Spins in Microwave Cavity

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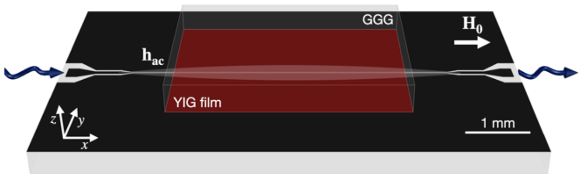
Abstract: We present our approach to the general problem of interacting matter-radiation, consisting in magnetic systems embedded in coplanar superconducting resonators. We focus on three cases related to the weak, strong and ultra-strong regime of coupling.

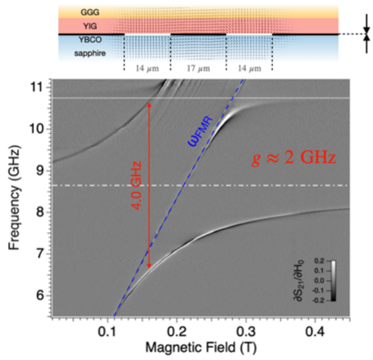
The problem of a two-level quantum system in a resonant electromagnetic cavity is paradigmatic in the study of interacting matter and radiation. Possibility of tuning the key parameters, such as the coupling and/or dissipation, in a wide range offers the possibility to explore different regimes.

Here, we present our approach to this problem consisting in magnetic systems embedded in coplanar superconducting resonators. We shall focus on three cases related to the weak, strong and ultra-strong regime of coupling.

In the first example, we show how far it is possible to tailor properties of molecular spins in order to achieve the strong coupling regime [1]. This is the prerequisite to encode microwave pulses thus using these molecular spins as quantum memories [2] or quantum sensing [3]. On this line we intend to pursue with our BAC Spoke 5 project SMILE SQUIP.

Ultra-strong regime is achieved by optimizing the coupling between a spin excitations in ferrimagnetic YIG (Yttrium Iron Garnet) film in contact with a high Tc superconducting coplanar resonator [4]. The interplay between spin waves and superconductivity is an intriguing problem on itself [5].





Finally, we present a case in which we can fine tuning the parameters of the problem and drive the hybrid system in the weak coupling regime. By exploiting features of molecular spins we can map a wide region of the phase diagram and find several conditions for observing *Coherent Perfect Absorption* [6], an interesting regime for quantum sensing.

REFERENCES:

[1] C. Bonizzoni *et al. Advances in Physics: X*, 3 (2018), 1435305.
[2] C. Bonizzoni *et. al. NPJ Quantum Inf.*, **6** (2020), 68.
[3] C. Bonizzoni *et al. NPJ Quantum Inf.* 10, 41 (2024)
[4] A. Ghirri *et al.,* Phys. Rev. Appl. 20 (2023) 024039
[5] A. Ghirri *et al.,* Phys. Rev. Applied **22,** 034004 (2024)
[6] C. Bonizzoni *et al. submitted* (2025).