A-7

# Supercurrent decay via quantum phase slips in one-dimensional Bose gases

Ippei Danshita[1], Anatoli Polkovnikov [2]
[1] Computational Condensed Matter Physics Laboratory, RIKEN;
[2] Department of Physics, Boston University
E-mail address: danshita@riken.jp

[キーワード] phase slip, instanton, dipole oscillation

We study transport properties of one-dimensional (1D) superfluid Bose gases. In 1D, superflow at zero temperature can decay via quantum nucleation of phase slips even when the flow velocity is much smaller than the critical velocity predicted by mean-field theories. Using instanton techniques, we calculate the nucleation rate $\Gamma_{\rm prd}$ of a quantum phase slip for a 1D superfluid in a periodic potential and show that it algebraically increases with the flow momentum $p$ as $\Gamma_{\rm prd}/L \propto p^{2K-2}$ when $p \ll \hbar/d$ [1]. Here $L$ is the system size, $K$ the Tomonaga-Luttinger parameter, and $d$ the lattice spacing. Based on the relation between the nucleation rate and the quantum superfluid-insulator transition, we present a unified explanation on the scaling formulae of the nucleation rate for periodic, disorder, and single-barrier potentials.
In order to make a connection with cold atom experiments, we also consider dipole oscillations of 1D Bose gases confined in a parabolic potential, where the transport is characterized by the damping rate $G$. From a simple physical argument, we conjecture the following relation that $G \propto \Gamma/p$. Using the exact numerical method of time-evolving block decimation, we analyze the dipole oscillation dynamics of the hardcore Bose-Hubbard model with a single barrier to corroborate this conjecture. We also compute the dipole oscillation dynamics of the softcore Bose-Hubbard model with no barrier potential. We find that the damping rate does not obey the scaling formula for a periodic potential $G_{\rm prd} \propto p^{2K-3}$ [1], but obeys the one for a single barrier $G_{\rm sb} \propto p^{2K-2}$ [2]. This interesting behavior can be interpreted as meaning that the unit filling regions of the trapped gas behave as if they are barrier potentials for the other part of the gas.

[1] I. Danshita and A. Polkovnikov, arXiv:1110.4306v1 (2011).
[2] Yu. Kagan, N. V. Prokof'ev, and B. B. Svistunov, Phys. Rev. A **61**, 045601 (2000).