# Boosting faraday rotation in a one-dimensional coupled resonator magneto-plasmonics structure made by silica matrix doped with magnetic nanoparticles

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**ABSTRACT** The study aims to evaluate the Faraday rotation of one-dimensional structure coupled resonator magneto-plasmonics by a metal cover layer. To this purpose, we used SiO2/ZrO2 or SiO2 /TiO2 crystals doped with magnetic nanoparticles by sol-gel process in different configurations and a gold layer of 10 nm thick for the excitation of the surface Plasmon Polaritons (SPPs). Based on Tamm plasmon, a wide range of wavelengths is detected by which the merit factor increases due to the interaction of light with the Tamm plasmon and surprisingly the optical window in this region in addition to the main resonance. These structures offer the opportunity to improve the performance of magneto-optical devices.

**INDEX TERMS** One-dimensional magneto-plasmonics crystals (1DMPCs), Micro-cavity, Faraday rotation effect

## I. 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 photonics 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 photonics band gap (PBG) zone, yielding an enhanced MO rotation. Recently, the combination of plasmonics with other material properties has become increasingly appealing. In particular, magneto-plasmonics and magneto-photonics are emerging areas that aim at combining magnetism, plasmonics and photonics to find new ways of controlling the properties of plasmon 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. Many studies have been reported on the use of localized surface plasmon resonance, propagating surface plasmon and Tamm plasmon (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 photonics crystals (1D-CRMPC) to evaluate the effect of MO response of this new structure.

## II. 1D-CRMPC STRUCTURE

One-dimensional coupled resonator magneto photonics crystals (1D-CRMPC), consists of a multilayer structure in

periodic lattice (M) ($SiO_2/ZrO_2$ or $SiO_2/TiO_2$) doped with magnetic nanoparticles with air gaps, of period $a = 0.70$ µm.
The structure is characterized by a background index of 1.51 to 1.57 and an air-to-air (refractive index = 1).
The thickness of the layers of material is $d_1$ and the gap width is $d_2$ with ($a = d_1 + d_2$).
The central layer corresponds to a defect that allows light to pass through the center of the photonics 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 photonics crystals (Fig. 1).

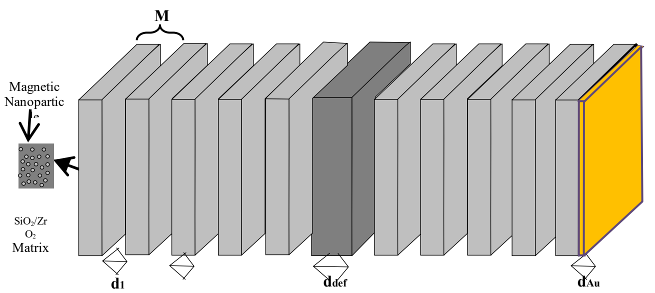
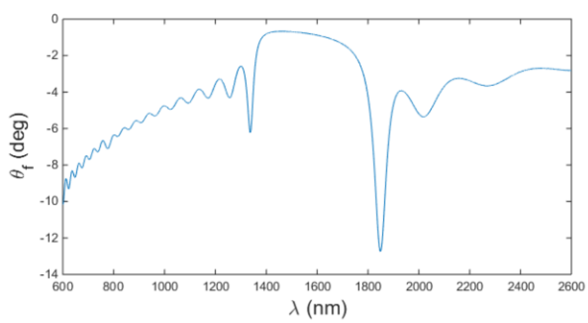



FIGURE 1. Schematic of 1D photonics crystal structure made with magneto-optic layers with one defect.

The thickness of the layers of material is $d_1 = 0.258$ µm and the gap width is $d_2 = 0.387$ µm with ($a = d1+d2$). The central layer corresponds to *a* defect characterized by *a* width ($ddef = 2 \times d_1$), and the gold layer thick $d_{au}$=10 nm.
Figure.1 illustrates the 1D-CRMPC structure used for the study.
In the representation Fig. 2 (a) we have demonstrated the presence of photonics band gap in 1D photonics crystals compound of $SiO_2/ZrO_2$ made by sol-gel process.

(a)




(b)

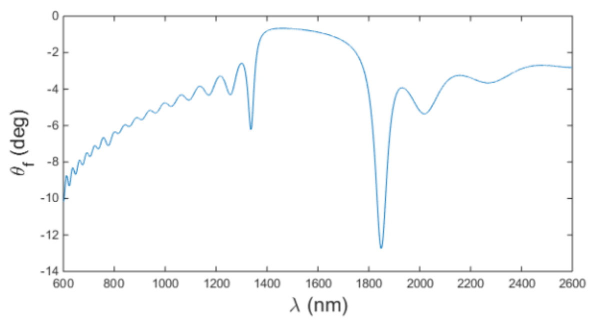



FIGURE 2. Transmittance (a) and the Faraday rotation (b) spectra of 1D photonics crystal made with magneto-optic layers without defect [4].

In the representation of the transmission spectrum (Fig. 2(a)), we distinguished the existence a photonics band gap in the NIR region from 1400 nm to 1800 nm with a band gap of about $\Delta\lambda = 400$ nm.
In Fig. 2 (b), there is an increase in the value of the Faraday rotation (θf) at the edges of the photonics 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. This enhances are because of optical Borrmann effect [5-8].
In order to study the effect of the gold layer on the photonic band gap and the Faraday rotation, the simulations are carried out under the Rigorous Coupled Wave Analysis (RCWA) (RSoft Design Group, Diffract Mode, Inc. 200 Executive Blvd. Ossining, NY 10,562), to produce Figure 3 and Figure 4.

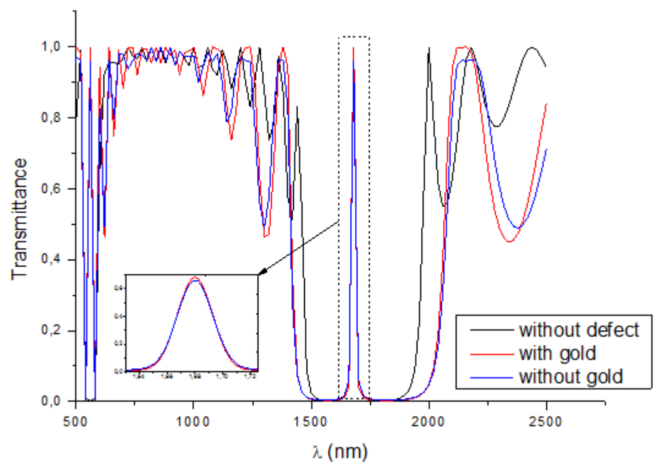



FIGURE 3. Transmittance spectra of 1D photonics crystal made with magneto-optic in different configurations.

Fig.3 In the representation of the spectral transmission, curves we distinguish the existence of two photonic bandgaps. The first photonic band gap is in the visible region with a range (562 nm -585 nm) and the second is in the NIR region from 1500 nm to 1950 nm.

The results obtained for this case show us an improved transmittance spectra for the considered structure in figure 1 compared to the results obtained in the different structure carried out.

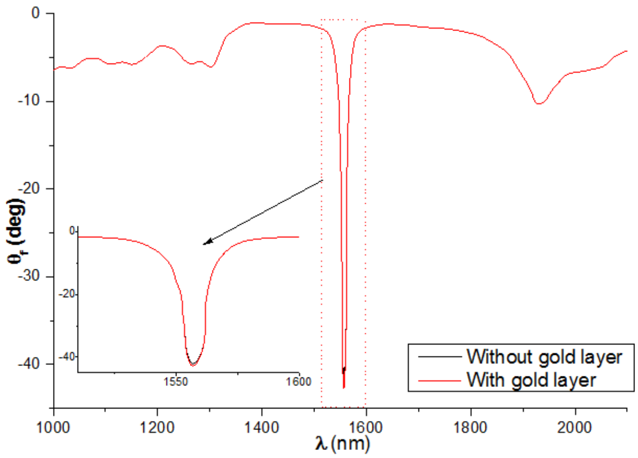



FIGURE 4. The Faraday rotation spectra

Fig. 4 Shows the Faraday rotation (θf) spectra of 1D-CRMPC made with magneto-optic of the structure represented in Figure 1. From the spectral representation obtained, an increase in the value of the Faraday rotation is observed in the photonic bandgap. Indeed, the value of the Faraday rotation is greater than that of the reference layer.

## V. CONCLUSION

In this paper, we represent a new design for magneto-photonic crystal platform. We have used a new artificial magneto-optical materials ($SiO_2/ZrO_2$ matrix doped with magnetic nanoparticles) in magneto-photonic crystals as a magnetic defect layer. 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. The value of the transmittance in the bandgap and the Faraday rotation are sensitive to the concentration of magnetic nanoparticles VF% of the structures, to the photonic crystal cavity and to the presence of gold layer.

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