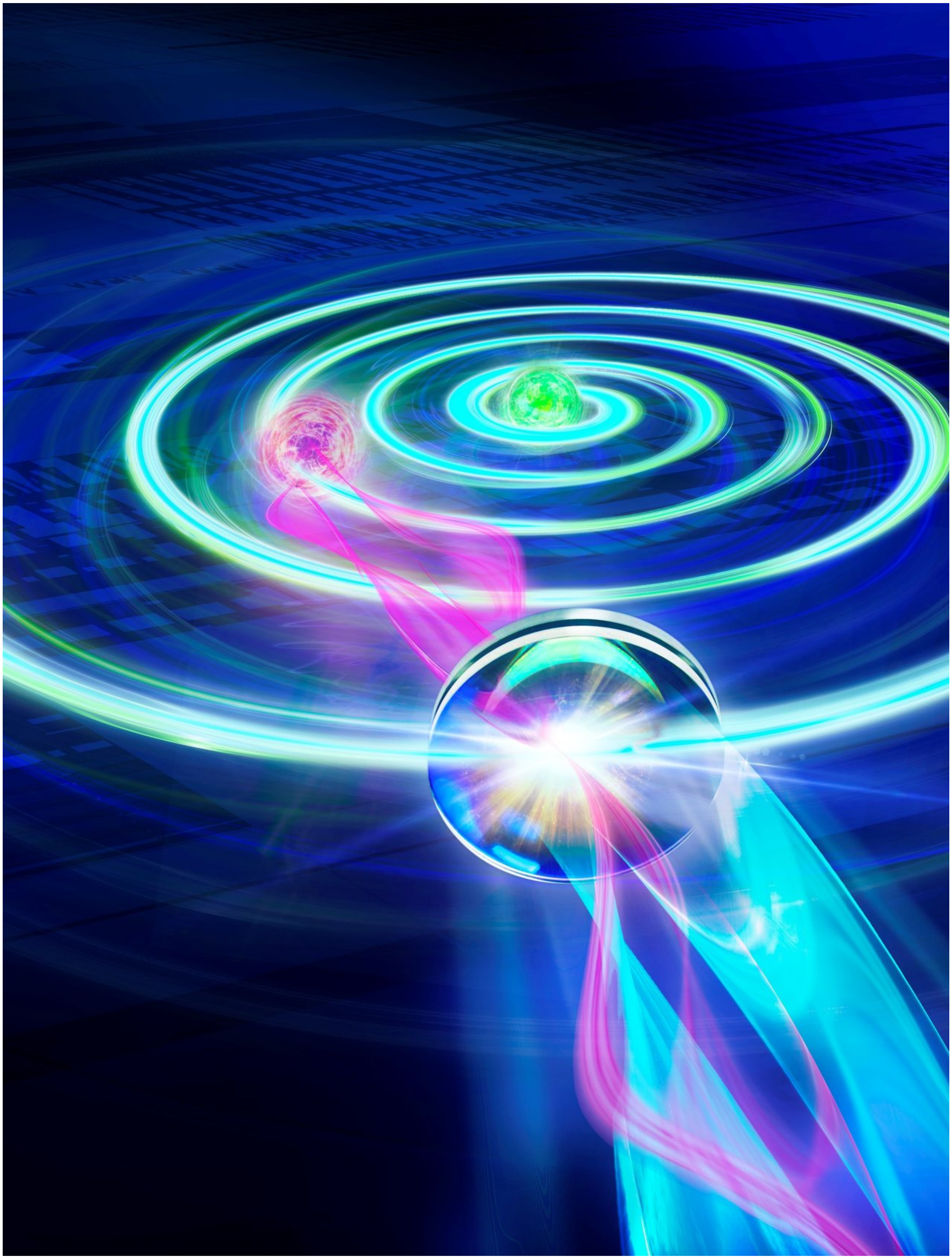
Physics: Not everything is where it seems to be

October 16 2018



The spiral wavefront of the elliptically polarized light hits the lens at a slight angle, leading to the impression that the source of the light is somewhat off its actual position. Credit: IQOQI Innsbruck/Harald Ritsch

Scientists at TU Wien, the University of Innsbruck and the ÖAW have for the first time demonstrated a wave effect that can lead to measurement errors in the optical position estimation of objects. The work now published in *Nature Physics* could have consequences for optical microscopy and optical astronomy, but could also play a role in position measurements using sound, radar, or gravitational waves.

With modern optical imaging techniques, the position of objects can be measured with a precision that reaches a few nanometers. These techniques are used in the laboratory, for example, to determine the position of atoms in quantum experiments.

"We want to know the position of our quantum bits very precisely so that we can manipulate and measure them with laser beams," explains Gabriel Araneda from the Department of Experimental Physics at the University of Innsbruck.

A collaborative work between physicists at TU Wien, Vienna, led by Professor Arno Rauschenbeutel, and researchers at the University of Innsbruck and the Institute of Quantum Optics and Quantum Information, led by Rainer Blatt, has now demonstrated that a systematic error can occur when determining the position of particles that emit elliptically polarized light.

"The elliptical polarization causes the wavefronts of the light to have a spiral shape and to hit the imaging optics at a slight angle. This leads to the impression that the source of the light is somewhat off its actual position," explains Yves Colombe from Rainer Blatt's team.

This could be relevant, for example, in biomedical research, where luminous proteins or nanoparticles are used as markers to determine biological structures. The effect that has now been proven would possibly lead to a distorted image of the actual structures.

Any kind of waves could show this behavior

More than 80 years ago, the physicist Charles G. Darwin, grandson of the British natural scientist Charles Darwin, predicted this effect. Since that time, several theoretical studies have substantiated his prediction. Now, it has been possible for the first time to clearly prove the wave effect in experiments, and this twice: At the University of Innsbruck, physicists determined, through single photon emission, the position of a single barium atom trapped in an ion trap. Physicists at Atominstitut of TU Wien (Vienna) determined the position of a small gold sphere, about 100 nanometers in size, by analyzing its scattered light. In both cases, there was a difference between the observed and the actual position of the particle.

"The deviation is on the order of the wavelength of the light and it can add up to a considerable measurement error in many applications," says Stefan Walser from Arno Rauschenbeutel's team. "Super-resolution light microscopy, for example, has already penetrated far into the nanometer range, whereas this effect can lead to errors of several 100 nanometers."

The scientists believe it is very likely that this fundamental systematic error will also play a role in these applications, but this has yet to be proven in separate studies. The researchers also assume that this effect will not only be observed with light sources, but that radar or sonar measurements, for example, could also be affected. The effect could even play a role in future applications for the position estimation of astronomical objects using their gravitational waves emission.

More information: G. Araneda et al, Wavelength-scale errors in optical localization due to spin–orbit coupling of light, *Nature Physics* (2018). DOI: 10.1038/s41567-018-0301-y

Provided by University of Innsbruck