BEC Waveguide Michelson Interferometer on a Chip

Dana Z. Anderson,[1] Victor M. Bright,[2] Eric Cornell,[1] Quentin Diot,[1] Mara Prentiss,[3] Stephen R. Segal,[1] Ying-Ju Wang,[1] and Saijun Wu[3]

[1]Department of Physics and JILA, University of Colorado and National Institute of Standards and Technology, University JILA UCB 440, Boulder CO 80309-0440
[2]Department of Mechanical Engineering, University of Colorado, Boulder, CO 80309
[3]Department of Physics, Harvard University, Cambridge, MA, 02138

Abstract

An atom Michelson interferometer is formed using a 1-dimensional waveguide configuration. Atoms are trapped and cooled in a pyramid MOT, then transported to a Ioffe-Pritchard trap where they undergo further cooling but remain above the critical temperature for the formation of a Bose-Einstein condensate. The cooled atoms are then launched towards and captured on an atom chip. The magnetic waveguide and other atom manipulation structures on the chip are produced by current-carrying wires lithographically patterned on the chip substrate. A one-dimensional waveguide is formed by a current in one of the central wires acting in conjunction with a bias magnetic field. Mounted on the chip is a pair of prism-shaped mirrors. Atoms are transported through a small tunnel lying underneath the first prism to the approximate center of the atom waveguide region between the mirrors, where they are again trapped, then evaporatively cooled to form a condensate. The two mirrors are arranged to form a standing light wave, which lies parallel to and directly above the waveguide conductor. The atoms sitting within the waveguide can thus be subject to the standing light field.

The initial condensate is split into two, oppositely directed atom clouds of momenta $p = \pm 2\hbar k$ by exposing the cloud to a double-pulse standing light field. After a propagating a short time, the atoms are exposed to an optical "Bragg" pulse, which reverses their momentum. The atoms thus return to their starting point, where they are finally exposed to a second double-pulse. Thus the three exposures of light serve to split, reflect, and recombine the atoms. Upon re-combination the atoms generally form three clouds: a zero-momentum ($p = 0$) cloud, and a pair of oppositely directed non-zero ($p \neq 0$) clouds.

The atom optical path length between the initial two propagating atom clouds is varied either by varying a magnetic gradient along the waveguide direction, or by giving the initial condensate cloud an initial velocity. We observe interference in the final atom cloud configuration by comparing the population of the zero-momentum cloud with the two non-zero momentum cloud as a function of the relative phase difference. The interference contrast is seen to be excellent out to approximately 4 ms. For times on the order of 10 ms, however, the interference contrast falls to about 20%, indicating either a real or apparent loss of atomic coherence.

We describe further details of the experiment, and make some speculations regarding the observed loss of coherence.