Monolithically Integratable Optical Isolators with Semiconductor / Ferromagnetic Metal Hybrid Waveguide

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1. Introduction

Optical isolators are one of the indispensable devices to protect semiconductor laser diodes (LDs) from backward reflected light in integrated optics. In order to realize optical isolators, nonreciprocal propagation of light (breaking of time inversion symmetry) is necessary, which can be realized by magnetic materials. Conventional optical isolators are composed of Faraday rotators and two polarizers. Ferrimagnetic garnets are widely used as magneto-optic materials exhibiting Faraday rotation. However, these optical components are not compatible with integrated optics. Therefore, semiconductor optical isolators for integrated optics have been strongly desired. Recently, these integrated optics have been expected on Si as well as III/V waveguides in order to integrate them with electronic driving circuits in optical transmitters and receivers. Semiconductor optical isolators, where semiconductor and ferromagnetic materials are integrated, are one of the most important applications in spin-optics.

2. Principle of Operation

We have developed semiconductor optical isolators based on nonreciprocal loss, where the ferromagnetic metals are deposited on semiconductor optical amplifier (SOA) waveguides. Ferromagnetic metals provide the optical isolation owing to the transverse magneto-optic Kerr effect, and the SOA gain compensates the propagation loss by the ferromagnetic metals, as schematically shown in Fig. 1.

3. Experimental results

We have demonstrated optical isolation of 14.7 dB/mm [1], monolithic integration with LDs [2], and optical isolation with amplifying characteristics [3]. These advantages of semiconductor optical isolators are promising for integrated optics.

4. Prospect for larger optical isolation

Use of the surface plasmon excited at the boundary between the ferromagnetic metals and dielectric materials / semiconductor is one of the solutions in order to increase the optical isolation ratio, because the propagating light can be confined to the interface between the ferromagnetic metal and semiconductor. Zayets et al have found the enhancement of the transverse non-reciprocal magneto-optical effect and theoretically proposed plasmonic waveguide optical isolators having double dielectric materials, such as Co / SiO_2 / Si and Co / Al_2O_3 / AlGaAs [4]. We have estimated optical isolation of 0.18 dB/μm in a Co / Al_2O_3 / AlGaAs plasmonic waveguide [5].

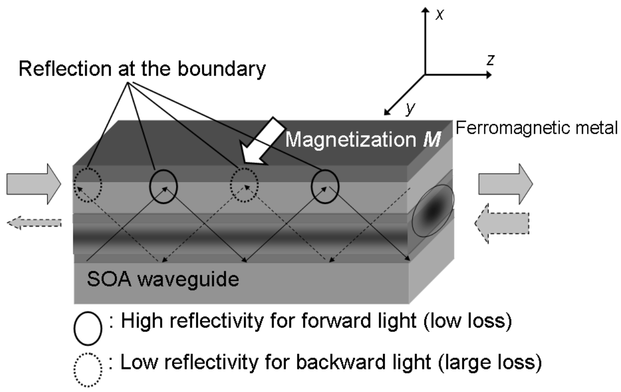

Fig. 1 A schematic image of transverse magneto-optic Kerr effect in the optical waveguide with ferromagnetic metal.

5. Conclusions

In summary, we have developed monolithically integratable optical isolators with semiconductor / ferromagnetic metal hybrid structures. We have found that the use of surface plasmon is one of the solutions in order to enhance the optical isolation.

6. Open Questions

- Use of noble metals (Au and Ag) is general to excite the surface plasmon. However, use of ferromagnetic metal in surface plasmon is one of the challenges in optics. Is it possible to excite surface plasmon at the semiconductor / ferromagnetic metal interface ?

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