Nebraska Team First To Observe Kapitza-Dirac Effect; Could Lead To Extremely Accurate Measuring Devices

Sep. 19, 2001 — Lincoln (Neb.) -- The luminous green lasers in Herman Batelaan's laboratory at the University of Nebraska-Lincoln are more than just pretty. They are the critical element in Batelaan's team becoming the first to observe the Kapitza-Dirac effect, an accomplishment that could make possible measuring devices that are thousands of times more accurate than those in use today.

The Kapitza-Dirac effect is the diffraction of a beam of particles, electrons in particular, by a standing wave of light. It was predicted in 1933 by a pair of future Nobel Prize winners, Russian Peter Kapitza (1894-1984) and Englishman P.A.M. Dirac (1902-84), but the technology needed to demonstrate it didn't exist at the time, and wouldn't until well after the laser was invented in 1960.

Early lasers weren't capable of producing the Kapitza-Dirac effect and it wasn't until April 11, 2001, when it was observed for the first time in Batelaan's lab in NU's Behlen Laboratory for Physics.

The confirmation was reported by Batelaan and his team of Daniel Freimund and Kayvan Aflatooni in the Sept. 13 issue of Nature, the international weekly journal of science. Freimund, the lead author of the Nature article, a doctoral candidate under Batelaan, earned his bachelor's degree in mechanical engineering and his master's in physics at Nebraska. Aflatooni, who was a post-doctoral researcher in Batelaan's lab at the time of the discovery, earned his bachelor's, master's and doctoral degrees in physics at Nebraska and now is an assistant professor of physics at Fort Hays (Kan.) State University.

A basic physics experiment that illustrates the wave nature of light involves placing a screen with two slits in it at a distance from a point source of light and placing a second screen beyond the first. Instead of two bars of light appearing on the second screen directly in line with the light and the slits, multiple light bars appear across the second screen. That's because the slits diffract the light and the bars mark the convergence of light waves. It's Quantum Mechanics 101.

Batelaan and his team in essence repeated that experiment in April, except they used an electron beam instead of a light beam and substituted a laser beam for the slitted screen. They saw that the electrons were diffracted by the laser, just as Kapitza and Dirac had predicted 68 years earlier.

Scientists have long used diffraction of optical, acoustic and radio waves in interferometers, devices that among other things measure very small distances and thicknesses. They're also used as rotation sensors in the avionics systems of airplanes. And now that Batelaan and his team have shown that particle waves can also be diffracted, Batelaan said it's possible that particle waves can be used to make a much more accurate interferometer.

"The average wavelength in a laser beam is one micron (one-millionth of a meter), which is 1 percent of the thickness of a human hair," Batelaan said. "The wavelength of this electron wave, because the electrons also have a wave, is 10,000 times smaller. That's the size of one atom.

"If you use the Kapitza-Dirac effect multiple times, you can make an interferometer. But we haven't done that yet. We're trying to figure out what the implications are for use in rotation sensors and electromagnetic field sensors."

Batelaan and his team observed the Kapitza-Dirac effect with funding from the Research Corp. A $350,000 grant received in July from the National Science Foundation will help start the search for an electron wave interferometer. Batelaan said he's excited about the possibilities of the ongoing research, but that doesn't keep him from savoring his team's discovery.

"The effect was predicted in 1933 and we were the first ones to observe it - and that's kind of nice," he said, sitting in his office beneath portraits of Kapitza and Dirac. "There were four attempts in the 1960s, but they all failed. If someone had tried it in the '90s, they would have pulled it off, so in a sense we're a bit lucky. But, hey, you need luck."