Homogeneous spin precession in superfluid ^{3}He confined to aerogel

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Abstract

We report on systematic studies of creation and relaxation of a macroscopic region of homogeneous spin precession (homogeneously precessing domain – HPD) in B-like phase of ^{3}He in aerogel. Long lived free induction decay signal has been observed after filling up the whole cell with the HPD and switching off the CW radiofrequency field. Characteristics of CW NMR and free induction decay signal were found to be similar to those known for bulk ^{3}He-B.

Key words: superfluidity; helium3; aerogel;

By present time a number of NMR experiments [1,2] performed in superfluid ^{3}He confined within ^{4}He preplated aerogel have made it clear that a low temperature phase has a B-type structure of the order parameter. In the bulk superfluid ^{3}He-B the order parameter gradients result in the existence of spin supercurrents which can play a vital role in spin dynamics. In particular they result in existence of homogeneously precessing domain (HPD) [3,4]. A main feature of the HPD is a coherent (i.e. with nearly the same phase) precession of the magnetization in a cell in presence of a magnetic field gradient. The HPD can be created e.g. in CW NMR experiments [5]. If we switch off a radiofrequency (RF-) excitation after the HPD formation then the volume of the HPD would decrease and a domain wall (which separates the HPD and the remaining part of the sample with equilibrium value of the magnetization) would move from a region of higher magnetic field to a lower one. The precession frequency of the HPD equals the Larmor frequency in the middle of a domain wall. Therefore the frequency during the relaxation follows the wall position and in case of constant dissipation (as it usually takes place) changes linearly with the time. In recent CW NMR experiments in Grenoble [6] the HPD-like signal was observed in B-phase of ^{3}He in aerogel. However, the obtained signal was rather short, i.e. only small part of the cell was probably occupied by the HPD. In our experiments we have succeeded in filling up the entire volume of the cell with the HPD.

Experiments were performed at a pressure of 25.5 bar, in magnetic field of 284 Oe (NMR frequency was 923 kHz). An experimental cell design is described in [7]. An important feature of the design is a finite gap (0.15 mm) between the aerogel sample and the cell walls. An external magnetic field consisted of homogeneous component as well as linear gradient component created by a separate coils. In order to create the HPD the homogeneous component of the external magnetic field was slowly swept down (the initial value of the field exceeded the value ω_{RF}/γ) in presence of RF-field. It was found that at high enough amplitude of RF-field (about 0.01 Oe) the NMR line drastically changed and its form corresponded to the HPD formation just as it is known for the bulk ^{3}He-B [5]. A solid curve on Fig.1 shows a formation and further growth of the HPD while lowering an external magnetic field. Finally the HPD occupied almost the entire volume of the experimental cell. If the field is swept up after the breakdown of the HPD then we get usual CW NMR signal which has much smaller amplitude (the HPD

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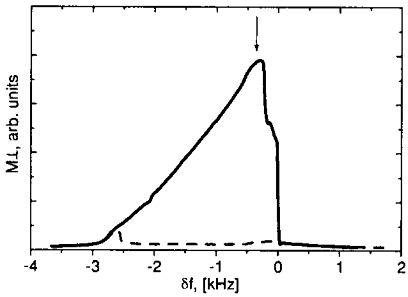

Fig. 1. The total transverse magnetic moment versus the field (recalculated to the frequency). The HPD is created while sweeping magnetic field down (solid line); the sweep in inverse direction does not result in formation of the HPD (dashed line). The arrow marks a point where the RF field was switched off to get FIDS signal. The gradient of the magnetic field applied $\nabla H = 1.5\, Oe/cm$

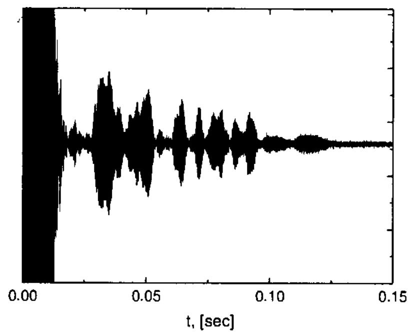

Fig. 2. FIDS of the coherent precessing structure after filling up the whole cell with the HPD and switching off the RF-excitation.

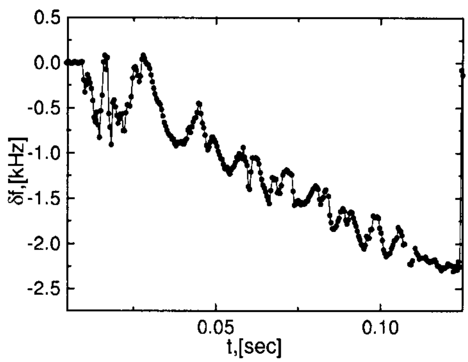

Fig. 3. The frequency of the FIDS during the HPD relaxation

does not appear).

We have found that if we try to create the HPD anew after its breakdown then we have to wait for $\approx$5 min because otherwise the HPD does not appear. Moreover, if the HPD is created and we stop the sweep, then the absorption slowly grows and can finally result in the HPD breakdown. The reason for that could be an overheating of the ^{3}He in aerogel due to large magnetic dissipation ($\approx$1 nW) and rather small thermal conductivity of ^{3}He in aerogel [8]. The gap between aerogel sample and cell walls seems to be very important and saves us of having this thermal relaxation time too long.

Fig.2 shows free induction decay signal (FIDS) after the HPD had filled the cell and RF-field was switched off. In spite of rather complicated amplitude dependence of the FIDS, we point out that the duration of the FIDS $\approx 0.1\, s$ is apparently much longer than the dephasing time due to the gradient of the external magnetic field $\tau_2{}^* = 1/\gamma(\nabla H)l_{cell} \approx 0.5\, ms$. The complex amplitude dependence of the FIDS can be attributed to the large oscillations of the coherent structure which do not result in its collapse.

Fig.3 shows the dependence of the FIDS frequency on the time for the signal shown on Fig.2. It is seen that the frequency follows nearly linear dependence as it should be in the case of HPD relaxation in a bulk ^{3}He. It is worth to point out that as it was expected the total frequency change of the FIDS corresponds well to $\delta f_L = \gamma(\nabla H) l_{HPD}$, where l_{HPD} is the initial HPD length (e.g. from Fig.3 $\delta f_{FIDS} \approx 2.3 kHz$ and $\delta f_L = \gamma(\nabla H) l_{cell} \approx 2.44 kHz$).

The existence of the HPD in a low temperature phase of ^{3}He in aerogel means that a phase coherence or long-range order exists at the whole aerogel sample in spite of the aerogel intrinsic inhomogeneities. It also points out that spin supercurrents can play an important role in spin dynamics of superfluid ^{3}He in aerogel.

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