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Photonics Technology News

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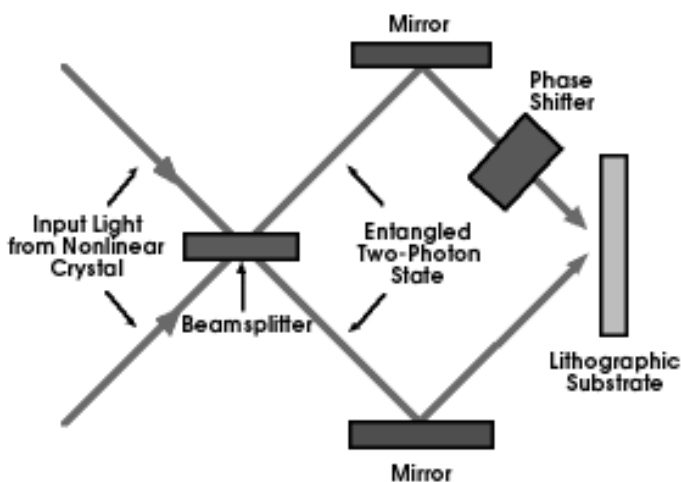
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Spooky Photons May Beat Diffraction

PASADENA, Calif. -- Light is fundamentally a quantum mechanical entity, but most of today's photonics technology does not depend upon this quantum nature and, in fact, ignores it altogether. Classical or semiclassical approaches to modeling the behavior of light are sufficient to understand the behavior of most photonic devices. Researchers at the Jet Propulsion Laboratory at the California Institute of Technology and the University of Wales in Bangor, UK, however, have demonstrated that the propagation of an entangled photon pair, which cannot be understood in a classical or semiclassical sense, may extend the usefulness of optical lithography.

Jonathan P. Dowling of the Jet Propulsion Laboratory led the team's theoretical investigation of the propagation of entangled photons through an interferometric lithography setup.

Exploiting the quantum mechanical nature of light, an interferometric lithography technique proposed by researchers at the Jet Propulsion Laboratory and the University of Wales may beat the Rayleigh diffraction limit. Entangled photons serve as the source beams, and the beamsplitter constrains them to reach the target closer than they would in a classical system. Courtesy of California Institute of Technology/Jet Propulsion Laboratory.



In the technique, two initially entangled photons, incident on opposite sides of a beamsplitter, would be routed to two grazing incidence mirrors. One of the paths would lead directly to a target, while the other would include a phase shifter before the target.

Classically speaking, light interferes in such a setup, yielding an intensity pattern

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that varies as both a slowly and quickly varying function of phase shift. The slow variation limits the spatial resolution to the Rayleigh diffraction limit.

According to quantum mechanics, however, the setup beats that limit. The beamsplitter correlates the photons even more. Each generates a new state with equal probability amplitudes for presence on both the upper and lower paths.

In a sense, the position-state of each photon is linked to the other. Once one photon strikes a given location on the target, its partner is constrained to move on the same path. Most importantly, the resultant intensity pattern varies with only the high spatial frequency of the semiclassical solution, eliminating the lower frequency term and thus halving the minimum spot size at the target.

The researchers visualize using the technique in optical lithography. The ability to generate feature sizes below the diffraction limit may extend the usefulness of optical sources well beyond the current estimates. "We hope our paper will stimulate research in this direction," Dowling said. A lithography system based on multiple entangled photons would be even more impressive. Essentially, an N-photon-entangled state offers a resolution enhancement that varies with N. The challenge is to reliably generate such entangled photons, possibly by using multiple or cascaded down-conversions, Dowling said.

For the moment, the work remains theoretical as the group extends the model to two- and three-dimensional systems.

The researchers are also working with Yanhua Shih of the University of Maryland in Baltimore to verify the effect experimentally.

Dowling said that it is intriguing in itself to find a potential practical application of a quantum mechanical curiosity: "These weird, 'spooky' photon states are useful and can be technologically implemented." ■

Richard Gaughan

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