Pulsed NMR in the Nuclear Spin Ordered Phases of Solid ^{3}He in a Silver Sinter

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Abstract

To obtain the exact spin structure of the nuclear magnetically ordered phases of solid ^{3}He, in the bcc lattice called U2D2 and high field phase, both occurring below about 1 mK, we started a project of neutron scattering from the solid at the Hahn-Meitner Institut, Berlin. This experiment faces three main difficulties: to cool the solid to temperatures below 1 mK (or even much lower in the case of the hcp lattice), to keep it there under neutron flux, and to grow a single crystal within the sintered material needed for this purpose. As a first step we have performed pulsed NMR measurements in the ordered phases of solid ^{3}He in a silver sinter of 700 Å particle size down to temperatures of 600 μ K at various molar volumes. The samples remained in the ordered state for as long as 110 h. This work was funded by EU project HPRN-CT-2000-00166

Key words: Helium3; nuclear magnetism; NMR; neutron scattering

1. Introduction

In order to establish the spin structure of the nuclear magnetically ordered phases of solid ^{3}He by neutron scattering, it is crucial that a single crystal can be formed in the sinter needed to cool it and that the solid remains in the ordered state for long enough time even under neutron irradiation. For checking these goals we designed a cell for pulsed NMR measurements on solid ^{3}He in a 700 Å sinter. We started to look for the existence of a single crystal which would be indicated by the characteristic line splitting of the u2d2 phase. The cell temperature and its warmup behavior after demagnetization of our 0.9 mole $PrNi_5$ nuclear stage was monitored by pulsed NMR on a copper sample thermally connected to it.

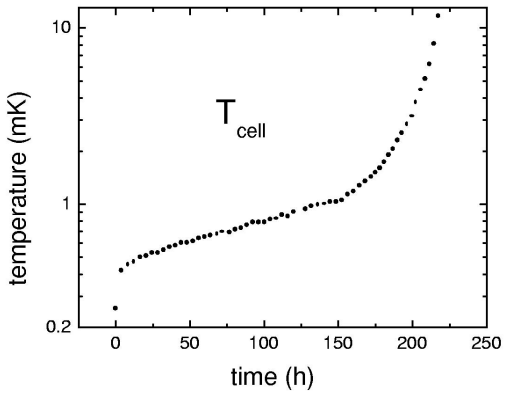

Fig. 1. Temperature of the nuclear stage after demagnetization determined by pulsed NMR on ^{63}Cu

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The Fast Fourier Transform of the free induction decay of the solid ^{3}He signal was used to establish the magnetization of the solid in the paramagnetic phase, the frequency, and the full width at half maximum of the NMR line.

2. Results

Fig. 1 shows the warm-up behavior of the cell after demagnetization. The faster warming after 170 h is due to additional external heating.

In Fig. 2 the NMR signal intensities of a solid ^{3}He sample grown at 41.6 bar (i.e. 23.4 cc/mole) are shown vs the temperature of the nuclear stage which is practically identical to that of the cell body. In the paramagnetic phase these intensities are proportional to the magnetization of the solid. The drop in the ordered state to below 20 % of the maximum is very peculiar. We found neither a line splitting nor a line broadening in the ordered solid.

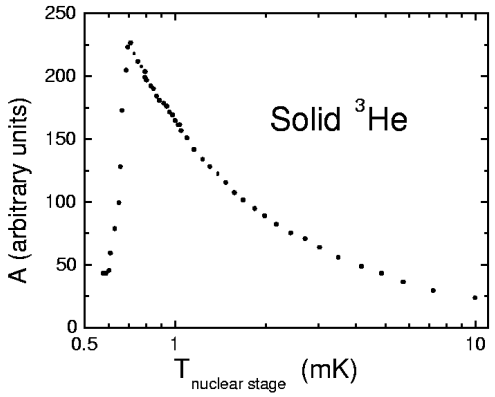

Fig. 2. NMR intensity of solid ^{3}He vs the cell temperature

The large drop of the line intensity then can have several origins: either we missed additional lines although we searched for them in a wide frequency range, or we had a single crystal of special orientation with respect to the pickup coil, or we do not have the U2D2 phase in the sinter at this molar volume.

In Fig.3 we present an NMR spectrum from solid ^{3}He in a silver sinter in the low field ordered state. In our last run we also cooled the same sample into the high field phase and measured NMR spectra and line intensities there. The analysis of the data shows the expected enhancement for this weak ferromagnetic phase, see Fig. 4.

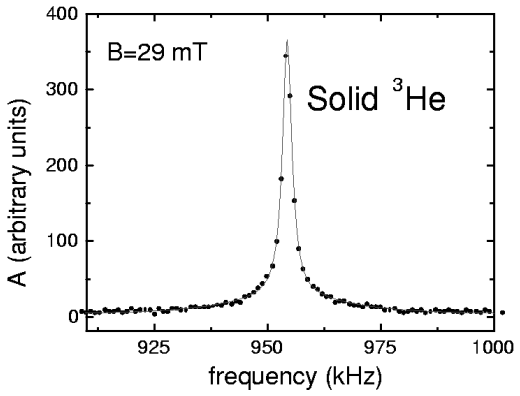

Fig. 3. NMR spectrum of solid ^{3}He in a 700 Å silver sinter at T= 600 μK

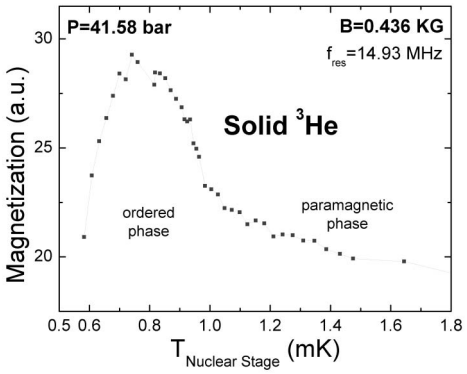

Fig. 4. NMR intensity of solid ^{3}He in a 700 Å silver sinter at B = 0.44 T

Acknowledgements

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