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Efficient generation of mesoscopic superposition states in lower dimensional Bose-Einstein condensate

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Bose-Einstein condensate (BEC), being a coherent atomic excitation, matter wave interference is one of the most important aspects and experimentally realized. A highly asymmetric trap parameter makes the condensate in a quasi-1D or 2D configurations. In this work, we emphasize mainly on two aspects: (1) Proposing a host of mesoscopic superposition states in quasi-1D BEC by utilizing quantum mechanical tunneling and reflection by a potential spike and (2) producing a variety of spatial interference pattern in the long time evolution of a 2D BEC trapped in a toroidal potential. We present couple of situations to create Schrodinger-cat state and its generalizations. Compass-like state is well known to show better sensitivity for quantum precision measurements. We consider a composite trap, made of harmonic potential and a Gaussian spike inside it. During the course of evolution, the solutions collide with the Gaussian spike and experience tunneling and reflection, simultaneously. By properly choosing the position of the spike potential and the time of observation, we propose the generation of Schrodinger-cat state and compass-state, rotated arbitrarily in phase-space. On the other hand, a toroidal trap allows the condensate to radially expand along the minimum of the effective potential and experiences self-interference. However, the detailed analysis of the dynamics of two condensates in a toroidal trap and its long time evolution, which reveals a number of interesting phenomena, has not yet reported in the literature. We report fractional revivals phenomena and the corresponding spatial interference at the origin, when the central Gaussian trap is switched off. The pattern is quite different from other quantum systems and can be explained through phase analysis of the constituent subsidiary states. We investigate a number of physical scenarios which are quite important towards quantum metrology.

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