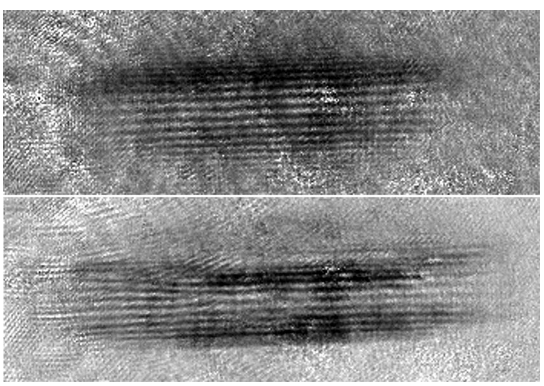
Observation of vortex phase singularities in Bose-Einstein condensates

Bose-Einstein condensates of dilute atomic gases offer a unique opportunity to study quantum hydrodynamics. The low density of the gas allows direct comparison with first principle theories.

Recently, vortices in a Bose-Einstein condensate have been realized experimentally and are currently under intensive study [1-3]. In most of this work, vortices were identified by observing the density depletion at the cores. The velocity field was inferred only indirectly, with the exception of the work on circulation in a two-component condensate [1]. The flow field of a vortex can be directly observed when the phase of the macroscopic wavefunction is measured using interferometric techniques. In our work, we created one or several vortices in one condensate by moving a laser beam through it and imaged its phase by interfering it with a second unperturbed condensate which served as a local oscillator [4].

The characteristic signature of vortices were dislocations in the interference fringes. The "extra" fringe which terminates at the vortex core corresponds to one quantum of circulation h/m (where m is the atomic mass and h Planck's constant) or a phase change of 2π integrated along a path around the vortex core.



Observation of the phase singularities of vortices created by sweeping a laser beam through a condensate. Without the sweep, straight fringes of about 20 μm spacings were observed (upper image), while after the sweep, fork-like dislocations appeared (lower image). The speed of the sweep was 1.1 μm/ms corresponding to a Mach number of 0.1. The field of view of each image is 1.1 mm x 0.38 mm.

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