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Tuning Spin Wave Dispersion in Synthetic Antiferromagnetic Systems

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Synthetic antiferromagnets (SAFs) typically consist of two ferromagnetic layers coupled antiferromagnetically via a non-magnetic spacer layer through Ruderman–Kittel–Kasuya–Yoshida (RKKY) or dipolar interactions. They have attracted interest in spintronics and magnonics due to their minimal stray fields, efficient spin transport, and rich spin-wave dynamics [1], and the antiferromagnetic interaction can be tuned by varying the spacer and magnetic layer thicknesses. SAFs provide a useful testbed for determining antiferromagnetic dynamics and their coupling with ferromagnetic modes, as their GHz-range resonant frequencies allow for conventional microwave-based measurements. Therefore, understanding and controlling spin-wave dispersion in SAFs [2] is essential for designing next-generation magnonic devices.

Here, we investigate the field-dependent spin-wave dispersion in sputter-grown SAFs using ferromagnetic resonance (FMR) measurements, systematically varying key material parameters, including the thickness of the magnetic (CoFeB) and non-magnetic spacer (Ru) layers, deposition conditions, and the composition of the CoFeB layer. We observed a transition from monotonic spin-wave dispersion to non-monotonic behaviour on decreasing the effective magnetic layer thickness. Moreover, the magnetic field region where non-monotonic regime manifests can be tuned by varying the Ru layer thickness, and shifts to higher resonant magnetic fields as the Ru thickness decreases. This dependence might be due to an increase in interlayer exchange coupling (IEC). We observed a similar shift in SAF samples with the same stack structure grown under different sputtering base pressures. Additionally, we found that altering the Co: Fe ratio in CoFeB (from 1:1.6 to 1.4:1) in a similar SAF structure caused a transition from non-monotonic to monotonic dispersion.

In summary, our key finding is that a non-monotonic spin-wave dispersion can be induced and tuned by carefully optimising magnetic layer composition and spacer thickness which could be useful for designing broadband (~ 2 GHz) spin-wave filters at different frequency ranges. We are performing micromagnetic simulations to gain deeper insights into the underlying mechanisms. Initial results suggest that the shifting of nonmonotonic regions can be controlled by varying the IEC. This precise control over dispersion highlights the potential of SAFs for reconfigurable magnonic devices.

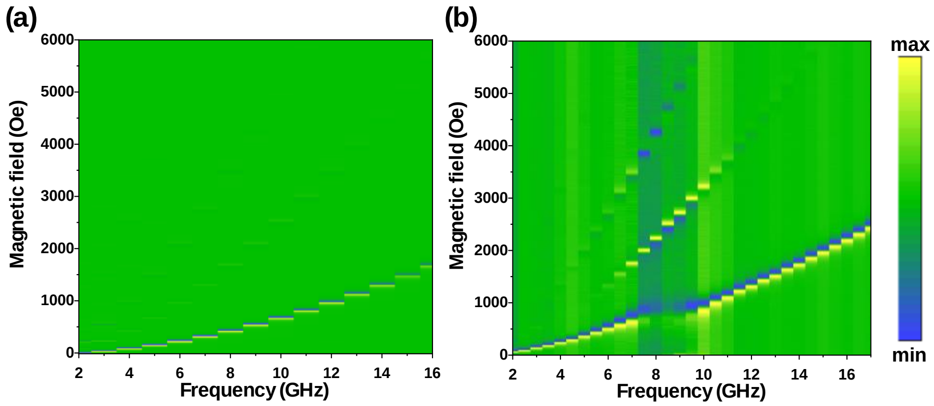

Fig. 1. FMR signal on sweeping magnetic field and microwave frequency in two different SAFs: (a) CoFeB(10)/Ru(0.42)/CoFeB(5) and (b) CoFeB(5)/Ru(1)/CoFeB(2.5). The numbers in parentheses are the layer thicknesses in nanometres (nm). The colour bar on the right side corresponds to the FMR signal.

[1] B. Flebus, et al., *The 2024 magnonics roadmap*, J. Phys.: Condens. Matter **36**, 363501 (2024).

[2] J. Zhou, et al., *Ultrafast laser induced precessional dynamics in antiferromagnetically coupled ferromagnetic thin films*, Phys. Rev. B **101**, 214434 (2020).