Data-Driven Prediction of Spin-Wave Dispersion Using Higher-Order Dynamic Mode Decomposition

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We use Higher Order Dynamic Mode Decomposition (HODMD) to predict spin-wave dynamics in yttrium iron garnet (YIG) films. HODMD uses time-lagged snapshots and can be seen as superimposed DMD in a sliding window, and utilizes time-delay embedding with delay parameter d to augment temporal resolution and capture high-frequency spin-wave modes. We simulate a 1 µm thick YIG film with periodic boundaries along x and y and unit cell size of 10 nm x 10 nm x 100 nm, and with gridsize of 1024 x 512 x 10 cells. Magnetization dynamics m_z (x, y, z = 500 nm, t) are extracted from a 10 ns simulation, with the first 3 ns discarded as from theoretical estimation, the highest velocity surface spin waves take approximately this time to reach the probe region which spans 6.12 µm x 5.12 µm and is 2.56 µm away from the leftmost edge. The HODMD model is trained on magnetization data from the 3-8 ns time window and subsequently used to predict dynamics during the 8-10 ns interval. We have compared two dispersion curves, one obtained by FFT on m_z from 3-10 ns, and the other obtained from HODMD model. The comparison demonstrates the method's enhanced capability to resolve closely-spaced frequency components and accurately extrapolate spin-wave propagation characteristics beyond the training window. This data-driven framework offers a computationally efficient approach for predicting magnetization dynamics from limited observation windows.

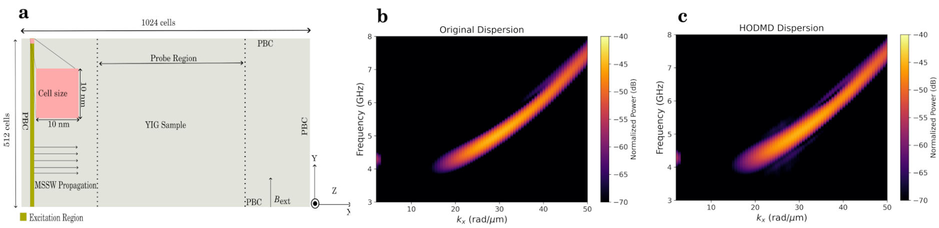

Fig. 1.(**a**) Simulation geometry showing the 1 µm YIG film with periodic boundary conditions (PBC) applied along the x and y directions. The PBC effectively replicates the film three times on each side in the x and y directions, eliminating edge effects and enabling the study of surface spin waves in an extended geometry. (**b**) Simulated ground truth obtained by FFT on m_z from 3-10 ns. (**c**) HODMD model: trained on m_z from the 3-8 ns time window, predicted dynamics in the 8-10 ns interval, and reconstructed the full dispersion curve for 3-10 ns.

References:

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