Superfluid ^{3}He confined in a slab geometry

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Superfluid ^{3}He was discovered in 1971, and the order parameter of the A and B phases was soon identified by their NMR response. The 1996 Nobel Prize was awarded to Osheroff, Richardson and Lee [1] for this work. Superfluid ^{3}He provided the first example of a non s-wave (unconventional) superfluid/superconductor. After this discovery non s-wave pairing was observed in a number of other systems: high Tc superconductors, UPt_3, and $SrRu_2O_4$ are well known examples. In these cases the determination of the order parameter is more complex, and there is still controversy over the order parameter of many unconventional superconductors.

In contrast to these metallic systems the Fermi surface of bulk ^{3}He is a sphere. The anisotropic superfluid state emerges from an isotropic normal state, simplifying the identification of the order parameter. The richness of the phenomena observable in superfluid ^{3}He derives from the complex symmetries of the ground state.

Numerous theorists [2-6] considered the effects on the order parameter of confining superfluid ^{3}He to a region where one length scale is on the order of the coherence length of the Cooper pair. While considering different models, they agree that the A or planar phase (degenerate in the weak coupling limit) would stabilize in slabs a few coherence lengths thick, and the B phase with an anisotropic distortion towards the planar phase has the lowest free energy in thicker slabs. Recent work has proposed a "stripe" phase with spontaneously broken translational symmetry in the plane of the slab to be stable in a narrow region of the phase diagram between the B and the A or planar regions [6].

At a diffusively scattering wall, all components of the superfluid order parameter are suppressed and they recover over a length scale on the order of the temperature dependent coherence length, $\xi(T)$, away from the wall [7]. The zero temperature coherence length, ξ_0, which can be thought of as the `size' of a Cooper pair, is a function of pressure and varies from 77 nm at zero pressure to about 15 nm at melting pressure.

Experimental realisation of superfluid ^{3}He films has faced the combined problems of cooling and confining such a thin film while being sensitive to the nature of its superfluidity. However several groups [8-15] have overcome these technical challenges and measurements on film flow, third sound and NMR (on multiple slabs) have been carried out in various geometries. After reviewing these experimental results I will discuss our recent work using DC SQUID based NMR to measure a signal from a single slab of ^{3}He confined in a nanofabricated d = 635 nm deep cavity, in a 3 mm thick silicon wafer. The thick walls allow us to vary the pressure in the cell, and hence explore a large region of the phase diagram as a function of d / ξ_0. For pressures greater than 3 bar, and at low temperatures, we observe a transition into an as yet unidentified phase.

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