Spin-Wave Instabilities at a Single Temporal Interface in Ultrathin PMA Films Near the Stripe-Domain Transition, with and without DMI

P. Gruszecki,[a] and K. Sobucki[a]

a: Institute of Spintronics and Quantum Information, Faculty of Physics and Astronomy, Adam Mickiewicz University, Poznań, Poland;

Temporal modulation of magnetic media provides a new route for controlling spin-wave dynamics beyond static magnonic architectures [1]. Here we investigate spin-wave scattering at a single temporal interface in ultrathin ferromagnetic films with perpendicular magnetic anisotropy (PMA) operated near the field-driven transition from the uniform state to a stripe-domain pattern. We compare systems with and without interfacial Dzyaloshinskii–Moriya interaction (DMI), focusing on the emergence of instability and its implications for spin-wave amplitude enhancement.

Using analytical theory and micromagnetic simulations, we show that an abrupt temporal change of magnetic parameters conserves the wavevector and redistributes the incident spin wave between forward- and backward-frequency branches. In the stable regime, this produces temporal reflection and frequency conversion. When the post-switch field is reduced below the critical field for stripe-domain formation, H_c, the post-interface dynamics become unstable. Importantly, our analysis reveals two distinct instability regimes. In systems with DMI, the exceptional-point field H_{EP} is separated from the critical field H_c, which opens a finite slow-instability window $H_{\mathrm{EP}} < H < H_c$, where the growth rate scales linearly with the Gilbert damping parameter. For lower fields, $H < H_{\mathrm{EP}}$, the system enters the strong-instability regime, dominated by rapid growth associated with the underlying magnetic instability. In contrast, for systems without DMI, the exceptional-point field coincides with the critical field, $H_{\mathrm{EP}} = H_c$, so the slow-instability window collapses and the dynamics cross directly from damping to strong instability.

These results show that a single temporal interface already captures the essential physics of instability-enabled temporal magnonics and reveals the potential for spin-wave amplitude enhancement. At the same time, they identify DMI as the key ingredient that makes this enhancement controllable by opening a distinct slow-instability regime above the strong-instability threshold [2].

References:

[1] E. Galiffi et al., Advanced Photonics 4 (2022) 014002.

[2] K. Sobucki and P. Gruszecki, arXiv:2512.07713 (2024).