Current controlled magnon propagation in Pt/$Y_3Fe_5O_{12}$ heterostructure

Sarker Md Shamim (D1)[1]*, Hiroyasu Yamahara[1], Hitoshi Tabata[1]
[1]*Department of Electrical Engineering and Information System, The University of Tokyo, Japan*
**E-mail: sarker@g.ecc.u-tokyo.ac.jp*

We present a dynamic modulation technique for spin wave using dc current by manipulating the magnetic properties of an ultra-low damping $Y_3Fe_5O_{12}$ thin film. Microwave excitation and detection technique with two coplanar waveguide antenna arrangement on $Y_3Fe_5O_{12}$ surface was used to characterize the spin wave. An additional Pt stripe connected to dc current source was integrated between a pair of coplanar waveguides to demonstrate the spin wave resonance frequency and amplitude modulations by the current induction. We have used Pt stripe due to its significantly lower spin wave absorption property. *dc* current applied through the Pt stripe generates local joule heating that modifies magnetic properties of the $Y_3Fe_5O_{12}$ film. Changing temperature due to local heating modify the saturated magnetization of the $Y_3Fe_5O_{12}$ films, which interns modulates the spin wave frequency. Moreover, the amplitude of the spin wave spectra was found to be tuned by the *dc* currents amplitude. This phenomenon has been attributed to magnon-phonon scattering induced by relaxation rate enhancement in $Y_3Fe_5O_{12}$.

An 80 nm-thick homogenous YIG film was grown on a single crystalline (100)-oriented gadolinium gallium garnet ($Gd_3Ga_5O_{12}$, GGG) substrate by pulsed laser deposition (PLD) technique. The growth temperature, oxygen pressure and pulse rate were maintained at 750°C, 0.1 Pa, and 5 Hz, respectively as optimum environment. In the subsequent step, two 100 nm-thick metallic coplanar waveguides (CPWs) made of gold (Au) was fabricated on the YIG film surface by electron beam lithography and magnetostatics sputtering techniques where around 3-nm thick chromium (Cr) has been used as the adhesion layer. The separation between the closest edge of the signal lines was kept as 145 μm. A 90 nm-thick Pt stripe with 85 μm width has been fabricated in SW propagation path between the CPWs. The two edge of the Pt stripe are connected to dc current source by Au electrodes for injecting the dc current through the Pt stripe. Optical image and schematic diagram of our proposed device has been shown in Fig.1(a) and (b), respectively.

We recorded FMR spectra for in plane external bias magnetic fields by measuring S_{11} for our device (which has not been shown here). The response of FMR spectra has been measured with dc current flow through the Pt layer from 0 mA to 190 mA (in the steps of 0, 4×10^9, 8×10^9, 12×10^9, 16×10^9, $21\times10^9$and 25×10^9Am^{-2}). The FMR spectra is found to be shifted to the lower frequencies with increasing current density, summarized in Fig.1(c). This phenomenon has been attributed to the current induced change of the saturation magnetization due to temperature change. Our experimental observation matched well with theoretical prediction. Moreover, the transmitted spin wave amplitude is found to be reduced gradually with increasing currents shown in Fig.1(d)-(h) and has been summarized in Fig.1(i). The group velocity also observed to be reduced gradually with increasing current density. These two phenomena have happened due the magnon-magnon and magnon-phonon scattering in magnonic crystal in higher temperature.

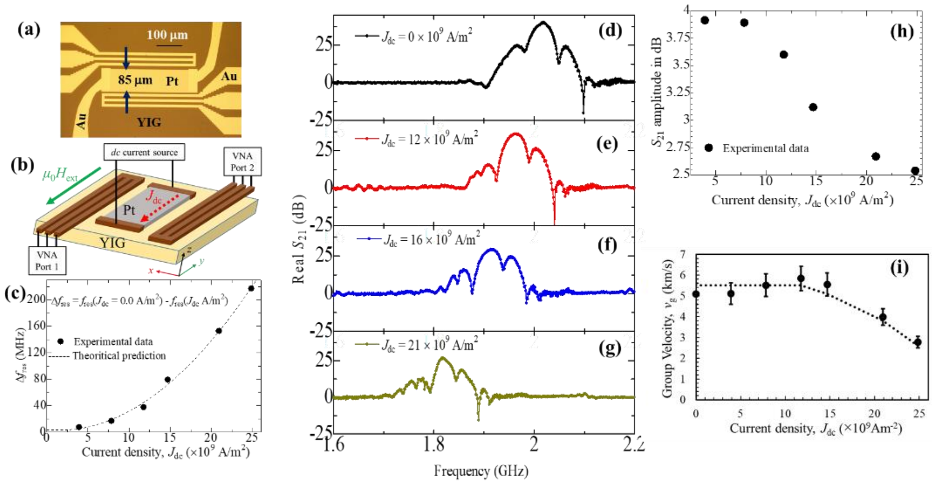

Figure 1.(a) Optical image and (b) schematic diagram of proposed device (c) Current dependent SW resonance shifts. SW transmission spectra for (d) 0×10^9 (e) 12×10^9 (f) 16×10^9 (g) 21×10^9. (h) SW intensity reduction with raising *dc* currents. (i) Current dependent SW group velocity