Artificial Magnetic Lattices and Their Optical and High Frequency Applications

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Artificial magnetic lattices (AMLs) introducing the artificial structure of the scale from a few 10 nm to several 100 nm show a novel magnetic functions attributed to their structures, so the studies utilizing these AMLs become an important engineering field. A magneto photonic microcavity (MPM) is a typical AML, in which transparent ferromagnetic garnet is sandwiched with two Bragg mirrors, and shows giant magneto-optical (MO) effect[1)]. This presents a feasibility of new optical media controlling its optical properties by spin. On the other hand, the magnoic crystals, in which the light of MPC is replaced with the spin waves in ferromagnetic material, can control the precession of spin of the magnetic material and show the magnonic band gap[2)]. In this symposium, these optical and high frequency applications using the artificial magnetic lattices are presented.

Holography is a key technology for three-dimensional (3D) displays, shape measurements, and high-capacity data storage. A holographic display is a realistic 3D display because it produces an exact copy of the wave front of scattered light from 3D objects[3)]. Recently, we developed a 3D magneto-optic spatial light modulator (3D-MOSLM) that had a two-dimensional magnetic pixel array with sub-micrometer-scale pixels for a wide viewing holographic display. A thermomagnetic recording with an optical addressing method is used to form sub-micrometer-scale magnetic pixel arrays without a driving line, and 3D image is reconstructed using the MO effect. The first 3D-MOSLM used an amorphous TbFe (*a*-TbFe) film as magnetic film[4)], but the brightness of reconstructed images was very low. To achieve bright 3D images, the magnetic film should have high transmittance and a large Faraday rotation angle, so we developed a 3D-MOSLM with MPM structure using the Bi substituted rare earth iron garnet (Bi:RIG) as a recording magnetic layer. As a result, as shown in Fig. 1 (b)-(d), we could achieve the reconstruction 3D image as bright as 100 cd/m^2 by using the designed 3D-MOSLM having a MPM structure with high diffraction efficiency[5)]. Another application of holography is the hologram memory that is a promising candidate for next data-storage technology with high recording densities of greater than 1 TB/disk. We have employed a collinear holographic system that can write and read data using a single optical axis with a spatial light modulator[6)]. Similar to 3D-MOSLM, we have also selected the Bi:RIG film as a recording medium, and succeeded to record and reconstruct data on the Bi:RIG film using the collinear holographic system as shown in Fig. 2(a)[7)]. However, the reconstructed image was dark and unclear due to the low diffraction efficiency of the garnet medium. To improve the diffraction efficiency, we again designed MPM structures for the recording media. Figure 2(b) and (c) show the reconstructed images from the usual single layer garnet film and the MPM medium[8)]. The image reconstructed from the MPM medium had approximately twice the brightness of that reconstructed from the single layer film. These mean that the MPM structure is very attractive recording media.

In addition to these optical applications, we also apply the AML structure to control the magnetostatic waves (spin waves), which is supported by the magnetostatic coupling of spins in a few GHz frequency region. An analogy of photonic crystal, when the propagation medium such as YIG have some periodicity, a magnonic band gap (MBG) can be observed for the spin waves. This MBG can be designed within a excitation frequency band by selecting the appropriate periodicity of the metal strips. We demonstrated experimentally the existence of the MBG using the sample with the one-dimensional periodic structure of Cu strip as shown in Fig. 3. As shown in Fig. 3(b), a clear and deep band gap was observed at approximately 3.00 GHz, and the frequency of the band gap is very sensitive to the magnetic field applied to the crystal[2)]. This high-Q MBG would be used for magnetic sensor. Similar to MPM, the localized mode of spin wave was also observed as shown in Fig. 3(d) by introducing a defect layer in periodic structure[9)]. These results indicate that we can manage the spin wave propagation in the same manner as the light in photonic crystals using AML structure although we have to consider the effect of shape magnetic anisotropy of the spin-wave waveguide.

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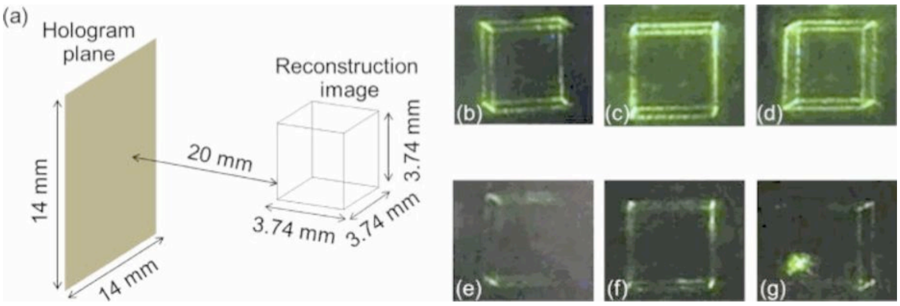

Fig. 1 (a) A model of 3D image for generating the hologram. The wireframe cube was constructed by point light sources. (b)–(d) Reconstructed images from MPC and (e)–(g) those from *a*-TbFe for comparison. The images of (b) and (e) were from left view point of 11°, (c) and (f) were from center, and (d) and (g) were from right view point of 11°.

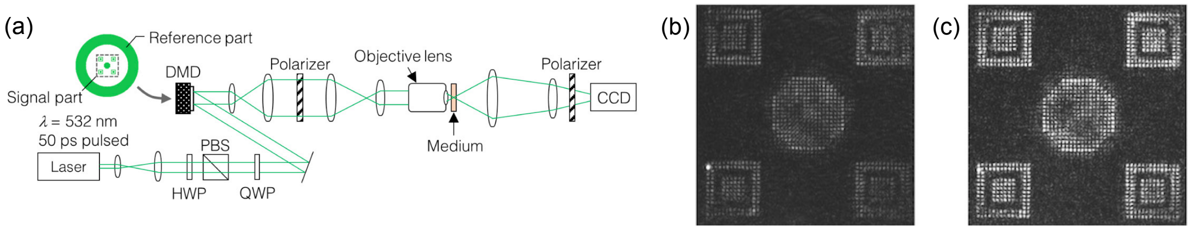

Fig. 2. Experimental setup and reconstructed two-dimensional data patterns. (a) Schematic illustration of the experimental setup for writing and reconstructing magnetic holograms. Reconstructed signal patterns from (b) the single layer Bi:RIG film and (c) the two-pair MPC medium. The MPC medium provided a clear and bright image because the diffraction efficiency of MPC medium was as double as that of the single layer film.

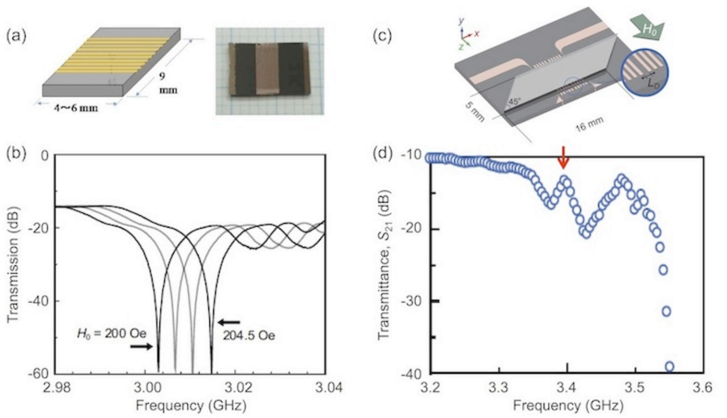

Fig. 3. (a) Schematic illustration and photogragh of the 1D magnonic crystal composed of a YIG single crystal film and a periodical metal strips. (b) Frequency shift in the magnonic band gap corresponding to the change in the bias field from 200 Oe to 204.5 Oe with an interval of 1.5 Oe. (c) Schematic illustration of a magnonic crystal in the shape of a microcavity. (d) Transmission spectrum showing a localized state of spin wave at 3.395 GHz under the applied magnetic field of 400 Oe.

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