Quantum Plasticity of Solid ^{4}He: NMR Studies of the Motion of ^{3}He Impurities

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Introduction

A number of experiments have demonstrated some remarkable and unexpected properties for solid ^{4}He at low temperatures. These include anomalies in the sound attenuation, the rotational moment of inertia and the shear modulus below about 0.2K. Originally thought to be signatures of a possible superfluid phase, the lack of any evidence for critical behavior particularly in sensitive NMR experiments [1] has lead to the interpretation of these anomalies in terms of an unusual quantum plasticity of the solid.

Experimental

We measured the nuclear spin-lattice relaxation of very dilute concentrations of ^{3}He in solid ^{4}He. The ^{3}He impurities tunnel through the lattice by quantum tunneling and are thus very sensitive to even small changes in the elastic properties of the lattice. Conventional 90-t-180 pulse techniques were used to measure the relaxation times. The experiment was carried out using a dedicated NMR spectrometer for low temperature applications in in the NHMFL High B/T Facility.

Results and Discussion

The temperature dependence of the NMR relaxation times of ^{3}He impurities (27 ppm) in solid ^{4}He is shown in **Figure 1**. At high temperatures a temperature independent variation is observed consistent with quantum tunneling. In the vicinity of 175 mK a smooth peak is observed in the same temperature range where the other anomalies are observed. An excellent fit t the data (broken blue line in Fig. 1) is obtained by including a thermally activated lattice relaxation term for the ^{4}He lattice following a quantum jump of a ^{3}He atom from one lattice site to another.

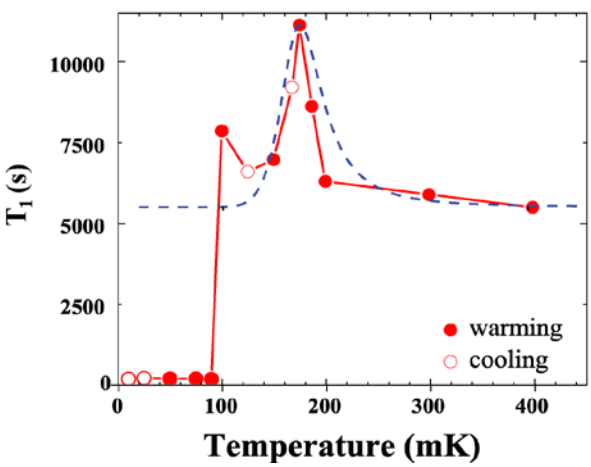

Figure 1. Temperature dependence of the nuclear spin-lattice relaxation for ^{3}He impurities in solid ^{4}He. The concentration of the ^{3}He was 27 ppm.

Conclusions

The temperature dependence of the nuclear spin-lattice relaxation of ^{3}He impurities in solid ^{4}He shows no evidence of the critical behavior expected for a supersolid transition and is consistent with an unusual quantum plastic property of the ^{4}He lattice.

Acknowledgements

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References

[1] Kim, S.S. *et al.*; Phys. Rev. Lett. **186**, 185303 (2011).