Mode-resolved micromagnetics simulations for nonlinear spin wave processes in confined systems

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Nonlinear spin wave processes in confined systems, such as parametric excitation in yttrium iron garnet (YIG) disks and three-magnon scattering in vortex states, are currently being explored for neuro-inspired computational tasks such as pattern recognition [1]. In order to process complex time series data, it is crucial to understand the role of the transient dynamics of these nonlinear processes because history and noncommutativity of driving sequences can affect how modes are populated. Here, we discuss a means of time-resolving the individual spin wave populations in micromagnetics simulations with a mode-projection method. This is achieved with the finite-difference micromagnetics code MuMax3 [2] by projecting out the calculated dynamical magnetization $\mathbf{m}(\mathbf{r}, t)$ onto precomputed spin wave eigenmode profiles $\psi_k(\mathbf{r})$ [3], which gives directly the mode population $n_k(t)$ as a function of time. The left panel in Fig. 1 shows an application of this method to compute the spin-wave power spectral density of a 1-μm diameter, 50-nm thick YIG disk at 300 K, under parametric excitation of $f_{\mathrm{rf}}/2 = 2.9$ GHz and $b_{\mathrm{rf}} = 1$ mT, where the profiles of primary and secondary modes can be clearly identified. We observe that modes 11 and 12 are simultaneously excited, which would be difficult to resolve using standard frequency analysis because of the proximity of the mode frequencies. The right panel shows how n_k evolve with time, where clear differences in the growth sequences and growth rates can be seen. Access to temporal behaviour can be useful for applications in processing time-series data. This work was supported by the Horizon2020 Research Framework Programme of the European Commission under contract no. 899646 (k-Net).

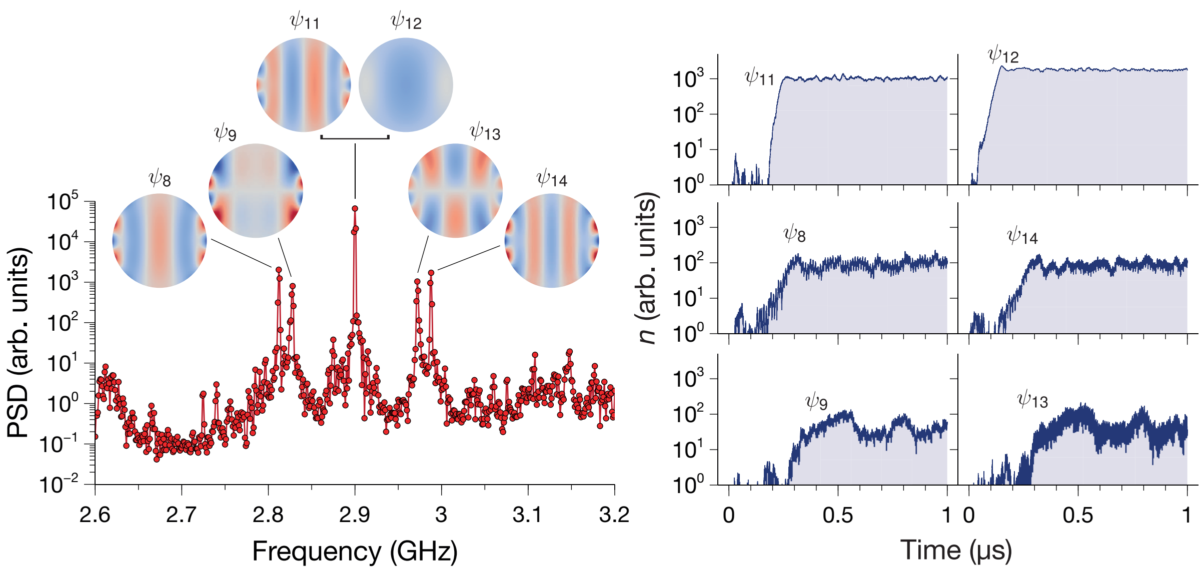

Figure 1: Left panel: Spin wave power spectral density (PSD) under parametric excitation at $f_{\mathrm{rf}}/2 = 2.9$ GHz, with selected mode profiles ψ_k shown. Right panel: Time dependence of selected mode populations n_k.

References

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