論文の内容の要旨

論文題目 Effects of Geometric Confinement on Strongly Correlated Superfluids

（強い相関を持つ超流体における幾何学的閉じ込めの効果）

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In this thesis two cases of boson systems subject to the effects of geometric confinement are presented. First, the response to an external velocity field of a one dimensional bosonic quantum fluid is investigated. Contrary to the majority in $d \geq 2$, one dimensional systems are known not to thermalize or do so only very slowly, owing to the presence of an infinite or non-zero number of conservation laws. This difference is reflected in the fact that in dimensions $d \geq 2$ the static and dynamic definitions of the superfluid and normal component of a quantum liquid are largely equivalent. Here the external potential and the velocity field generated by it are theoretic constructs whose explicit forms are largely irrelevant since they only serve as a means to guarantee the occurrence of thermalization and the potential's effects can be incorporated in the boundary conditions of the velocity field. This however changes in the case of one dimensional fluids, where the exact form of the potential needs to be taken into account and the static and dynamic definitions of superfluidity at finite temperature disagree drastically, the former vanishing for infinite systems while the latter can be non-zero. A specific example in the framework of Tomonaga-Luttinger liquid theory is discussed and said difference in the static and dynamic quantities is exemplified. Furthermore, in order to compare the theoretical predictions to experimental results on ^{4}He in one dimensional nanotubes, the momentum-momentum response functions are calculated using the memory matrix formalism, which allows to take into account the effects of hydrodynamic slow modes present in the model.

Second, the effects of disorder on the critical phenomena in a system of superfluid bosons is studied. Motivated by experiments on ^{4}He in nanoporous Gelsil glass, where under pressurization the fluid can be driven from a superfluid to a normal regime at zero temperature, a theory based on the bosonic version of the Hubbard tight binding model is developed. Making use of a mapping from the quantum model to a classical statistical mechanics problem in higher dimensions, scaling laws for the superfluid density and the phase boundary in the pressure-temperature phase diagram are derived. Notwithstanding the fact that particle-hole symmetry breaking is a relevant perturbation, it is argued

that due to the high-filling of each pore and the random distribution of the pore sizes, the effects of particle-hole symmetry breaking are negligible at the experimentally accessible temperatures. As a consequence, it is shown that the system is well described by the clean four dimensional XY universality class except in the close vicinity of the critical point, where a crossover to a disorder dominated regime occurs. The theory is compared to experimental results in the above mentioned ^{4}He system and in a highly underdoped cuprate compound.