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Boosting Faraday rotation in a one-dimensional coupled resonator magnetoplasmonic structure made by silica matrix doped with magnetic nanoparticles

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Abstract

The present study aimed to evaluate the magneto-optic Faraday rotation of one-dimensional coupled resonator magnetoplasmonic structure by metallic cover layer in each resonator. To this purpose, transfer matrix method was used where crystals made by SiO2/ZrO2 or SiO2/TiO2 doped with magnetic nanoparticles using sol-gel process in different configurations and use and 10-nm thick gold or silver layer for the excitation of the surface plasmon polaritons (SPPs). Tamm plasmons are surface modes that result from forcing the field to be confined at the metal-dielectric interface via a method different than total internal reflection. Optical Tamm states can be formed in both the TE and TM polarizations. Based on these modes, a wide range of wavelengths is detected by which the figure of merit increases due to the interaction of light with Tamm plasmons and surprisingly the flat optical window in this region in addition to the main resonance. These structures can open a new gate for enhancing performance of the magneto-optic devices.

1. Introduction

To achieve new functionalities, multilayer's magneto-photonic crystals have attracted a great deal of attention due to their applications in designing and constructing magneto-optical devices like as modulators [1], sensors, wavelength division multiplexing [2], isolators and the like . In these structures, reaching a high and multi-channel magneto-optical (MO) rotation accompanied by enhanced transmission plays a significant role in motivating scientists to design waveguides based on these structures. In this regard, decreasing the total thickness introduced as one-dimensional coupled resonator magneto photonic crystals (1D-CRMPC) is regarded as one of the main waveguides which can help the researchers to reach the objective [3]. This efficient structure is designed based on the famous coupled resonator optical waveguide and formed by placing MO resonators in a linear array in order to guide light from one end of the chain to another by photon hopping between adjacent resonators. In these structures, each resonator consists of dielectric and magneto-optical layers. Photons can hop from one tightly confined mode to the neighboring mode due to their weak interaction and accordingly the electromagnetic waves propagate through coupled cavities. Furthermore, due to the strong optical confinements in resonators, 1D-CRMPCs allow low group velocity at the photonic bandgap (PBG) zone, yielding an enhanced MO rotation.

Recently, the combination of plasmonics with other material properties has become increasingly appealing. In particular, magnetoplasmonics and magnetophotonics are emerging areas that aim at combining magnetism, plasmonics and photonics to find new ways of controlling the properties of plasmons using magnetic fields or vice-versa, to control magnetic properties with light. The enhancement of optical confinement in nanometer scale and accordingly light-matter interactions and increased MO rotation are made possible by plasmonics in other new categories named as magneto-plasmonic structures In these structures, plasmonic media like noble metal nanostructures play an important role to offer interesting possibilities when combined with the MO media to confine and enhance electric fields and finally magneto-plasmon activity. A large number of studies have been reported on the use of localized surface plasmon resonance, propagating surface plasmon and Tamm plasmons (TPs) as non-propagating surface states.

In the present study, a new structure is introduced based on the combination of plasmonic media and 1D-CRMPC structure as one-dimensional coupled resonator magneto photonic crystals (1D-CRMPC) to evaluate the effect of MO response of this new structure.

2. 1D-CRMPC structure

one-dimensional coupled resonator magneto photonic crystals (1D-CRMPC) is formed by placing alternation of magneto-optical layers (SiO2/ZrO2 or SiO2/TiO2) doped with magnetic nanoparticles using sol-gel process with a high refractive index and low index air layers. The central layer corresponds to a defect that allows light to pass through the center of the photonic band gap. Our structure consists of a thin layer of gold, a metal that exhibits both a plasmonic behavior, on end of a 1D coupled resonator magneto photonic crystals (Fig. 1).

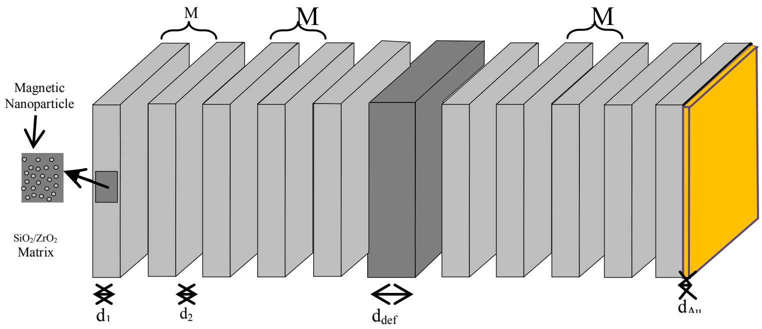

Figure 1: Schematic of 1D photonic crystal structure made with magneto-optic layers with one defect.

The structure is characterized by a background index of 1.57 and an air-to-air refractive index = 1. The thickness of the layers of material is d 1 = 258 nm and the gap width is d 2 = 387 nm with (a = d1+d 2). The central layer corresponds to a defect characterized by a width (d def = 2*d1). Fig. 1 illustrates the 1D-CRMPC structure used for the study

In the representation Fig. 2 (a) we have demonstrated the presence of photonic bandgap in 1D photonic crystals compound of SiO 2 /ZrO 2 or SiO 2/TiO2 made by sol-gel process.

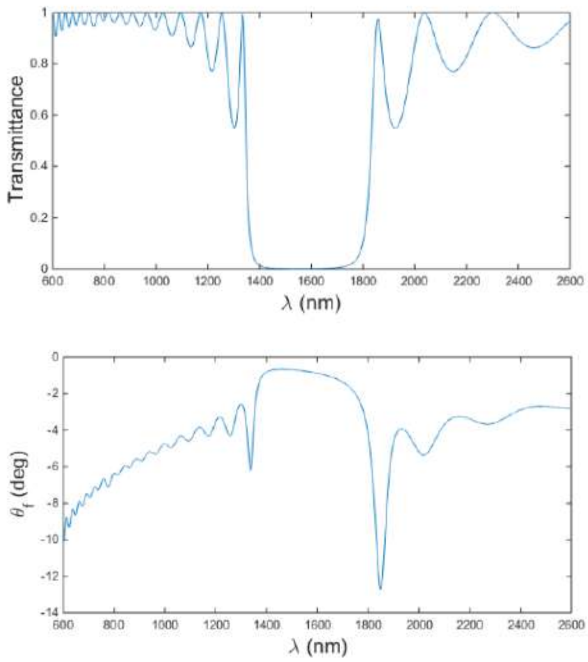

Fig. 2 Transmittance (a) and the Faraday rotation (b)spectra of 1D photonic crystal made with magneto-optic layers without defect.

In the representation of the transmission spectrum (Fig. 2(a)), we distinguished the existence a photonic bandgap in the NIR region from 1400 nm to 1800 nm with a band gap of about Δλ = 400 nm.

In Fig. 2 (b) there is an increase in the value of the Faraday rotation at the edges of the photonic band gap. Indeed, a first peak is observed at the lower edge towards a wavelength of 1400 nm and a second larger peak is observed at the upper edge towards a Wavelength of 1800 nm. These enhances are because of optical Borrmann effect [4]

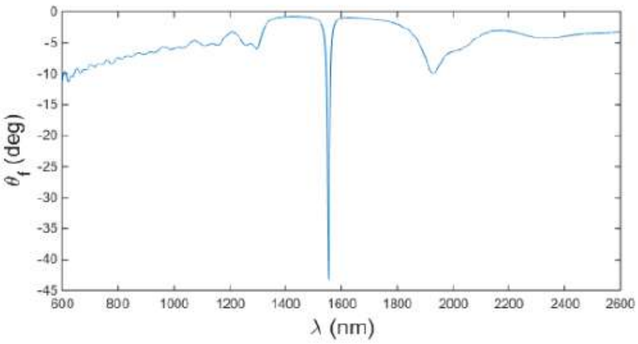

Figure 2: The Faraday rotation spectra

In order to investigate the properties of photonic band gap and defect mode(s) of the structure regarding the various magneto-optical defect layer positions, we produced the Fig. 2. This figure shows the transmittance and Faraday rotation spectra of the considered structure.

3. Conclusions

In this paper , we represent a new design for magneto-photonic crystal platform. We have used a new kind of artificial magneto-optical materials (SiO2 /ZrO2or SiO2/TiO 2 matrix doped with magnetic nanoparticles) in magneto-photonic crystals as a magnetic defect layer , haracterized by Low refractive index material 1.51. This magnetic layer can be realized by sol-gel process. The present study aimed to evaluate the effect of metallic cover layer on the MO Faraday rotation, ellipticity, transmittance, along with the phases of one-dimensional coupled resonator and coupled resonator magneto-optical waveguide.

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