Investigation of strongly hybridized electro-nuclear spin system in $LiHoF_4$ using Cavity-Magnon-Polariton technique

Yikai Yang[1], Peter Babkevich[2], Richard Gaal[1], Ivica Živković[1], Henrik M. Rønnow[1]

[1] *École Polytechnique Fédérale de Lausanne, Switzerland*
[2] *Credit Suisse AG, Kalanderplatz 1, 8045 Zürich, Switzerland*

We derive and present a microscopic relation between generalized susceptibilities in linear response theory and input-output formalism to describe strongly hybridized cavity-magnon-polariton (CMP) systems. The method is then applied to analyse experiments, in conjunction with Mean Field (MF) treatment to the full spin Hamiltonian and magnetic susceptibility under random phase approximation (RPA), on a model quantum Ising magnet ($LiHoF_4$) coupled to a high-finesse 3D re-entrance cavity resonator in the strong coupling regime. We extract quantitative information on the hyperfine levels in $LiHoF_4$ and demonstrate the ability of numerically reproducing experimental observations across a wide spectrum in the parameter space including an applied external magnetic field that traverses through a quantum phase boundary. This work is intended to not only provide a comprehensive picture of the collective behaviour of the electro-nuclear spins in $LiHoF_4$, but as well a testing ground readily deployable for further theoretical development in characterizing complex magnetic systems alike.

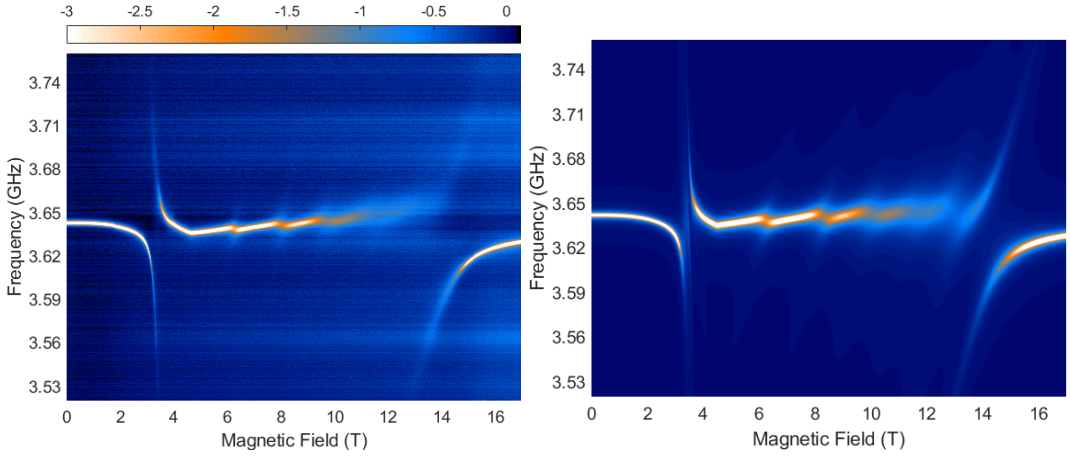

Figure 1: (a) Experimental data of |S11| of a CMP system consisting the fundamental mode of a re-entrance cavity and a single crystal of $LiHoF_4$ at 150 mK and under a transver magnetic field. (b) Numerical simulation of (a) using methods developed in this report.