Enhancing MUMAX³ software for Magnon-Cavity Interactions

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MUMAX3 is an open-source software which is GPU-accelerated and it is used to perform micromagnetic simulations, it was developed and maintained at the DyNaMat group at Ghent University (The design and verification of MuMax3 [1]).

We implement a new feature that extends the current capabilities of MUMAX3 by including the effects of coupling a given magnetic material to an electromagnetic cavity. This will enable the study of analytically-intractable models in the field of magnetic cavity QED materials.

To implement these modifications, a fork of the MUMAX3 code was created. The Landau–Lifshitz–Gilbert (LLG) equation that MUMAX3 solves is understood as a phenomenological analogue of the Heisenberg equations of motion of the spin degrees of freedom of the magnetic material. These are extended to include the coupling to the cavity and then the equation of motion of the cavity is integrated out, giving rise to an effective term for the spins. The effect of the cavity is thus included in MUMAX3 as a new contribution to the effective field given by the cavity's zero-point field times a memory factor.

As a benchmark, we simulate the dynamics of the Dicke model, which serves as an analytically-solvable toy model of a paramagnetic material interacting with a single-mode cavity (Photon Condensation and Enhanced Magnetism in Cavity QED [2]). Preliminary results show promising signs, with the observation of two resonant peaks at the polaritonic frequencies of the Dicke model.

In addition, we simulate the coupling between different shaped ferromagnets and cavity photons yielding results comparable with recent experiments.

References

[1] A. Vansteenkiste et al., AIP. Adv. **4** (2014) 107133
[2] J. Román-Roche, F. Luis, D. Zueco, Phy. Rev. Let. **127** (2021) 167201