Characteristics of Magneto-Photonic Crystals based Magneto-Optic SLMs for Spatial Light Phase Modulators

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We demonstrate a newly developed magneto-photonic crystal (MPC) based magneto-optic spatial light modulator (MOSLM) which was designed to enhance the performance of a conventional MOSLM, and describe the preparation and fundamental properties of it. By introduction of MPC, the magneto-optical property of MOSLM was improved, and as driving properties, the saturation of brightness was shown around ±1 kOe and the change occurred from about ±300 Oe by external magnetic field. Also, we confirmed that Kerr rotation angle of this device was varied by applying voltage to PZT film. The change of each pixel by applying voltage, however, could not be detected because of the small variation of brightness.

Key words: magneto-optical property, MPC, MOSLM, PZT film, brightness

1. Introduction

Magneto-optic spatial light modulators (MOSLMs), which enable to modify the light amplitude, phase or polarization in a page data image, have been intensively studied for various applications such as optical correlators, optical computers, and holographic memories. The reason is that they are very fast solid-state SLMs with robustness and nonvolatility. The switching speed of MOSLM reaches to several GHz, while a conventional SLM has the switching speed less than MHz. In our previous experiments for accomplishing the stable driving properties of MOSLM we were confronted by two kinds of difficulties. First, in the case of current driving MOSLM, power consumption and heat generation was high because it requires high current\(^1\)). Second, the pixel contrast of MOSLM depends on the Faraday rotation angle of magnetic material. However, the value was not enough to display a change of image though superior magneto-optical materials were used. Accordingly, to solve these problems we have paid attention to a voltage driving MOSLM (vMOSLM) using magneto-photonic crystal (MPC) in which Faraday rotation angle is apparently enhanced by the light localization of magnetic defect layer\(^2,3\)). Here PZT piezoelectric material acts as a medium to give a stress to magnetic material for easy change of the magnetization direction by a low external magnetic field. In this study, as a first step, we describe the preparation and fundamental properties of MPC-based vMOSLM with Bi-substituted Dy-Y-Fe-Al garnet (Bi:DyYIG) film which has a high magnetostriction property.

2. Experimental

2.1 Fabrication of MPC-vMOSLMs

The Bi:DyYIG, SiO\(_2\) (90 nm) and Ta\(_2\)O\(_5\) (60 nm) were deposited by RF magnetron sputtering with controlling their thicknesses so as to obtain the localization of light at the wavelength around 532 nm. As shown in Fig. 1(a), the MPC has a reflection-type micro-cavity structure, where the Bi:DyYIG film (159 nm) deposited using RF magnetron sputtering using magneto-photonic crystal (MPC) in which Faraday rotation angle is apparently enhanced by the light localization of magnetic defect layer\(^2,3\)). Here PZT piezoelectric material acts as a medium to give a stress to magnetic material for easy change of the magnetization direction by a low external magnetic field. In this study, as a first step, we describe the preparation and fundamental properties of MPC-based vMOSLM with Bi-substituted Dy-Y-Fe-Al garnet (Bi:DyYIG) film which has a high magnetostriction property.
2.2 Measurement
For calculation and design of the structure of MPC-vMOSLM device, matrix approach method was used, and the magneto-optical and optical properties were investigated by a magneto-optic spectrometer (MO) and a spectrophotometer (UV), respectively. The variation of pixel brightness was observed by a polarization microscope with CCD camera.

3. Results and Discussions
3.1 Fundamental properties
Figure 2 shows Kerr rotation and reflectance of MPC-vMOSLM. From the figures, we can see that the localized mode of light appeared around the wavelength of 528 nm within a photonic band gap. However, this was slightly different from a desired wavelength, which was 532 nm, due to the disparity of thickness of magnetic film (calculated thickness: 166 nm). Therefore, it is apparent that the optimal fabrication is important to get a good agreement between calculation and measurement. Kerr rotation angle and the reflectance of MPC-vMOSLM fabricated were 8.3 degree and 20%, respectively, and Kerr rotation showed about 4 times higher than a MOSLM without MPC. Figure 3 shows the variation of Kerr rotation by applying voltage to PZT film. As can be seen from Fig. 3, Kerr rotation angle was changed more or less by applying voltage to PZT film. This result indicates that PZT gives a stress to Bi:DyYIG garnet film, and the magnetization of it is decreased by magnetostriction effect. However, it is not repeatable when 0V was applied again after applying 20V. It seems that a remaining stress due to the poling of PZT film affects the garnet material. Consequently, Kerr rotation cannot help decreasing because Kerr rotation has a relation intimately to the magnetization of magnetic material. Here, we can expect that the magnetization direction of Bi:DyYIG garnet film will be changed easily by lower external magnetic field compared to a current driving MOSLM.

3.2 Driving properties
Figure 4 and 5 show the change of pixel brightness by applying an external magnetic field. Brightness of each pixel was changed by an external magnetic field and the saturation of brightness was shown around ±1
kOe and the change occurred from about ±300 Oe. From Fig. 5, it is confirmed that the variation of brightness is in agreement with the Kerr rotation of MPC-vMOSLM. In the case of change of each pixel by applying voltage, it could not be detected because the small variation of brightness could not be verified adequately. However, it can be convinced that each pixel has been operated by applying voltage to PZT film as previously mentioned with experimental results.

Fig. 5 Comparison of Kerr rotation and brightness as a function of an external magnetic field.

3. Conclusion

We developed newly designed MPC-MOSLMs and investigated the preparation and fundamental properties of it. By introducing MPC, magneto-optical property of MOSLM was enhanced and the change of image observed certainly. Also, we confirmed that Kerr rotation angle of this device was varied by applying voltage to PZT film. However, the change of each pixel by applying voltage could not be detected because of the small variation of brightness. Consequently, in order to get much higher performance about this device, a study on the optimal fabrication condition, superior magnetic materials and a design should be performed.

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References


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