Contribution ID: **11** Type: **not specified**

Nonclassical Motional State Excitation in Bose-Einstein Condensates

Wednesday, 18 October 2023 14:18 (3 minutes)

We present the experimental observation of macroscopic excited motional states in Bose-Einstein condensates. The interference of the states exhibits a non-smooth density distribution. Unlike the conventional collective oscillation modes, the perturbative approach is not applicable for its dynamics. In our protocol of the trap frequency jumping, the condensate is self excited by lowering the potential well allowing it to release the chemical potential to the kinetic energy. To observe and enhance the obtained effects, we transferred BECs to a quasi-2D potential well with a chirped trap frequency, and then effectively converted the 3D atomic ensemble to a sequence of 2D slices. We have observed the cloud deformation as a non-Gaussian wave packet, and then its revival. The excited atomic cloud undergoes coherent superposition and possesses collective oscillation among excited motional states. The momentum space observation (time-of-flight imaging) provides a strong implication of squeezing. Our method can be applied for the matter-wave propagation and manipulation of nonclassical motional states.

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Session Classification: Poster section

Track Classification: Poster section