A parametric amplifier of matter waves

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Abstract

Matter wave optics with ultracold samples has reached the point where non-classical states can be prepared and their fascinating properties can be explored. In optics, parametric down conversion is routinely used to generate light with squeezed observables as well as highly entangled photon pairs. The applications of these non-classical states range from fundamental tests of quantum mechanics to improved interferometers and quantum computation. Therefore, it is of great interest to realize such non-classical states with matter waves. Bose-Einstein condensates with non-zero spin can provide a mechanism analogous to parametric down conversion, thus enabling the generation of non-classical matter waves. We observed magnetic field dependent spin resonances [**?**] where the spin dynamics is enhanced. On these resonances, a parametric amplification process produces entangled matter waves excited spatial modes. We show that this exponential amplification can amplify both classical matter waves as well as vacuum fluctuations to macroscopic clouds [**?**]. Intriguingly, these spatial modes can carry orbital angular momentum. A first analysis shows that the system may serve as a source of atomic Bell pairs with entangled angular momentum states, possibly allowing for Bell type measurements with neutral atoms.

Keywords: SPINOR BOSE-EINSTEIN CONDENSATES, PARAMETRIC AMPLIFICATION, NON CLASSICAL MATTER WAVES, VACUUM FLUCTUATIONS

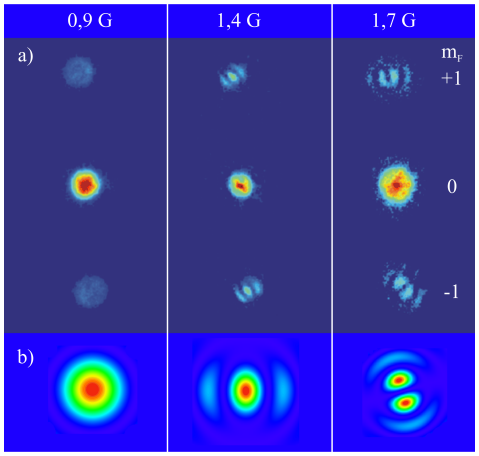

Figure 1: Parametric amplification of excited spatial modes. (a) Absorption images of spinor condensates after the separation of the spin components m_F for specific magnetic field strengths. (b) Spatial distribution from a simple model: ground state (left), radially excited mode (center) and angular momentum mode (right).

References

[1] C. Klempt, O. Topic, G. Gebreyesus, M. Scherer, T. Henninger, P. Hyllus, W. Ertmer, L. Santos, and J. Arlt, Phys. Rev. Lett. **103**, 195302 (2009).

[2] C. Klempt, O. Topic, G. Gebreyesus, M. Scherer, T. Henninger, P. Hyllus, W. Ertmer, L. Santos, and J. J. Arlt, arXiv:0907.3413 (2009).