Experimental studies of one dimensional Bose gases

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By recent advances of laser cooling and manipulating of neutral atoms, one can periodically trap ultra-cold atoms at nodes (or anti-nodes) of standing waves of counter propagating laser beams. Such system, known as an optical lattice, a quantum analog of egg cartons, is defect free, well-controlled with high precision. It provides an ideal experimental system to study fundamental concepts and theories in quantum and statistical mechanics.

By loading Bose-Einstein Condensate of Rb atoms into two standing waves (2D optical lattices), the atoms are tightly confined in a radial direction and weakly trapped in an axial direction, becoming one dimensional bosons. We have performed a series of experimental tests of the exact 1D Bose gas theory from the weak to the strong coupling regimes and also observed the fermionic behavior of bosons, predicted in 1960 as in a 1D Tonks-Girardeau gas. Because 1D system is a nearly integrable, a theory predicts they do not approach thermal equilibrium. We have confirmed it by creating the quantum analog of a Newton's cradle. This is the first experimental demonstration of dynamics from out of equilibrium of integrable many-body systems.

We are exploring a completely different type of optical lattices, 2D anti-dot lattices where potential hills are arranged and energy minima are connected one another to form a mesh-like structure (you can imagine them by flipping up and down egg cartons). At first glance, atoms are never localized anywhere, which in turn we may study non-equilibrium dynamics, transport phenomena, a billiard of quantum gas, etc. I will present some new results concerning phase coherences of atoms and an onset of dissipations of superfluid flows.