Remote spin-spin interactions mediated by superconducting circuits for quantum applications.

C. del Río[1]
Marcos Rubín[1], D. Rodriguez[2], M. C. de Ory[2], D. Granados[3], D. Pinkowicz,[4] N. Crivillers,[5] M. C. Pallarés,[1] A. G. Lostao,[1] D. Zueco[1], M. J. Martínez-Pérez[1], A. Gomez[2], F. Luis[1]

1. Instituto de Nanociencia y Materiales de Aragón (INMA), CSIC - Universidad de Zaragoza, 50009 Zaragoza, Spain
2. Centro de Astrobiología (CAB) CSIC-INTA, 28850 Torrejón de Ardoz, Madrid, Spain
3. IMDEA-Nanoscience, Cantoblanco,28049 Madrid, Spain
4. Jagiellonian University, Faculty of Chemistry, Krakow, Poland.
5. Instituto de Ciencia de Materiales de Barcelona, CSIC, Barcelona, Spain.
cdrio@unizar.es

Hybrid platforms combining molecular spins and superconducting circuits allow scaling up quantum computational resources by either exploiting the chemical design of molecules behaving as multiple qubits or qudits or via a proper engineering of the superconducting circuit [1-3]. Here, we address experimentally this second option. We focus on circuits based on lumped element LC resonators. Their relevant properties, resonance frequency ω_r and quality factor Q, can be widely tuned without affecting the transmission through the readout line. Here, we realize resonator pairs able to introduce communication channels between remote spin qubit ensembles (Fig. 1). A superconducting chip consisting of seven LC resonator couples has been designed and fabricated. Resonators have ω_r ranging from 1.7 GHz to 3.0 GHz, which makes them individually addressable. Couplings between resonators in each pair have been engineered by the design of the two capacitors and their mutual distances. We explore their coupling to free radicals, model *S*=1/2 spin qubits, deposited onto either one or the two inductors of each pair (Fig.2). In the first case, we observe strong coupling of the spin ensemble to "its local" resonator and, besides, to photon modes in its remote companion. In resonator pairs hosting two different organic radicals we have observed evidences for the coherent coupling between the polaritonic light-matter states of both resonators. These experiments provide a method for performing spin resonance on a given specimen at two resonances simultaneously and pave the way for introducing coherent communication channels between two remote spin qubit ensembles, thus for scaling up this hybrid platform.

References

[1] M. D. Jenkins, D. Zueco, O. Roubeau, G. Aromí, J. Majer and F. Luis, Dalton Trans. 45, 16682-16693 (2016)
[2] S. Carretta, D. Zueco, A. Chiesa, Á. Gómez-León, and F. Luis, Appl. Phys. Lett. 118, 240501 (2021)
[3] A. Chiesa, S. Roca, S. Chicco, M.C. de Ory, A. Gómez-León, A. Gomez, D. Zueco, F. Luis, and S. Carretta, Phys. Rev. Applied **19**, 064060 (2023)

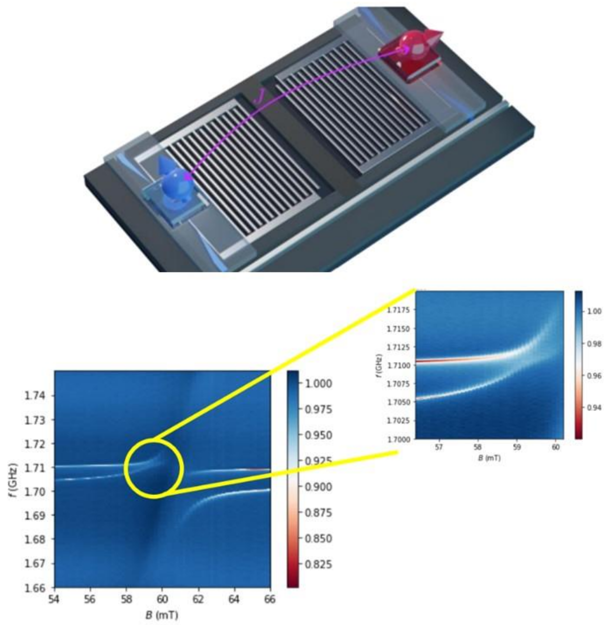

Figure 1: Top: sketch of two coupled resonators hosting two different molecular spin ensembles. Bottom: Microwave transmission data showing an additional anticrossing between two polaritons, which bears evidence of coherent communication between the spin ensembles.