Abstract

Subrata Das, **Light-induced vortex and quantum turbulence in two-dimensional Bose-Einstein condensates**, Indian Institute Technology Kharagpur, 2022

The disk-shaped Bose-Einstein condensate (BEC) has been an excellent platform for studying non-linear structures like a vortex, and phenomena like two-dimensional quantum turbulence. Further, it is well-established that quantized vortices can be created in the condensate using a Laguerre-Gaussian beam having well-defined orbital angular momentum. We show that when asymmetry is introduced in the beam profile, it carries a superposition of secondary vortices with consecutive topological charges along with the primary vortex. We theoretically manifest how this vortex superposition and orbital angular momentum carried by the asymmetric Laguerre-Gaussian beam can be transferred to the two-dimensional BEC. It results in a superposition of matter vortex states which can be controlled by tuning the asymmetry parameters of the beam. In order to characterize quantum turbulence, we explore the out-of-equilibrium dynamics due to collisions and vortex shedding in a BEC. Firstly, we numerically investigate the emergence of vortices and solitonic patterns due to the collision of a segmented BEC without directly transferring vortices from a light beam. Here, segmentation of the BEC occurs due to the interaction with a pair of identical LG beams with opposite helicity. We consider a two-component BEC where one component directly interacts with the light pulses, and another is only affected by the interspecies interaction. Secondly, in a similar way, we consider a rotating obstacle in one of the components of the BEC for vortex shedding. The particular obstacle is realized with a blue-detuned laser, which acts as repulsive potential. Depending on the rotation frequency, the obstacle creates vortex and antivortex of different patterns in both components of the BEC. The interspecies interaction between the components plays a significant role here. We identify frequency regimes of different kinds of vortex clusters and the maximum amount of angular momentum. We examine the compressible and incompressible kinetic energy of the condensates and discuss the scaling laws of two-dimensional quantum turbulence.

Keywords: Bose-Einstein condensate, Vortex, Quantum Turbulence, Laguerre-Gaussian Beam, Kinetic Energy Spectra