All-Magnonic Frequency Multiplication in Ferromagnetic Microstructures

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Poster – Preliminary Report

One of the challenges for the implementation of magnonics into computing applications is the conversion of charge currents in conventional electronics into phase-stable collective excitations of the spin system in the magnonic device. We have demonstrated all-magnetic frequency multiplication as one possible way to address this challenge and showed a six-octave frequency comb in polycrystalline NiFe thin films driven at MHz frequencies [1]. At very low bias fields, magnetic ripples cause local magnetization tilting, and MHz-range excitation induces rapid switching leading to high-harmonic, phase-stable spin wave emission up to the 60^{th} harmonic of the excitation frequency.

However, to enable practical applications, it is essential to miniaturize active components and optimize the frequency multiplication efficiency, aiming to generate GHz-range spin waves using MHz rf excitation in minimal-sized elements. Recently, frequency multiplication has also been observed in extended CoFeB layers [2]. This further motivates us to investigate the frequency multiplication effect on the microscale not only in microstructures made of NiFe but CoFeB as well. Using micromagnetic simulations, we analyze the impact of various material parameters, such as saturation magnetization, anisotropy, static bias field and the geometry itself, including shape, size and thickness of ferromagnetic elements, on the frequency comb generation efficiency. The numerical results are compared to experimental measurements performed via NV center magnetometry and SNS-MOKE techniques on actual samples (see figure 1).

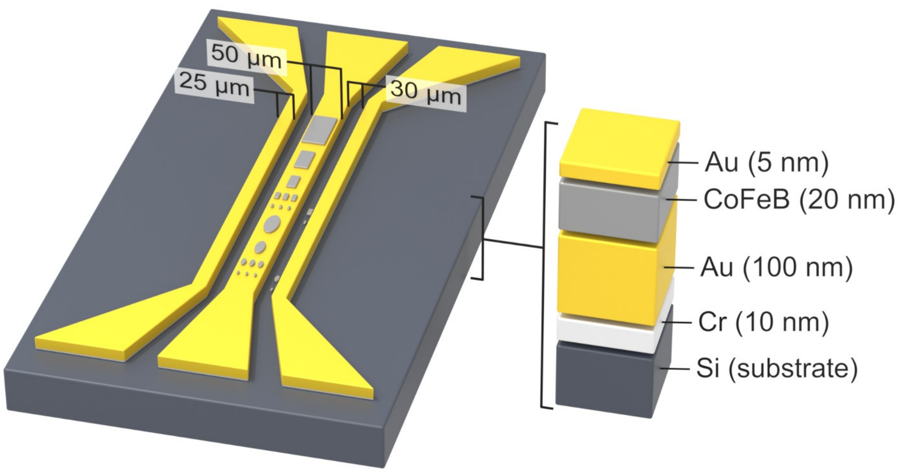

Figure 1: Coplanar waveguide made out of gold with micron-sized CoFeB structures on top. The MHz-excitation from the CPW is upconverted to coherent spin waves in a broad GHz regime.

[1] Koerner *et al.* Science **375**, 6585 (2022)
[2] Wu *et al.* npj Spintronics **2**, 30 (2024)

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