Non-equilibrium dynamics of Mott-to-superfluid transition in Bose-Einstein condensation in optical lattices

Naoya Horiguchi[a], Takashi Oka and Hideo Aoki*

Department of Physics, University of Tokyo, Japan

* E-mail: aoki@phys.s.u-tokyo.ac.jp

Bose-Einstein condensate of cold atoms realized in optical lattices is one of ideal test benches for studying dynamics of phase transitions, since the transition from the Mott insulator to superfluid driven by a quench (a sudden change) into the superfluid phase should give us deeper insights (Kibble-Zurek mechanism, etc) into non-equilibrium evolution of gauge-symmetry broken quantum phases. Two factors favour experimental accessibility: (a) the typical time scale in the non-equilibrium dynamics is very slow (ms), and (b) we can control, with the Feshbach resonance, the particle-particle interaction along with other parameters such as the optical potential depth. Here we have numerically obtained the features of the domain structure in real space, and correlation functions for the condensate when the interaction strength relative to the optical lattice potential is suddenly changed[1]. The system after the quench is shown to relax in three processes (Fig.): (i) an exponential growth of superfluid density, (ii) collapse of the domain structure, and (iii) vortex-antivortex pair-annihilation as the long-range superfluid order is formed. From these the topological picture due to Kibble-Zurek and Zurek's freeze-out scenario for slow quenches are confirmed.

[a] Present address: NEC corporation, Japan

[1] N. Horiguchi, T. Oka and H. Aoki, Proc. LT25 (Amsterdam, 2008).

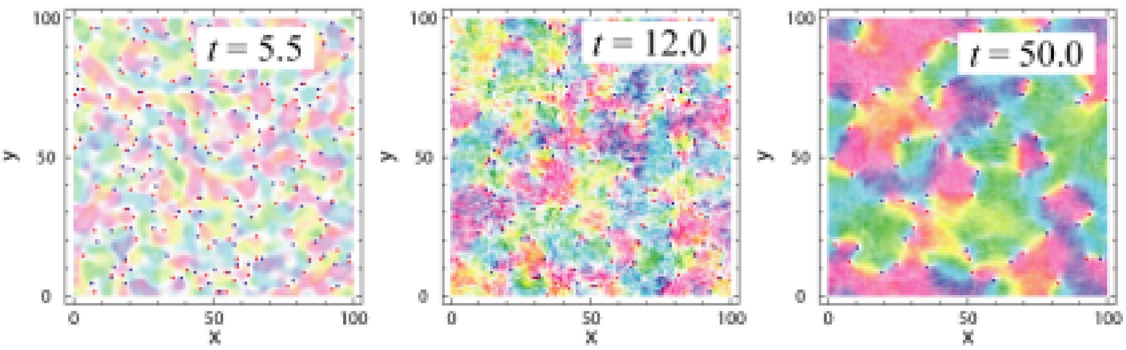

Fig. Snapshots of the temporal evolution (from left to right) of the superfluid order parameter (whose phase is colour-coded) in a 2D system after the quench at t =0. The blue (red) dots represent the position of vortices (anti-vortices).