Phase evolution in a two-component Bose-Einstein condensate

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Precision measurements and accurate knowledge of the matter wave phase are critical factors in interferometric measurements of a parameter. We study the spatial evolution of a two-component Bose-Einstein condensate and carry out relative phase measurements using a coherent superposition of the states $|F = 1, m_F = -1\rangle$ and $|F = 2, m_F = +1\rangle$ in a ^{87}Rb condensate generated on an atom chip [1]. Using a Ramsey interferometer scheme we prepare a phase-coherent two-component system with a π/2 two-photon microwave-radiofrequency pulse and probe the dynamical evolution of the system using the second state-mixing π/2 pulse with a variable time delay. The inter- and intra-species scattering lengths have slightly different values and, as a result, the first π/2 pulse prepares the system in a non-equilibrium and evolving state [2]. We measure the two-dimensional distribution of the column densities of each component along the axial and radial coordinates after a short time-of-flight expansion of the condensate before (n_1 and n_2) and after ($n_1^{'}$ and $n_2^{'}$) the application of the second π/2 pulse (Fig. 1). The spatial dependence of the relative phase can be extrapolated using the equation

$$\sin[\phi_2(x) - \phi_1(x)] = \frac{n_2^{'}(x) - n_1^{'}(x)}{2\sqrt{n_1(x)n_2(x)}}. \tag{1}$$

Our preliminary results [3] clearly demonstrate a non-uniform spatial growth of the relative phase along the axial direction of the microtrap and are in excellent agreement with the results of our modelling of the non-equilibrium dynamics using the three-dimensional numerical solution of coupled Gross-Pitaevskii equations.

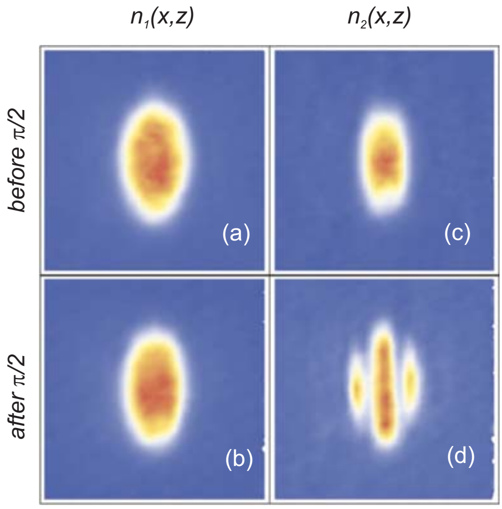

Fig. 1: Two-dimensional distribution of the column density of rubidium atoms in the state $|1\rangle = |F = 1, m_F = -1\rangle$ (a and b) and the state $|2\rangle = |F = 2, m_F = +1\rangle$ (c and d) along the axial (x) and radial (z) coordinates before and after the second π/2 pulse (the 40 ms delay after the first pulse). Interference fringes are clearly present in the state $|2\rangle$ (d) and are the result of the spatial dependence of the relative phase.

References

[1] B.V. Hall, S. Whitlock, F. Scharnberg, P. Hannaford and A. Sidorov, J. Phys. B: At. Mol. Opt. Phys. **39**, 27 (2006).

[2] K.M. Mertes et al, Phys. Rev. Lett. **99**, 190402 (2007).

[3] R. Anderson, B.V. Hall, C. Ticknor, P. Hannaford, and A.I. Sidorov, in preparation.