Pulsed-Wave Transmission Spectroscopy of Spin Ensembles through Planar Superconducting Microwave Resonators

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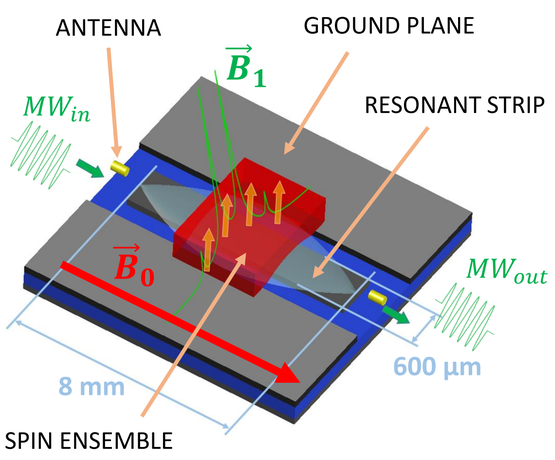
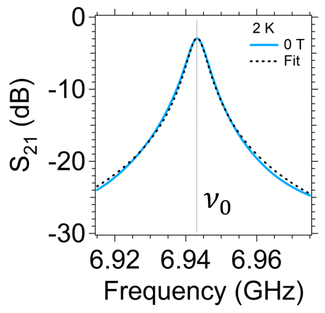
Encoding quantum bits as well as performing any quantum information processing requires the development of protocols for the initialization, the manipulation and the reading of quantum states. We have recently developed superconducting YBCO coplanar microwave resonators to perform transmission spectroscopy on molecular spin ensembles at low-temperatures [1,2] and we are currently developing a set-up for transmission spectroscopy in the pulsed-wave regime. In our implementation the synthesis of the pulses is based on an Arbitrary Waveform Generator, while the resonator is used to address the spins and to drive their evolution. Here we briefly present the behaviour of our empty YBCO resonators under single driving pulses and our preliminary results concerning the measure of the phase memory time of a molecular Vanadyl Phthalocyanine spin ensemble with the Hahn echo sequence [3].

COPLANAR RESONATORS

Superconducting coplanar resonators [1,2] are over-coupled to the feed lines to have high transmissions and to suppress cavity ringing.



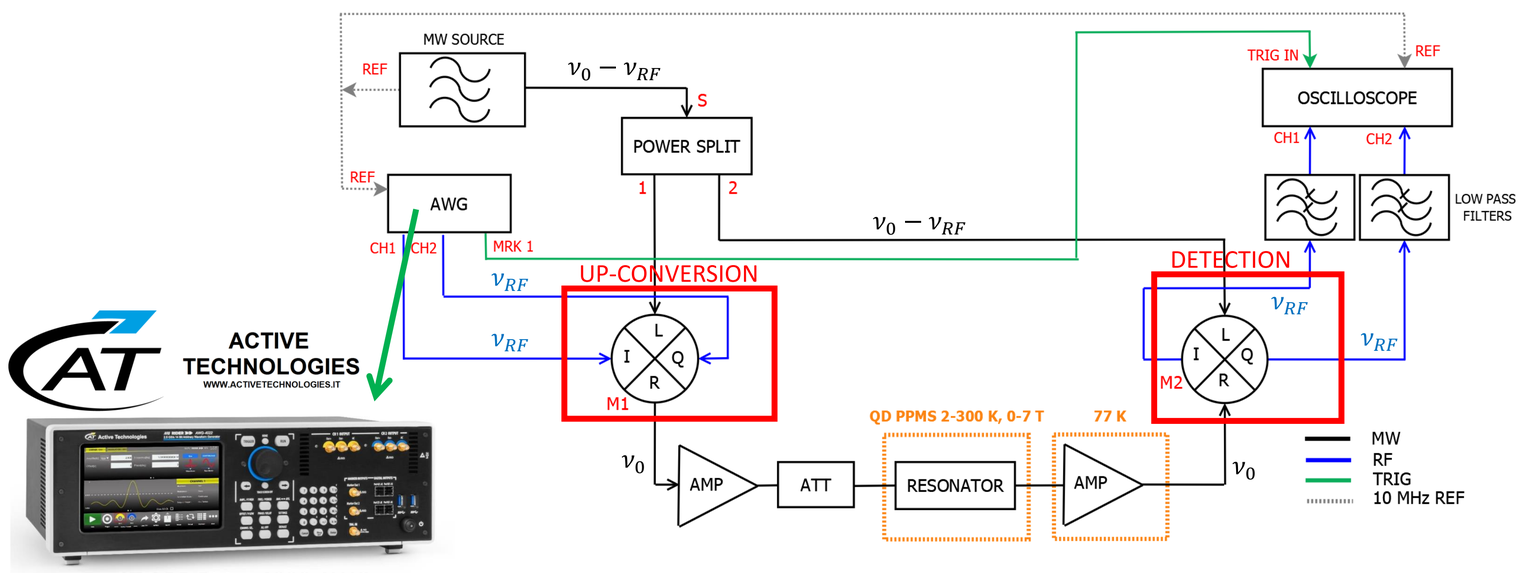


$$Q \approx 500 - 700$$

Ensemble couples to microwave field ($\vec{B}_1$) through magnetic dipolar interaction. Static magnetic field ($\vec{B}_0 \perp \vec{B}_1$) is applied along the longitudinal axis.

EXPERIMENTAL SET-UP FOR TRANSMISSION SPECTROSCOPY

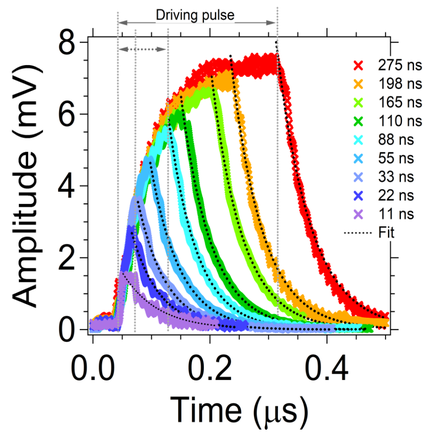
Pulse pattern generated with the Arbitrary Waveform Generator (AWG) and up-converted to microwave (MW) frequency (mixer M1). Signal acquisition is based on a heterodyne detection to get signal quadratures (downconversion at mixer M2).



AT ARB Rider 4022 AWG
2 channels, 2.5 GS/sec, 5 V_{pp} max out

SINGLE PULSE EXCITATION OF RESONATOR

Empty resonator excited by single pulse allows to observe cavity build-up and decay.

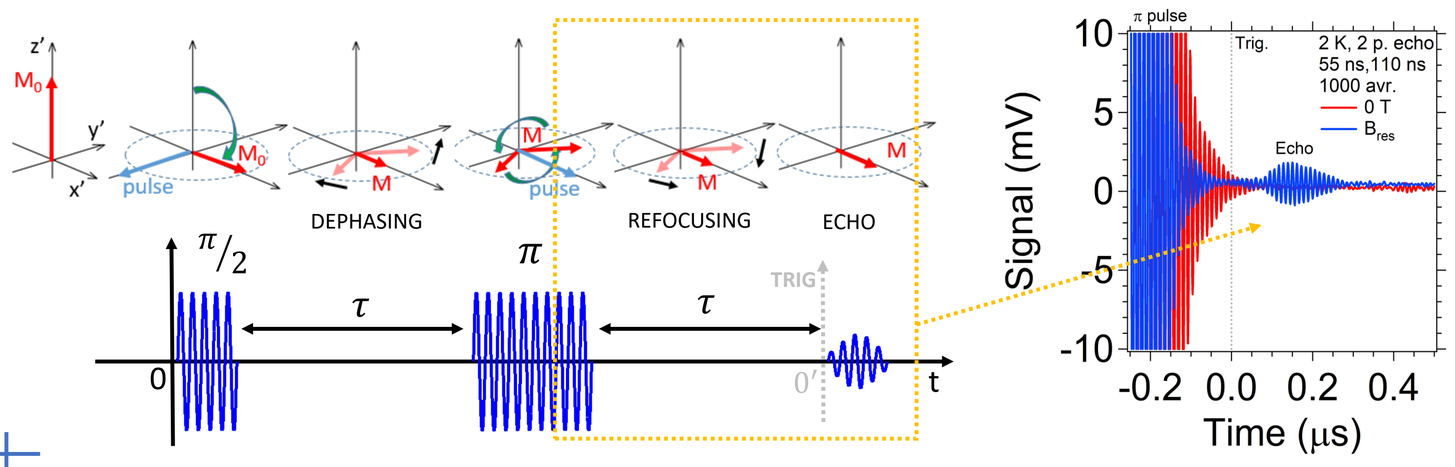


$$V(t) = V_0 e^{-2kt}$$

$$k = 10 \pm 1 \text{ MHz}$$

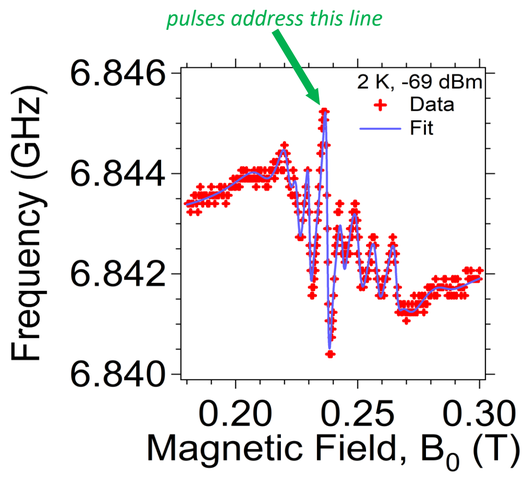
PERFORMING THE HAHN ECHO SEQUENCE

Magnetization of the ensemble (M_0) is driven out of equilibrium by first pulse ($\pi/2$). After a delay τ, a second pulse (π) induce spin refocusing. Echo is observed at 2τ on resonance.



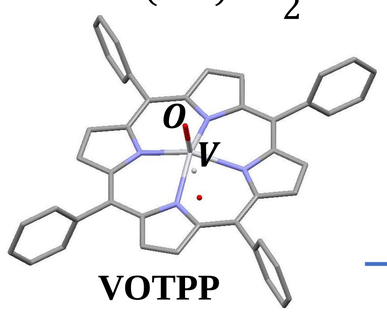
MOLECULAR SPIN ENSEMBLE UNDER TEST

We use an Oxovanadyl Phthalocyanine powder diluted in its diamagnetic host (12% VOTPP:TiOPP) [4].



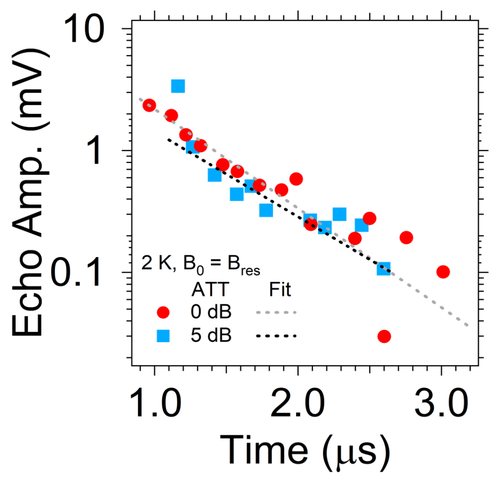
$$S(V = 0) = \frac{1}{2}$$

$$I(^{51}V) = \frac{7}{2}$$



Continuous wave spectroscopy with resonators [1,3] gives powder-averaged hyperfine multiplet. Here we focus on the main line (green arrow).

MEASURING THE PHASE MEMORY TIME



Echo decay monitored for different τ allows to measure the phase memory time (T_m) for the main line.

$$A(t) = A(t_0) e^{-\frac{(t-t_0)}{T_m}}$$

$$T_m = 600 \pm 50 \text{ ns}$$

CONCLUSIONS

We developed a set-up for pulsed-wave spectroscopy at microwave frequency and at low-T. Preliminary tests on molecular spin ensembles show that the spin ensemble can be addressed and manipulated, and that its phase memory time can be measured.

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[3] C. Bonizzoni, A. Ghirri, F. Troiani and M. Affronte – in preparation
[4] T. Yamabayashi et al, *J. Am. Chem. Soc.* 140, 12090 (2018).