Quantum Dynamics in Solid Helium

2009 NHMFL Science Highlight for NSF

DMR-Award 0654118

High B/T User Program / Microkelvin Laboratory, University of Florida

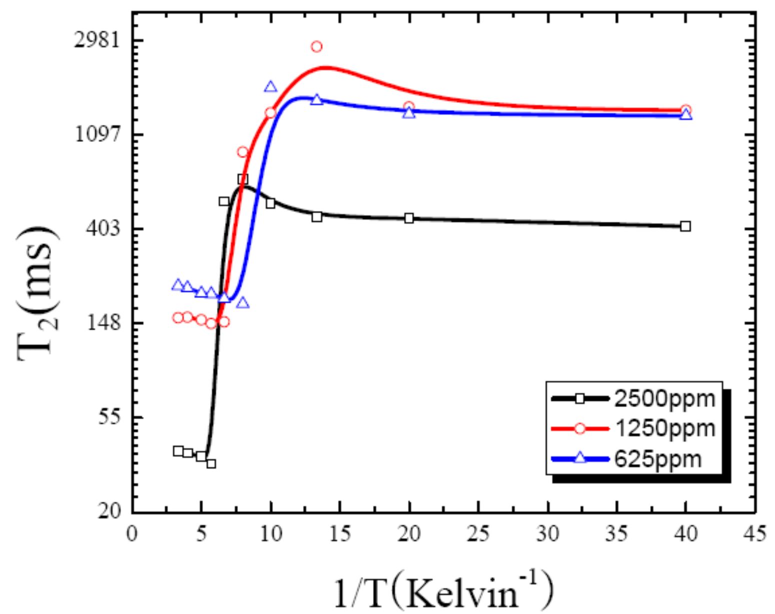
Unique NMR techniques have been developed at low temperatures to expose the quantum dynamics of solid helium four in the region where new "supersolid" phases have been postulated. The experiments measure the nuclear spin dynamics of helium three impurities that can quantum mechanically exchange sites with helium four atoms. This exchange is crucially dependent on the lattice and therefore can detect dynamical changes such as those occurring at phase transitions.

At low temperatures the quantum tunneling is seen as a temperature-independent relaxation time. Jumps by two orders of magnitude occur at the ^{3}He-^{4}He phase separations which produce nanoclusters of pure liquid ^{3}He.

Kim, S.S.[1]; Huan, C.[1]; Yin, L.[1]; Xia, J.S.[1]; Candela, D.[2] and Sullivan, N.S.[1], *NMR Studies of ^{3}He Impurities in ^{4}He in the Proposed Supersolid Phase*, Proc., QFS 2009 Conf., Evanston, 2009. [1]NHMFL; [2]U. Mass., Hasbrouck Laboratory

Measurements of the nuclear spin-spin Relaxations times, T_2, down to 22 mK in carefully annealed samples of solid ^{4}He

The jumps at high temperatures are due to ^{3}He-^{4}He phase separations.



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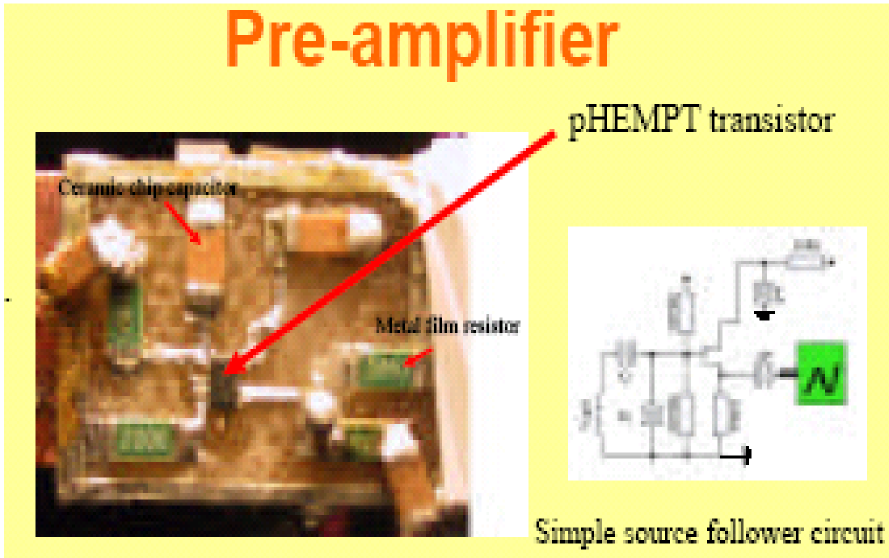

Circuit diagram and layout of the low temperature amplifier. The Overall noise temperature was less than 1.1K when operated at 2.1 MHz down to o.45 K. The device dissipation was approximately 0.5 mW.

S. S. Kim, C. Huan et al., Proc. QFS2009 Conf, Evanston, 2009

In order to carry out these studies of quantum motion in solid helium we developed a unique low temperature amplifier that could operate down to millikelvin temperatures in a high magnetic field. A pseudomorphic high electron mobility transistor was used, and its operating point could be adjusted externally by changing the gate bias. The circuit is oriented so that the lane of the chip is parallel to the applied field.

The simplicity of the circuit used and the high bandwidth of the device would allow it to be employed in a wide variety of NMR solid state studies in high magnetic fields.