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Seeing A Single Atom Where It Is Not

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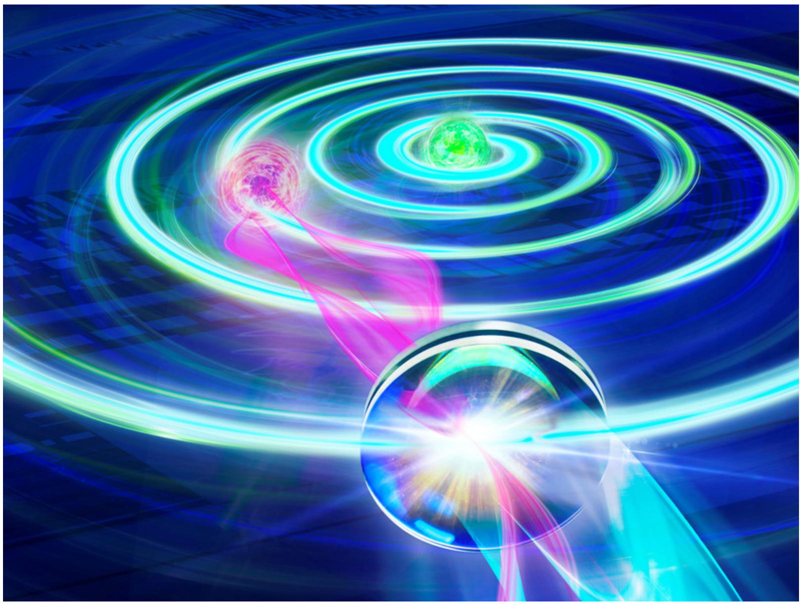
The precise determination of the position of sub-wavelength scale emitters and scatterers using far-field optical imaging techniques is of utmost importance for a wide range of applications in medicine, biology, astronomy, and physics. In this talk, I theoretically and experimentally show that, for a standard optical imaging system like an optical microscope, the image of an elliptically polarized point-like emitter does not coincide with the emitter's real position [1]. Instead, even for perfect, aberration-free imaging with high numerical aperture, the image will in general be shifted. This can lead to a systematic error in the optical localization of emitters which exceeds the typical precision of super-localization microscopes by far. Moreover, for the case of small numerical aperture, the shift can in principle reach arbitrarily large values. Imaging a single trapped atom as well as a single gold nanoparticle, we experimentally demonstrate this effect and observe wavelength-scale shifts. Beyond its relevance for optical imaging, the demonstrated phenomenon may also occur for sources of other types of waves. Consequently it can, e.g., impede the precision of the localization of remote objects with imaging radar and sonar as well as the future localization of stellar objects in gravitational wave astronomy.

[1] G. Araneda, S. Walser, Y. Colombe, D. B. Higginbottom, J. Volz, R. Blatt, and A. Rauschenbeutel, "Wavelength-scale errors in optical localization due to spin-orbit coupling of light", Nature Physics (2018), https://doi.org/10.1038/s41567-018-0301-y



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