Supercorrelation takes nanoscale measurements with light

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Scientists in Singapore have developed a new way to measure distances at the nanoscale using light, an advance that could be beneficial to advanced manufacturing processes.

According to Nanyang Technological University (NTU) Singapore, devices that use light to see objects, such as microscopes, have a fundamental limitation based on the laws of physics, which is their resolving power. The smallest distance that optical devices can reliably image is equal to half the wavelength of the light used, or the "diffraction limit." The diffraction limit is about 400 nm, about half the wavelength of near-infrared light and 250 times smaller than the width of a human hair.

Scientists are interested in observing objects like viruses and nanoparticles that range in size from 10 to 100 nm, so an optical resolution of 400 nm is insufficient. Currently, nanometer-scale measurements are made using indirect or non-optical methods, such as scanning electron microscopy, which is not always feasible, can be time-consuming and requires costly equipment to operate.

However, an advance described in Technology by Prof Nikolay Zheludev and Dr Guangyu Yuan at NTU’s School of Physical & Mathematical Sciences describes a new optical method that can measure distances of a nanometre using near-infrared light. In a statement, NTU said that their theoretical calculations indicate that devices based on this method could measure distances down to 146 nm of wavelength of light, roughly the size of a single atom.

Their achievement was accomplished using a 800 nm thick gold film with over 10,000 tiny holes cut into it that, when laser light is shone through the second layer, it exploits an optical phenomenon called supercorrelation, which occurs when a "sub-wavelength" in a light wave oscillates faster than the light wave itself. "Our device is conceptually very simple," said Dr Yuan, a postdoctoral fellow at the Centre for Disruptive Photonic Technologies (CDPT). "What makes it work is the precise pattern in which the slits are arranged. There are two types of slits within the pattern, oriented at right angles to each other. When polarised laser light strikes the gold film, it creates an interference pattern containing extremely tiny features, much smaller than the wavelength of light."

According to NTU, after this polarised light scatters from the device it produces two cross-polarised beams: one a supercorrelated "intensity pattern" containing fast phase variation and the other a reference wave to detect the phase of the supercorrelated field.

From the phase, it is possible to calculate the supercorrelations gradient, or local polarization, which has a wavelength narrower than the diffraction limit and can be used as a high-resolution optical ruler. A hurdle that the NTU scientists had to overcome was that these tinier supercorrelations do not appear in the amplitude of the light waves, but in its phase. To map out the phase of the light field, the scientists had to devise a special technique that could compare the intensities produced by different polarisation states of laser light.

"This phase-sensitive technique is a major improvement over previous attempts to use supercorrelation for optical measurements," said Prof Zheludev, Co-Director of NTU’s The Photonics Institute.

"Earlier methods, developed by us and others, used a class of supercorrelations that could not be classified as polarized light," said Dr Yuan. "This new method of optical measurement will be more useful in future, such as in the manufacturing of vacuum control of electronics, where extremely precise optical measurements are required, and to monitor the integrity of nano-structures."