All-optical detection of magnetization precession frequency shift due to spin-orbit torque

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Spin-orbit torque (SOT) has attracted considerable interest as a technique to manipulate magnetization for thin film. SOT has been mainly investigated using spin-torque ferromagnetic resonance and second harmonic Hall effect measurements. Even though these electrical methods are standard ways, it is known that there are parasitic voltages induced by spin-charge conversion and thermoelectric effect [1, 2]. Direct observation using all-optical measurement is free from such effects; thus it is a promising way. Previous studies have focused on the change in the relaxation time of the magnetization precession by SOT [3, 4]. Here we report the observation of the modulation of the precession frequency due to the SOT. The film stacking structure was Si/SiO_2/W(5)/CoFeB(2.4)/MgO(1.3)/Ta(1) (thickness in nm), which was fabricated by a DC/RF magnetron sputtering [5]. The film was patterned into a rectangular stripe ($10\times 40\ \mu m^2$). The magnetization precession modulated by SOT was investigated by an all-optical time-resolved magneto-optical Kerr effect microscope, in which an external field $\boldsymbol{H}_{\mathrm{ext}}$ was applied at an out-of-plane angle θ_{H} and a direct current I was applied parallel to y-axis [Fig. 1(a)]. Figure 1(b) shows typical normalized signals measured with $I = 0, \pm 5$ mA. The modulation of the precession frequency was clearly observed. The result was well explained by the change in angle of precessional axis of magnetization θ induced by SOT and the SOT generation efficiency was evaluated as -0.35 [6]. This work was partially supported by KAKENHI (19K15430) and CSRN.

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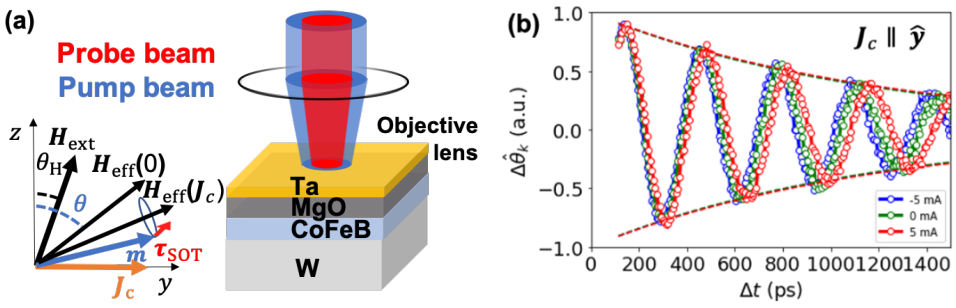

Fig. 1 (a) Schematic of the optical setup and experimental geometry. (b) Normalized signal $\Delta\hat{\theta}_{\mathrm{k}}$ as a function of the pump-probe delay time Δt with $I = 0, \pm 5$ mA (I // y).

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