR angles in dependence on frequency for selected inside-PBG modes at the incidence light angle $\theta$=30 deg. Blue lines (pink lines) correspond to *p*- (*s*-) polarized light. We considered the magneto-electric constant $\alpha = 0$ (solid lines) and $\alpha = 30$ ps·m$^{-1}$ (dotted lines) [4].

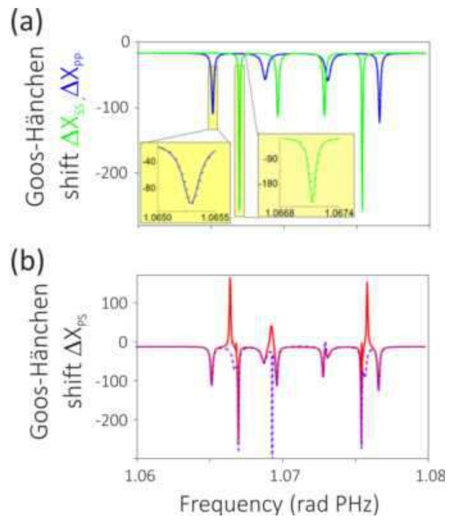


Figure 3: The GH shift vs frequency for (a) *s-s*, *p-p* transmission and for (b) *p-s* (*s-p*) transmission for selected inside-PBG modes at the incidence light angle $\theta$=30 deg. We considered the same structure as in Fig.1 and Fig.2 for the cases when the magneto-electric constant $\alpha = 0$ (solid lines) and $\alpha = 30$ ps·m$^{-1}$ (dotted lines) [5].

## Acknowledgements

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