SUMMARY OF Ph.D. DISSERTATION

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Title

Quantum Effects of ^{4}He Confined in Nanoporous Media

Abstract

Bose system in periodic or random potential has been attracted great attention in condensed matter physics. In these systems, novel quantum phases such as Mott insulator, Bose glass, or supersolid are expected. In dilute ultracold atoms with a periodic potential, a quantum phase transition between a superfluid phase and a Mott-insulator phase has been indeed observed. In contrast, liquid or solid ^{4}He provides us strongly correlated Bose system due to its hard-core nature. Thus, if we put strongly correlated ^{4}He on the periodic or random potential, exotic states which have never been seen before are expected to occur.

I have studied ^{4}He confined in nanoporous Gelsil glass with 2.5-nm pore diameter as a strongly correlated Bose system in random confinement potential. I have found that a pressure-temperature phase diagram shows an unprecedented superfluid-nonsuperfluid-solid quantum phase transition in this system by the measurements of superfluid density and constant pressure. The nonsuperfluid phase has small entropy and is entirely different from the usual normal fluid of bulk ^{4}He. This novel nonsuperfluid phase is expected to be a localized state of Bose-Einstein condensation. To elucidate the thermodynamics of the nonsuperfluid phase, I have carried our heat capacity measurements. Heat capacity has a peak at T_B which is much higher than the superfluid transition temperature T_c. Below T_B, the heat capacity data is well explained by thermal excitations of phonons and rotons which are unique to the Bose-Einstein condensate. These observations strongly demonstrate the existence for the Bose-Einstein condensation on nanometer length scales in the nanopores of Gelsil glass even above the superfluid transition temperature T_c.

Thus, these experiments offer the evidence that localization of Bose condensate occurs in strongly correlated Bose system with random confinement potential.