



# Microscopic Dynamics in “Supersolid” Helium

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DMR-Award 0654118

High B/T User Program / Microkelvin Laboratory

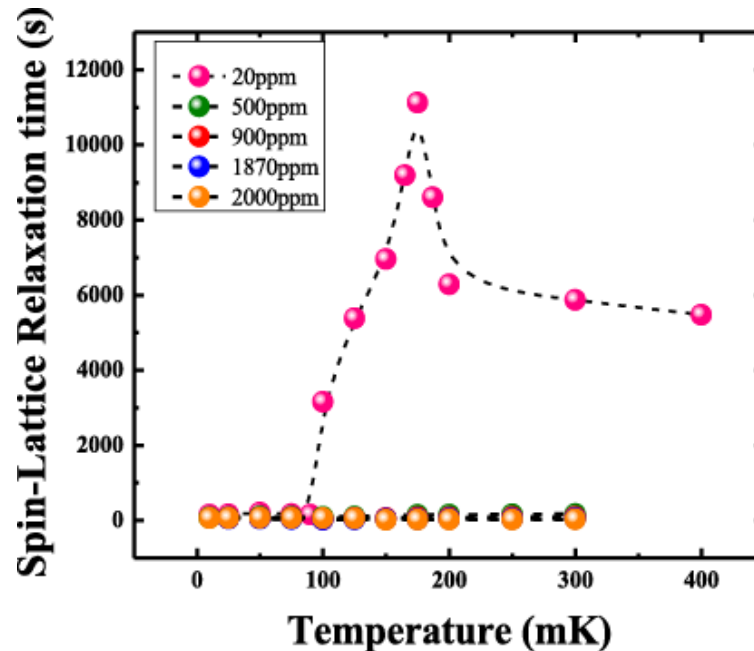


A ‘supersolid’ is a bizarre prediction of quantum mechanics with parallels to superconductivity and superfluidity. However, unlike its better known cousins, there is active debate whether a supersolid can really exist. In order to probe this possibility, users of the Magnet Lab’s ultralow temperature facility measured the NMR relaxation rates of  $^3\text{He}$  impurities in solid  $^4\text{He}$  near the so-called supersolid phase transition of  $^4\text{He}$ . This is the region where evidence of a supersolid has been reported.

These experiments are unique because NMR can measure microscopic quantum tunneling directly and thus probe the fundamental ground state better than traditional macroscopic rotation experiments.

A peak in the spin-lattice relaxation time is accompanied by a drop in the spin-spin relaxation times, pointing to a rapid change in the microscopic quantum dynamics near the supersolid transition.

Measurements of the nuclear spin-lattice relaxation time,  $T_1$ , down to 22 mK in carefully annealed samples of solid  $^4\text{He}$ , shown for five different  $^3\text{He}$  impurity concentrations. A sharp peak in  $T_1$  is observed at the same temperature where macroscopic superflow is reported.



Kim, S.S.<sup>1</sup>; Huan, C.<sup>1</sup>; Yin, L.<sup>1</sup>; Xia, J.S.<sup>1</sup>; Candela, D.<sup>2</sup> and Sullivan, N.S.<sup>1</sup>, *NMR Studies of  $^3\text{He}$  Impurities in  $^4\text{He}$  in the Proposed Supersolid Phase*, *Journal of Low Temperature Physics* 158, 584 (2010).

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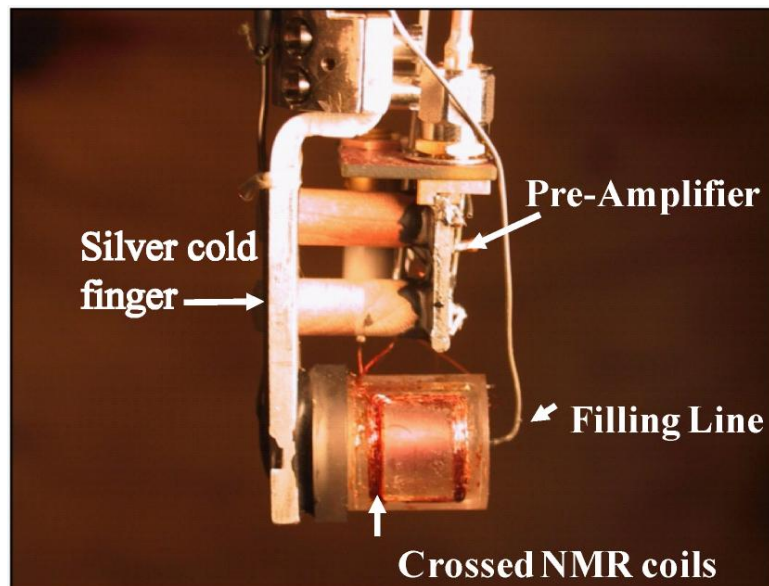
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NMR crossed coils and pre-amplifier shown in relation to the silver cold finger extending from the low temperature refrigerator. The nested coils are only weakly coupled to the cold finger and can float to  $T \sim 0.5\text{K}$  while the sample is maintained at  $T \sim 0.02\text{K}$ .

Huan, C.; Kim, S. S. *et al.*, *Journal of Low Temperature Physics* **158**, 692 (2010).

In order to observe the weak signals from the small number of  $^3\text{He}$  atoms (only 16 to 30 atoms for every 1,000,000 ordinary helium atoms), Magnet Lab scientists designed a unique low temperature amplifier and a nested crossed-coil configuration that could operate in an applied magnetic field down to millikelvin temperatures.

The preamplifier used a high electron mobility transistor oriented so that the plane of the chip was parallel to the applied field, an important design feature to avoid having the intense magnetic field interfere with the operation of the transistor. The operating point of the transistor could be adjusted externally by changing the gate bias, just as with ordinary transistors.

The overall noise temperature was extremely low, approximately 0.8K at 2MHz.