Proposal for integrated optical isolator at visible wavelength on silicon nitride waveguide platform

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Abstract: We propose an integrated optical isolator for the visible region of electromagnetic spectrum using silicon nitride waveguide platform. Nonreciprocal phase shift (NRPS) for two different integration routes of Ce-YIG on SiN waveguide is shown.

Optical isolator is an essential component of photonic integrated circuits (PICs) which allows light to propagate in a particular direction but blocks the light propagation in the opposite direction. Spurious reflection into laser cavity has detrimental effects on its stability and lifetime. Therefore, inserting an isolator in front of a laser is paramount important. Although several approaches to achieve optical isolation including the use of non-linear effects [1] or active modulation [2] exist, isolator utilizing magnet-optic (MO) effect is one of the most attractive solutions since it is passive and broadband in nature. In planner waveguide-based devices nonreciprocal phase shift (NRPS) is utilized to realize an optical isolator. This NRPS is arises due to magneto-optic interaction between light and magnetic material under the influence of an external magnetic field ($\vec{B}$).

Most of the optical isolator research so far has been focusing on communication wavelength bands (O and C-bands). However, PIC at visible wavelength band (400 – 700) nm is getting tremendous interest due to many potential non-telecom applications namely, in life science and medical areas. Therefore, optical isolator at this wavelength range is also very important. Not only 2-port optical isolator, other kind of nonreciprocal devices with multiple ports such as circulator are also going to be important for future PICs. Here we propose a design for an optical isolator which can be integrated on silicon nitride (SiN) waveguide platform by micro-transfer printing. In earlier MO-based isolator demonstrations MO materials were bonded on top of Mach-Zehnder interferometer (MZI) [3] or ring-resonator [4]. Here we have seen from simulation that when MO material is acting as a waveguide (butt-coupling), the MO interaction enhanced significantly than the evanescently coupling case.

Schematics in Fig. 1 depicting two scenarios. In our push-pull type MZI-based isolator, Ce:YIG block will be inserted between the SiN waveguides. A high-quality thin-film of Ce:YIG will be placed onto a predefined slot in SiN waveguide employing transfer printing technology. For guiding light a rib strucuture will be define afterwards by lithography and etching. Width and thickness of both layers are 800 nm and 200 nm, respectively. To minimze the reflection loss from the gap, an index matching material will be deposited. Anti-parallel magnetic field will be applied to bias the MO material.

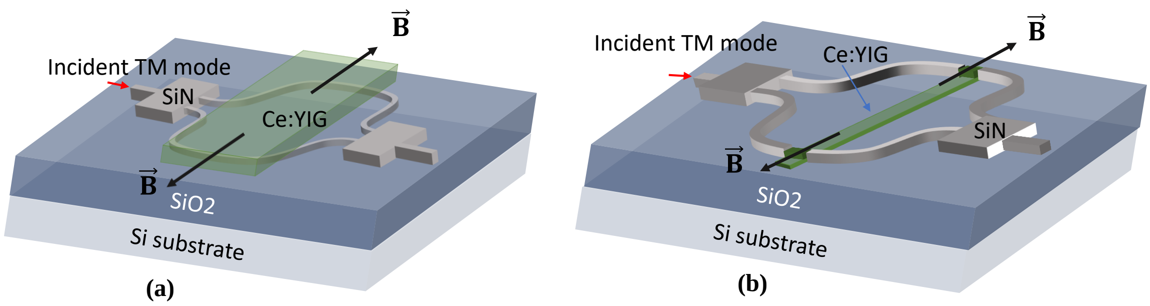

Fig. 1. Schematic of (a) conventional integrated isolator with MO material on top of optical waveguide and (b) proposed butt-coupling scheme where MO material is acting as a waveguide instead.

It is seen from the simulation that the magnitude of NRPS increases significantly due to higher coupling of mode from SiN waveguide to Ce:YIG. As the value of NRPS depends on the confinement of the mode in Ce:YIG, which is better in the second case.

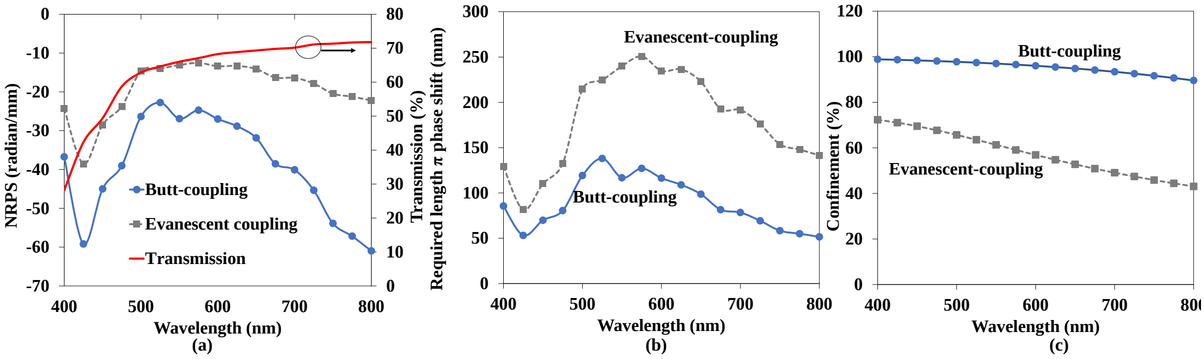

Fig. 2. (a) Non-reciprocal phase shift (NRPS) and Transmission vs wavelength. (b) Required length for NRPS vs wavelength. (c) Confinement of the mode in Ce:YIG vs wavelength.

Figure 2 shows NRPS at various wavelengths for two cases along-with the optical transparency for this material. Faraday rotation and optical transmission values are taken from the reference [5]. The Faraday rotation values for the wavelengths red, green and blue are 21903 degree/cm, 17243 degree/cm and 33823 degree/cm respectively. Length required for π NRPS at green region of the wavelength is around 125 μm which is about 5 times smaller than silicon-based 1550 nm isolator. Noteworthy to mention that, shorter device is highly desirable at this wavelength band since optical transparency decreases as compared to telecom wavelength.

Figure 2(c) shows the confinement of the mode in the MO material with wavelength. As seen from the graph, the mode is fully confined in butt coupling which yields a higher value of NRPS than evanescent coupling, which even drops with wavelength. Shorter device will ensure the accetable figure-of-merit (expressed as radian/dB). This initial simulation results pave the path towards compact optical isolator at visible wavelength.

References

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