Modulation of Surface Spin-wave Heat Emission by DC Current Observed by Lock-in Thermography

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Controlled propagation of spin waves (SWs) has exhibited potential applications in information transfer and processing[1]. Various methods to modulate SWs propagation via electric field, spin-orbit torque, and temperature gradient have been explored. Electrical control of SWs is a promising and tunable method to modulate the SWs propagation in spintronics devices and circuits. Therefore, ongoing efforts to modulate the SWs' propagation in magnetic devices using external current sources have gained attraction. Recently, the interplay between heat and SW yields novel transport phenomena, and the unidirectional heat conveyer effect in magnetostatic surface spin waves (MSSWs) was observed by lock-in thermography (LIT)[2]. Herein, we study modulation of the heat emission in ferrimagnetic $Y_3Fe_5O_{12}$ thin film upon applied current ($\mathbf{J_c}$) pulse using the LIT technique as illustrated in Fig. 1(a). The heat emission due to MSSWs damping was modulated by pulsed electric current (J_c) applied to thin Cu foil.

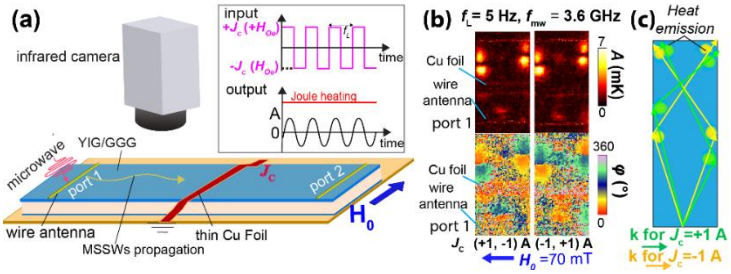

Fig. 1 (a) Schematic of the experimental setup. The infrared camera captures the modulated heat emission signal upon the applied current (J_c) pulse, and Fourier transformed lock-in amplitude (A) and phase (φ) map of the temperature change (ΔT) is obtained in LIT imaging. (b) A and φ map of LIT for the YIG under the applied J_c pulse of (+1, -1) A and (-1, +1) A at an applied microwave frequency (f_{mw}) of 3.6 GHz. (c) A model of modulation of heat emission upon applied J_c of (+1, -1) A.

The applied current pulse generates an alternating Oersted field (H_{oe}) with the same frequency as J_c in addition to constant Joule heating (Fig. 1 (b)). These effects change the effective magnetic field, which modulates the MSSWs' propagation. Under the applied pulse current of (+1, -1) A, a shift of modulated heat emission position was observed at the sample side edge, where the propagation direction (wavenumber k) of MSSWs was modulated (Fig. 1 (c)). By the pulse current J_c of different polarities (+1, -1) A, the phase image showed a phase shift of π indicating that the observed effect is not due to Joule heating.

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References

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