Spatially inhomogeneous phase evolution of a two-component BEC

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Accurate knowledge of the phase of matter waves is an important factor in studying BEC coherence, and its potential application to precision measurement. We observe the spatially dependent relative phase evolution of an elongated two-component Bose-Einstein condensate [1]. The pseudospin-$1/2$ system is comprised of the $|F=1, m_F=-1\rangle$ and $|F=2, m_F=1\rangle$ hyperfine ground states of ^{87}Rb, magnetically trapped on an atom chip [2] and interrogated via two-photon Ramsey interferometry. The first $\pi/2$ pulse prepares the pseudospin system in a non-equilibrium state. The subsequent evolution of each spin component leads to an inhomogeneous relative phase along the direction of weak confinement, varying by 2π across the condensate after $95\,\mathrm{ms}$ of evolution. The second $\pi/2$ pulse converts spatial variations of the relative phase into spatial variations of the longitudinal spin projection (Fig. 1). We observe Ramsey interference fringes whose decay ($1/e$ time $\sim 70\,\mathrm{ms}$) is due principally to the relative phase inhomogeneity, rather than decoherence or quantum phase diffusion. Our observations of the spatially dependent relative phase and subsequent loss of interferometric contrast are in striking agreement with simulations of the coupled Gross-Pitaevskii equations with decay terms corresponding to inter- and intra-state many body loss processes [1]. We have also demonstrated a new technique to simultaneously image each state, yielding sub-percent variations of the measured relative atom number, while preserving the spatial mode of each component.

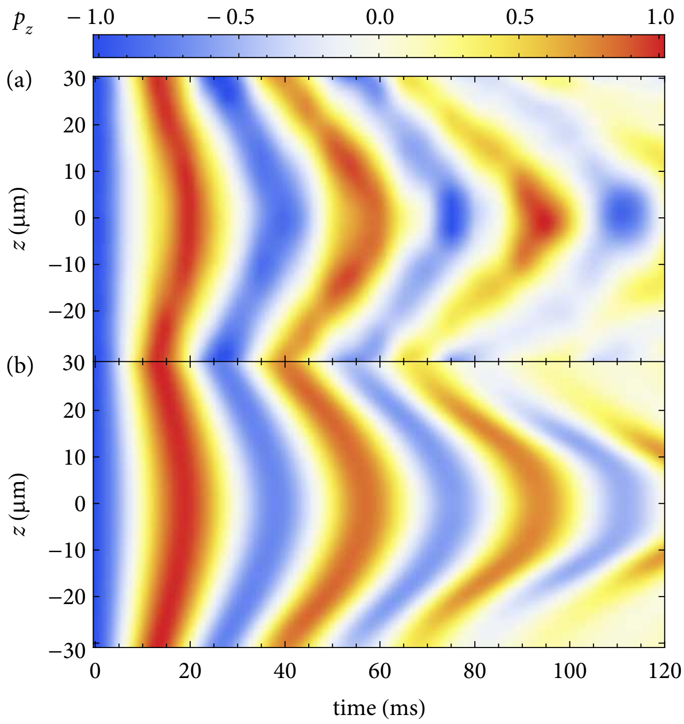

Fig. 1: Spatially resolved longitudinal spin projection of a pseudospin-$1/2$ BEC during Ramsey interferometry. Following the first $\pi/2$ pulse, the relative phase evolves inhomogeneously along the axial direction, z. This dephasing is manifest as spatial variation of the longitudinal spin projection, p_z, after the second $\pi/2$ pulse. (a) Experimental data, (b) coupled Gross-Pitaevskii simulation.

References

[1] R. P. Anderson, C. Ticknor, A. I. Sidorov and B. V. Hall, Phys. Rev. A **80**, 023603 (2009).

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