Nonlinear dynamics in spin wave active ring oscillators

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We experimentally investigate the nonlinear dynamics of surface spin wave active ring oscillators (SWAROs), with a YIG delay line within an RF ring circuit [1]. The transmission characteristics of the spin waves exhibited dipole gaps, see Fig. 1, where we observe a build of energy and the generation of oscillator modes [2]. The injected signal frequency was swept over a 5 MHz wide frequency range across a magnetostatic surface spin wave (MSSW) dipole gap, with the drive power varying from -10 to 10 dBm. We measured the output power spectra from the SWARO at different gains for each drive power and frequency combination. Near the drive frequency, we observe the formation of sidebands, which are the products of the nonlinear scattering processes. When the SWARO is injected with a GHz drive signal, in the vicinity of an oscillator mode, the spin wave nonlinearity in the ring oscillator is suppressed, and the SWARO spectrum is injection locked i.e. the oscillator frequency is pulled toward the drive frequency. This phenomenon was modelled using Adler's equations, under the assumption that the oscillator modes are independent of each other. However, there is scope for further improvements to the model as we experimentally observe that injection locking of one oscillator mode also suppresses the nonlinearity at a neighbouring oscillator mode.

In related efforts, micromagnetic simulations of surface spin waves of YIG films required extraordinarily long computation times due to the size of the sample relative to the exchange length. To mitigate some of this effort, a new simulation technique of dynamic mode decomposition (DMD) have been employed. We will discuss early results demonstrating the reconstruction of spin wave dispersion for YIG films using DMD, and their applicability to designing magnonics devices.

[1] A. A. Nikitin, I. Y. Tatsenko, M. P. Kostylev, and A. B. Ustinov, "Microwave magnonic micro-oscillator based on a nm-thick YIG film," Journal of Applied Physics 135, 123906 (2024).

[2] M. Wu, "Nonlinear spin waves in magnetic film feedback rings," in Solid State Physics, Vol. 62 (Academic Press, 2010) pp. 163–224.

This work is being submitted for consideration as an oral presentation.

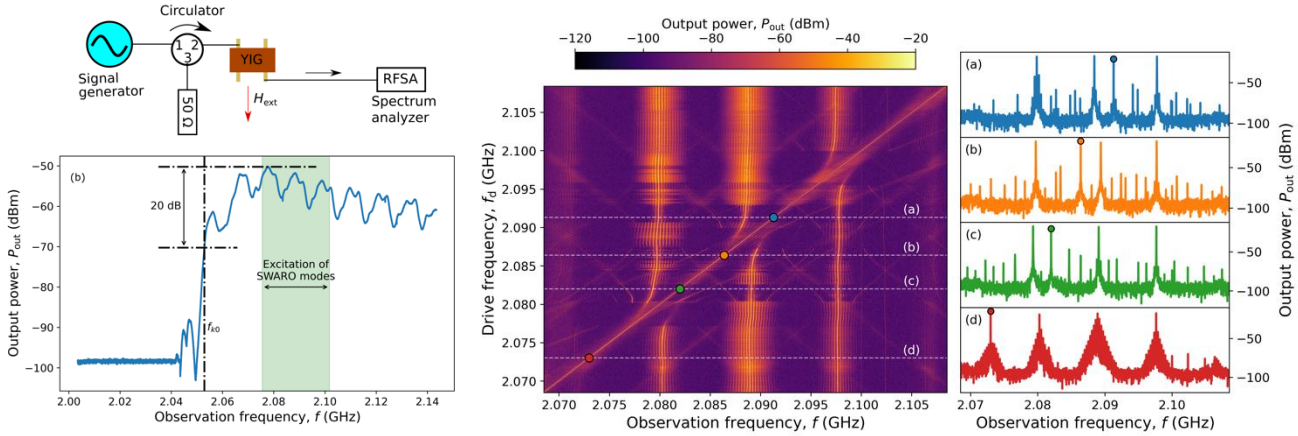

Fig. 1. (left) Dipole gaps in a surface spin wave delay line. (middle) Spectral output of SWARO at drive power P_d = -15 dBm, plotted as a function of observation frequency f and drive frequency f_d. (right) The output power spectra from the SWARO at fixed drive frequencies of (a) 2.0913 GHz, (b) 2.0864 GHz, (c) 2.082 GHz, and (d) 2.073 GHz. The drive frequency location is marked with a circle in each line plot in the surface plot.