Magnetophotonics and Their Applications

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Introduction of nano-scaled artificial structures into magnetic materials provides us a variety of opportunities for controlling light traveling in the media. Magnetophotonic crystals (MPCs)[1, 2] are classified into such materials, where optical-order periodic structures composed of magnetic and/or dielectric materials are introduced so as to create photonic band gap and to confine light in the vicinity of additional defects in the periodic structures. From one-dimensional (1D) (Fig.1) to 3-dimensional (3D) MPCs have been constructed actually, and among them, 1D or 2D artificial structures have been used and discussed in electronic and optical applications.

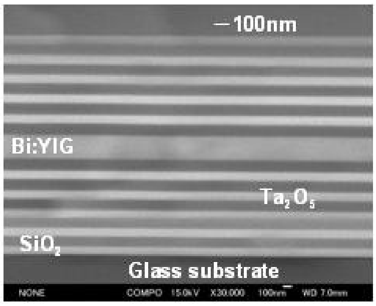

Fig.1 Cross sectional SEM image of a 1D magnetophotonic microcavity.

Magneto-optic (MO) spatial light modulators (MOSLMs)[3, 4] shown in Fg.2 are one of the applications of 1D MPCs. Spatial light modulator (SLM) is a real-time micro-device for modulating the amplitude (or intensity), phase, or polarization of optical waves as a function of the spatial position across the wavefront. Recent need of sophisticated SLMs enabling ultra-high speed modulation of light have resulted from the renewed interests in holographic data storage (Fig.3)[5] or 3-dimensional display, which necessitate high rate of data transfer. MOSLM meets the requirement, because of its ultra-high speed operation originating in the magnetization switching. Our recent studies[6] suggest that the microcavity structures with magneto-optic (MO) and electro-optic (EO) composite defects in Bragg mirrors are useful for realizing non-reciprocal light modulation without changing the magnitude or direction of magnetization. As shown in Fig.4, theoretical calculations revealed that very small change in voltage applied to the EO layer results in the large change in Kerr rotation angle or phase of light without modulating the magnetization. In the MO/EO microcavity structure, then, existence of permanent magnetization is not necessarily requested for MO modulation, and paramagnetic Verde material such as TGG and TAG is applicable. This is attractive for developing MOSLMs for blue light modulation, because the optical absorption of such Verde materials is generally small at short wavelength of light.

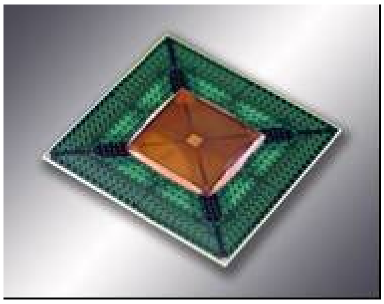
Fig.2 Magneto-optic spatial light modulator (FDK).

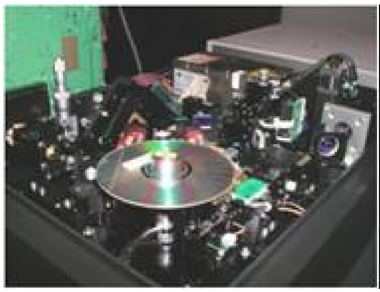
Fig.3 Collinear holography optical storage (Optware, Ecma standard)

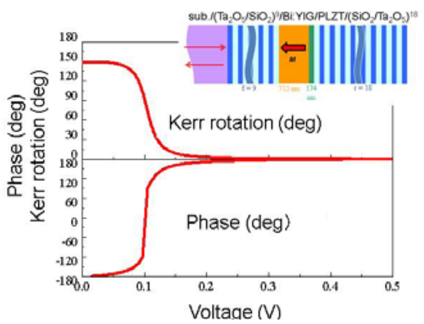

Fig.4 Kerr rotation angle (or phase of reflected light) as a function of the applied voltage to the thin EO layer. The inset upper right corner depicts the film structure used for the calculation.

Several applications of 2D structured MPCs are also discussed. Wang et al.[7] designed optical waveguide circulator devices with 2D MPC structures and showed that the device with 45 dB isolation can be realized. For real fabrication of the 2D MPC-based circulator element, however, the theoretically predicted structure was rather complicated. Recently, Yayoi et al.[8] calculated the fundamental properties of 2D MPC circulators whose structures were simple and feasible for constructing. They have also tried to form the element by utilizing focused ion beam (FIB) technique. As shown in Fig.5, Si-based PC with a ferromagnetic garnet nano-pole was constructed. Although 16 dB isolation was expected for this structure from the theoretical results, no localized mode of light at the magnetic defect was observed. This was due to the FIB formed imperfect air holes in Si waveguide, and the improvement of the fabrication accuracy is needed. For another 2D structures, several optical functions are also discussed[9,10] theoretically, and the experimental verification for those predictions are necessary.

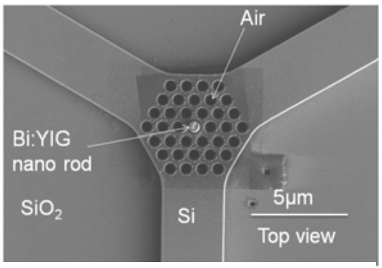

Fig.5 FIB-formed 2D MPC structure for Si waveguide circulator element.

Apart from MPCs, enhancement of MO Faraday and Kerr effects can be also achieved by utilizing the surface plasmon resonance (SPR)[11]: For instance, when Au nano-particles are embedded in magnetic garnet thin film, the Faraday rotation angle of film shows considerable enhancement at the SPR wavelength. This is also the case for Kerr rotation, suggesting that the MO responses might be manipulated by the use of localized evanescent field associated with the plasmon resonance. Several structures for the plasmon-assisted magnetophotonics have been proposed and discussed[12, 13]: Baryshev et al. discussed the use of surface states of light in MPCs for bio-sensing. They showed that the combination between Tamm state and SPR, or the combination between microcavity mode and SPR is effective in enhancing the sensitivity for bio-sensor applications.

At the conference, fundamental properties of magnetophotonic media and their applications will be presented mainly based upon our studies.

References

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