^{35}Cl NQR Studies of the Bose Einstein Condensate Quantum Magnet $NiCl_2$-4SC$(NH_2)_2$

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Introduction

A candidate ^{35}Cl nuclear quadruple resonance frequency f_Q = 30.180 MHz discovered in 2009 by then REU student Robert Baker has been investigated in the S=1 material $NiCl_2$-4SC$(NH_2)_2$ (Dichloro-tetrakis-thiourea-Nickel, abbreviated DTN), in which field induced Bose-Einstein condensation (BEC) of the spin degrees of freedom has been observed[1]. The effect of Br-doping of DTN has recently received some attention in the context of more intricate bosonic phases such as the Bose Glass[2]. Planned NQR experiments at low temperature will further describe the phase diagram of DTN and the onset of magnetic ordering in the system.

Experimental

The candidate NQR signals were captured using a home-made superheterodyne pulsed-NMR spectrometer. The small NQR signal was detected using a highly sensitive impedance matching bridge with a hybrid tee. The signal was observed as a transient following a short pulse width t_a that was varied from 20 μs to 40 μs; the time between pulses t_r was varied from 2 ms to 120 ms. The validity of the interpretation of the observation as ^{35}Cl NQR was tested by applying a small external magnetic field to the sample with a solenoid, and observing the corresponding change in the envelope shape.

Results and Discussion

The signal was very weak and careful optimization of the signal detection circuit was necessary to collect reliable data. As the NQR frequency displays strong temperature dependence, natural temperature shifts of the room limit the total time of signal averaging, which in turn limits the number of averaging cycles *N* that can be used for a given value of t_r. Signal clarity was also highly sensitive to the amount of post-gain provided by the specific combination of fast recovery amplifiers implemented between the bridge circuit and the oscilloscope. The runs depicted in Fig. 1 are with f_c = 30.178 MHz. The signals in Fig. 1 were observed with t_a = 30 μs; *t*r = 12 ms, *N* = 3200 cycles.

Conclusions

The observed signal indicates an NQR frequency of f_Q = 30.1735 MHz at room temperature. The shape of the envelope in the applied field of B = 0.9 G is altered, which does not rule out NQR. Because the value of the earth's magnetic field was measured to be 0.45 G at the position of the sample, more data collection, is needed to achieve resolution that confirms quadrupolar resonance via the applied field and its expected shift of 400 Hz/G for ^{35}Cl.

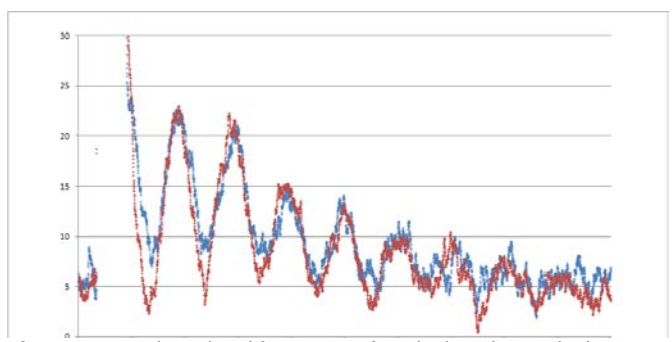

Figure 1. Transient signal form DTN after single pulse excitation at room temperature. The blue curve is the response in the Earth's magnetic field and the red curve is for an applied field of 0.9 G. Measurements were taken at room temperature T = 297 K and averaged over *N* = 3200 cycles.

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References

[1] L. Yin, *et al., Phys. Rev. Lett.* **101**, 187205 (2008).
[2] Rong Yu, *et al, Nature,* **489**, 379-384 (2012).