Magnetic thin-film insulator with ultra-low spin wave damping for coherent nanomagnonics

Wave control in the solid state has opened new avenues in modern information technology. Surface-acoustic-wave-based devices are found as mass market products in 100 millions of cellular phones. Spin waves (magnons) would offer a boost in today's data handling and security implementations, i.e., image processing and speech recognition. However, nanomagnonic devices realized so far suffer from the relatively short damping length in the metallic ferromagnets amounting to a few 10 micrometers typically. Here we demonstrate that nm-thick YIG films overcome the damping chasm. Using a conventional coplanar waveguide we excite a large series of short-wavelength spin waves (SWs). From the data we estimate a macroscopic of damping length of about 600 micrometers. The intrinsic damping parameter suggests even a record value about 1 mm allowing for magnonics-based nanotechnology with ultra-low damping. In addition, SWs at large wave vector are found to exhibit the non-reciprocal properties relevant for new concepts in nanoscale SW-based logics. We expect our results to provide the basis for coherent data processing with SWs at GHz rates and in large arrays of cellular magnetic arrays, thereby boosting the envisioned image processing and speech recognition.

The insulating ferrimagnet yttrium iron garnet (YIG) has recently attracted considerable interest in both spintronics and spin caloritronics. One reason is that bulk and micrometer-thick YIG offers the smallest possible damping parameter α for spin waves (SWs) in the GHz frequency regime. The value of α amounts to about 5×10^{-5} and is two orders of magnitude smaller compared to the best metallic magnets. At the same time the research field of magnonics has evolved rapidly based on nanostructured metals. In magnonics one aims at the transmission, storage and processing of information using propagating and interfering spin waves (SWs). A small damping parameter α is key for magnonic crystals and spin wave logic devices based on interference effects.

Here we report propagating spin waves in a 20 nm-thick YIG film exhibiting a damping parameter of 2.3×10^{-4}. We estimate a decay length of 580 um from our data surpassing l_d of metallic ferromagnets by an order of magnitude or even more. We explore spin wave modes with nine different wavelengths λ down to 560 nm. The group velocities v_g are found to vary between 0.6 km/s and 1.2 km/s depending on the wave vector and applied magnetic field H. The nonreciprocity is found to increase with increasing wavevector $\mathrm{k} = 2\pi/\lambda$ and is thus promising in view of nanocale spin-wave logic devices. Our experimental work demonstrates that the thin-film magnetic insulator YIG allows one to overcome the damping problem for nanomagnonics and to boost further developments in magnonic circuit technology for information processing at GHz operational frequencies.

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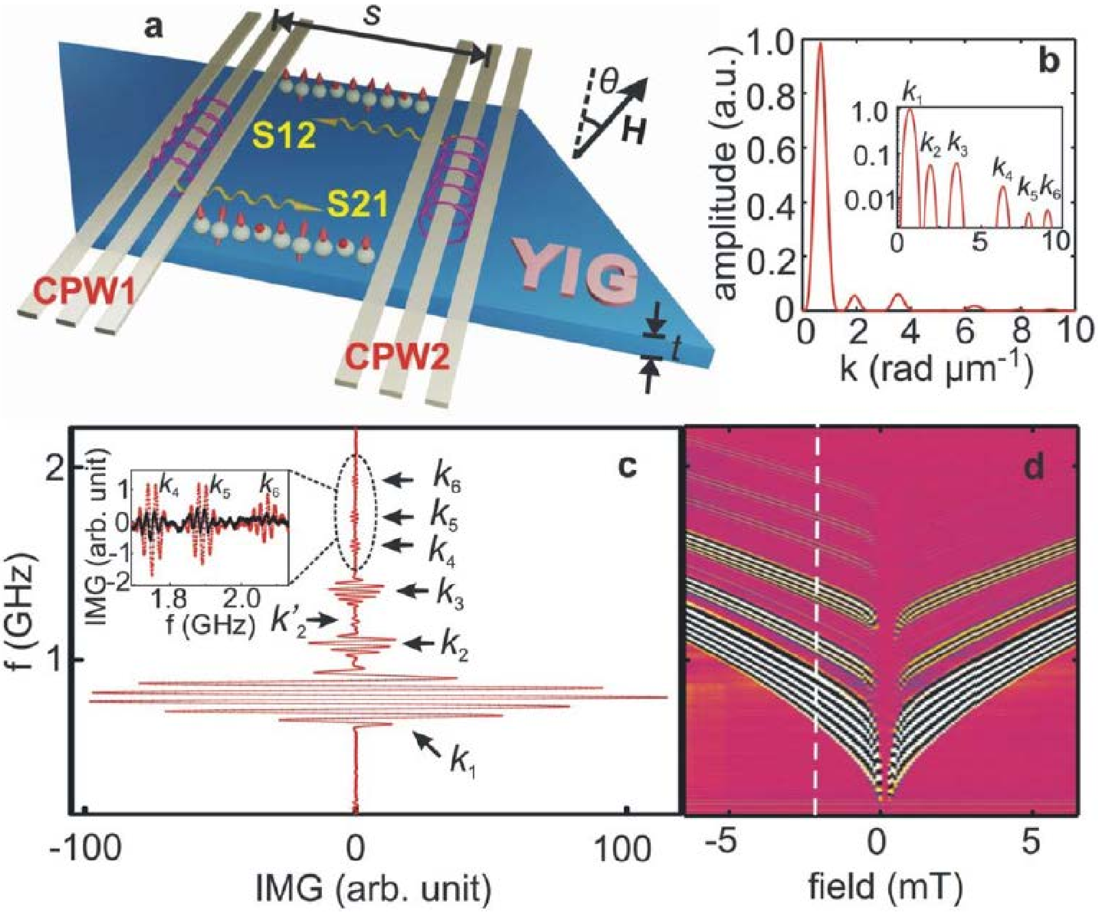

a
s
θ
H
S12
S21
YIG
CPW1
CPW2
t
b
amplitude (a.u.)
k (rad μm-1)
k1
k2 k3
k4 k5 k6
c
f (GHz)
IMG (arb. unit)
f (GHz)
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k5
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k'2
k2
k1
d
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