

Superfluid dynamics of two-component BEC in a toroidal trap

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Superfluidity is a striking example of the strange properties of quantum systems manifesting at the macroscopic scale. In addition to the familiar superfluid behaviour of liquid helium at low temperatures, Bose-Einstein condensates (BEC) of ultra-cold dilute gases also have superfluid phases. The high level of experimental control over ultra-cold atoms have made BECs an ideal medium to study superfluid behaviour. For this, ring shaped traps, capable of supporting quantized persistent currents, have been the main geometry of interest [1,2,3].

In the past years, we have developed our experimental system to study BEC of ⁸⁷Rb confined in ring traps, which are generated from time-averaged optical dipole potentials [4]. To date, most studies of superfluid behaviour in condensates has focused on single component systems. A natural extension is to study BEC of multi-component spin states. The internal degrees of freedom allows us to explore the superfluid behaviour of BEC spin mixtures, of various miscibility, in this geometry.

Using RF and microwave fields, we prepare the condensate in a variety of spin-mixtures in the hyperfine manifolds of ⁸⁷Rb. By preparation and population of particular states, the underlying dynamics can be controlled through the intra and inter-species scattering, and yield either miscible or immiscible (phase separated) states.

When the scattering length between inter-species is larger than the intra-species scattering, the system is immiscible and naturally phase separates. The ring geometry gives an unique symmetry to the problem, and allows the interplay with superfluid persistent currents to be examined. Depending on the relative scattering lengths and geometry, the system can phase separate azimuthally, or radially, with implications on the dynamics observed.

For azimuthal phase separation around the ring, the multiply connected nature of each condensate component is broken, and they can therefore rotate with arbitrary circulation and angular momentum. For systems near the boundary of miscibility, the application of rotational energy

can see the system oscillate between phase mixed to phase separated states [5].

We present here our preliminary results with this system, including the observation of classical solid-body rotation between two immiscible condensate components.

This system will allow the future exploration of many outstanding research questions, such as the onset of superfluid drag between two superfluids, surface instabilities at the boundaries of static and flowing superfluids, as well as study the interplay of classical and quantized rotation in multi-component superfluid systems.

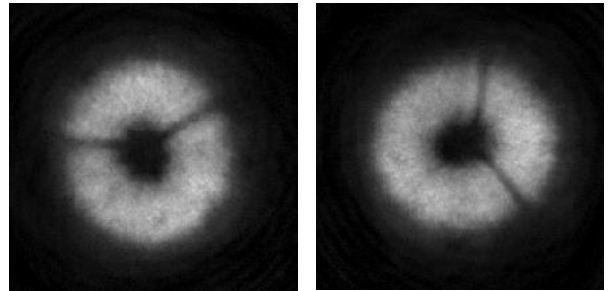


Figure 1: Solid body rotation of two-component ⁸⁷Rb BEC of $(F, m_F) = (1, -1)$ and $(1, 0)$ states. Due to the azimuthal phase separation of the immiscible states, the system rotates like a classical solid-body. The system is rotated by application of a 0.2 Hz rotating weak transverse magnetic gradient, applied to the $(1, -1)$ state.

References

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