Experimental report

13/09/2016

Proposal: **6-01-325**

Council: 10/2012

Title: Bose-Einstein Condensation, Superflow and Excitations of Liquid 4He Confined in nanoporous FSM-28

Research area: Physics

This proposal is a new proposal

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Samples: He SiO2

Instrument	Requested days	Allocated days	From	To
IN5	5	5	09/07/2013	14/07/2013

Abstract:

We propose neutron scattering measurements of the phonon-roton (P-R) and layer modes of liquid 4He confined in the nanoporous media FSM-28 on IN5. The superfluid density, superfluid critical temperature, TC, and the specific heat of liquid 4He in FSM-28 have recently been accurately measured. The aim is to explain these measurements in terms of the characteristic modes. We will use the same FSM-28 so that direct comparison of results can be made. The TC in FSM-28 is very low, far below TC in bulk liquid 4He. A specific goal is to determine the onset temperature for BEC, TBEC, from the temperature dependence of the P-R modes, to see whether TBEC lies above TC and whether there is a temperature range TC < T < TBEC in which there is BEC but no superflow in FSM-28. This region would be similar to the pseudo gap phase TC < T < T* observed in the cuprate superconductors where there is a localized gap and local pairing but no superconductivity. A second goal is to investigate which modes give rise to the specific heat, the P-R or the layer modes.

Bose-Einstein Condensation, Superfl ow and Excitations of Liquid 4He Co nfined in nanoporous FSM-16

The aim of the experiment was to measure of the excitation spectra of liquid ^{4}He confined in the 28 Å pore diameter of the FSM-16 nanoporous media versus filling, temperature and pressure. Because of a possible contamination of the FSM sample, only the high pressure measurements, i.e., close to the solidification of the helium ($\simeq 25bar$) have been fully exploited. The low SVP pressure (Saturated Vapour Pressure) has been recorded but shows significant unexplained fetures on the high energy end that preclude to "disantangle" the various helium contributions, namelly, the solid surface helium, the liquid layer, the bulk superfluid and the normal fluid contributions.

Introduction

Superfluid helium-4, in addition to the understanding of its cryogenic properties, is a toy model as a gas of interacting bosons. Analogies are made betweeen helium-4 and the gas of Cooper pairs in superconductor theories. Moreover, the suppression of superflow in porous media, whistl the Bose-einstein condensation (BEC) persists, can be seen as an analogue of the pseudo-gap phase in the high-T_c superconductors.
Other effects on ^{4}He, specific to the confinement, may arrise as well. Amongst the variety of porous media that have been studied by neutron scattering, the folded sheet Material (FSM) presents monodispersed channels of controled dimensions. The FSM-16 (16 refers to the chain lenght of the surfactant used for the fabrication) has a pore diameter of 28 Å where the confinement effects becomes as important as the bulk helium features. The strong depression of the superfluid temperature and the shift to higher pressures of the solidification makes it unique for the completion of the temperature-pressure phase diagram.

Experimental

3 g of FSM powder has been put in a sealed aluminium can, dried and purified by pumping 3 days under heating. The can was mounted on a dilution stick. Helium-4 filling was made by injecting a calibrated volume of helium while cooling the cell (Fig. 1). Between each filling the cell was allowed to reach the base temperature. Knowing the specific surface of the porous medium, the volume of helium to fill the pores before having bulk liquid at the exterior of the pores has been calculated. This define the Saturated Vapour (SVP) conditions (see Fig. 2).
The high pressure was achieved by overfilling and pressuring up to 40 bar and blocking the filling capilary in such a way that the FSM-external bulk helium becomes solid

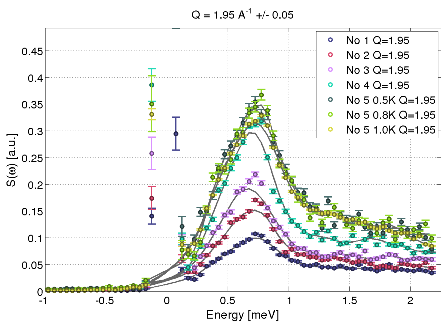

Figure 1: SVP data for the 5 first fillings (out of 10) at the roton minimum $Q = 1.95$ Å^{-1}. The background above 1 meV growth proportionally to the filling volume
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and contributes to the inelastic scattering as a well indentified density of states. From the roton minimum position it was established that the presssure inside the pores was around 25 bar.

Results

The inelastic scattering at the roton minimum seems to growth with the filling (Fig. 1) more than expected. In particular, the inelastic background above 1 meV is stronger than has been seen in a recent paper [1] on the same system (although focused on another part of the phase diagram). This unexplained result does not help for the SVP data analysis.

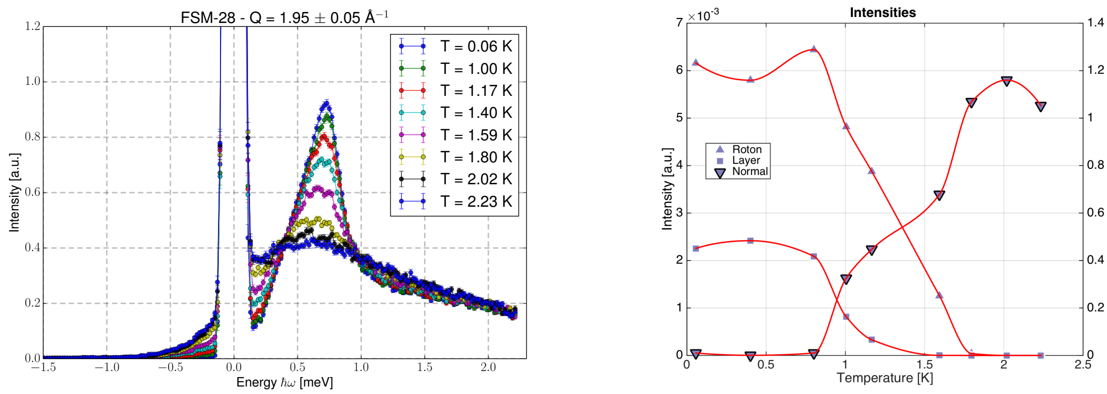

Figure 2: Temperature dependence at SVP at the roton minimum $Q = 1.95$ Å^{-1}

A preliminary modeling the liquid part (a bulk roton, a layer mode and a normal liquid mode) indicates, although without the necessary accuracy, that the superfluidity is suppressed way below T_λ. With the help of the maxon intensity temperature variations, that is less affected by the background, the transition temperature my be estimated between 1.6 and 1.8 K.
The high pressure data are more clear, the higher background given by the internal and external solid helium is better separated from the liquid features (Fig. 3). For the high pressure, a coherent description of the temperature evolution of the excitations has been established.

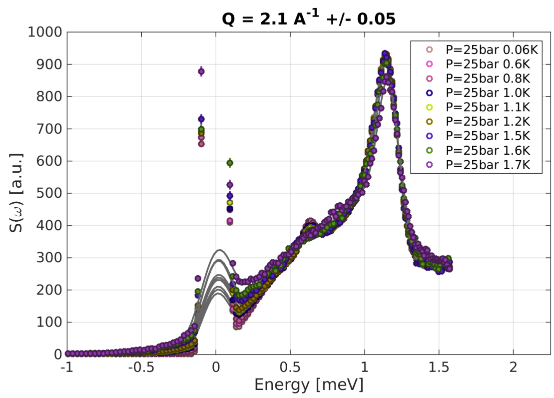

Figure 3: Temperature dependence at 25 bar at the roton minimum wavevector $Q = 2.1$ Å^{-1}

References

[1] T.R. Prisk et al. Phys. Rev. B **88**(2013)014521