SPECTRA HOME
CURRENT ISSUE TABLE OF CONTENTS
TECHNOLOGY
BUSINESS
PRESSTIME BULLETIN
ARTICLE ABSTRACTS
ACCENT ON APPLICATIONS
PHOTONICS RESEARCH
PHOTONICS MINI-MAG
INNOVATIVE PRODUCTS
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Condensates Coaxed to Exhibit Unique Interference

Thomas Young's classic setup for the demonstration of interference features light from one source incident on two vertical slits because the phenomenon occurs only if the light from the slits has a well-defined relative phase. Now a group at the MIT-Harvard Center for Ultracold Atoms at Massachusetts Institute of Technology in Cambridge has turned conventional wisdom upside down by creating interference from two distinct sources.

The sources are independently trapped Bose-Einstein condensates -- ensembles of atoms that are cooled and confined so they are quantum-mechanically indistinguishable. In the experiment, the scientists create interference between beams of sodium atoms freed from two neighboring potential wells. A frequency-stabilized dye laser supplies two counterpropagating beams, each slightly detuned from the other and from the 589.5-nm Na absorption line.

A photon from the first beam imparts momentum to an atom, stimulating it to emit a photon into the second beam and leaving it with additional recoil momentum. If the momentum is high enough to overcome the trapping potential, it liberates the atom from the trap. Illuminating two sodium condensates with the same counterpropagating light beams creates two overlapping beams of atoms.

Usually, beams from two independent atomic clouds would not be expected to interfere, but atoms within a Bose-Einstein condensate share the same quantum mechanical state, and once the relative phase between the clouds of atoms is established by an initial measurement, their relationship becomes fixed. In this case, however, the trapping potentials of the condensates differ slightly, creating an energy difference that translates to a slowly varying relative phase. The result is a spatially and temporally varying density distribution in the combined atomic beam; that is, interference fringes.

Previous attempts to quantify such phase differences had destroyed Bose-Einstein condensates.

Michele Saba, lead researcher on the project, pointed out that the phase relationship of the condensates can be monitored by observing variations not only in the density of the atomic beam, but also in the intensity variations of the excitation beams.

Interference between photons

"As the number of atoms flying out of the trap oscillates in time, the intensity of each beam oscillates with the same frequency," he said. "This is not interference between the original beams, but only between those photons that have been scattered by the atoms."

This technique makes it possible to investigate phenomena such as phase diffusion, the drift in the relative phase between the two Bose-Einstein condensates, which is analogous to the coherence time in a laser. Although excited simply by the ability to investigate basic phenomena, Saba noted that the approach might have applications in the fabrication of miniaturized atom interferometers.

"We will try to demonstrate that our technique can be integrated in a microchip device," he said.

by Richard Gaughan

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Return to the previous page

Browse

Accent on Applications | Presstime Bulletin | Article Abstracts
BusinessWorld | Technology World | Photonics Research
Innovative Products | Spectra Contents

top of page

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