Floquet magnons in spin-torque oscillators

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Floquet states arise in periodically-driven systems and represent time-periodic solutions analogous to Bloch states in crystals. For example, time-periodic driving of quantum materials has proven to be useful for inducing nonequilibrium topological phenomena. Recently, it has been shown that vortex gyration in thin-film disks can also give rise to magnon Floquet states [1,2]. These states evolve from the scattering of linear eigenmodes with the core gyration, resulting in rich spectra featuring frequency combs with a strong dependence on the azimuthal number m.

In this work, we discuss Floquet modes in spin-torque vortex oscillators in which the background magnetization state is nonuniform. In addition to a regular vortex state, we also focus on a rotating C-state [3] magnetization which can be likened to vortex gyration but with a virtual core outside the disk. This is a unique state of such ocillators that possesses a lower symmetry than the vortex state. We perform a numerical study on a 300-nm radius, 7-nm thick permalloy disk using the open source micromagnetic code MuMax3 [4].

In the case of a vortex free layer, Floquet modes can be genrated as desrcibed in [1,2]. Our main focus is to exploit the properties of the oscillator in order to control and tune the Floquet frequency combs. We show that by applying a current through our oscillator, we can damp or anti-damp the core gyration through spin-transfer torque, resulting in variation of the Floquet comb's spacing frequency and peak amplitude, which we can then exploit for reservoir computing applications [5].

We further show that the rotating C-state can also exhibit Floquet modes. These modes emerge from modulation of the linear eigenmodes of the frozen C-state, and recover cylindrical symmetry through time periodic rotation of the C-state, leading to similar dispersion relations as the ones of a gyrating vortex. These findings hold potential for unconventional computing applications. For example, by using an operating regime near the transition between vortex and C-state in spin-torque oscillators, it might be possible to alternate between two sets of Floquet states.

References:

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