Ultra-low spin wave damping in single-crystal yttrium iron garnet films

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In the emerging field of magnonics, the essential idea is to use collective spin excitations (spin waves) to carry and process information [1]. Since propagation of spin waves does not involve transfer of electronic charges, magnonic devices are not compromised by intense energy dissipation caused by Joule heating. One of the challenges of magnonics, however, is high spin-wave damping in metallic ferromagnets, which limits the distance over which information can be transferred. Ferrimagnetic oxide films with ultra-low damping, such as yttrium iron garnet (YIG), are now considered as promising alternatives.

Here, we report on the growth and spin-wave properties of high-quality YIG films on the gadolinium gallium garnet (GGG) substrates. We show that pulsed laser deposition of YIG results in smoothly epitaxial films (Fig. 1(a)) and ferrimagnetism up to a Curie temperature of 500 K (Fig. 1(b)). We use all-electrical broadband spin wave spectroscopy to characterize the transmission of spin waves through our YIG films. This technique utilizes one coplanar waveguide (CPW) to excite spin waves with different wavevectors (k1 - k5, Fig. 1(c)) and another identical waveguide to detect the spin waves after transmission. From our measurements, several key parameters are extracted, including the spin wave dispersion relation, group velocity, damping constant (α), and decay length (l_d). For 40 nm thick YIG films, we find $\alpha \approx 3.5 \times 10^{-4}$ and $l_d \approx 400$ μm, parameters that would suffice for coherent data processing in nanoscale magnonic devices.

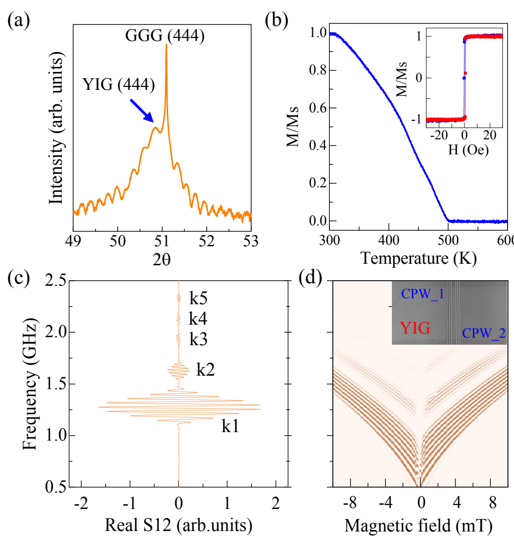

Fig. 1: (a) X-ray diffraction scan for a 40 nm thick YIG film on GGG. Laue oscillations indicate that the YIG film is uniform and smooth. (b) Saturation magnetization as a function of temperature for the same film measured by vibrating sample magnetometry. The inset shows a typical hysteresis loop. (c) Spin wave transmission spectrum and (d) evolution of the spectrum with applied magnetic field. CPW1 excites spin waves with different wavevectors (k1 - k5) and CPW2 detects the spin waves after transmission through the YIG film.

[1] A. V. Chumak, V. I. Vasyuchka, A. A. Serga and B. Hillebrands, Nature Physics 11 (2015) 453.