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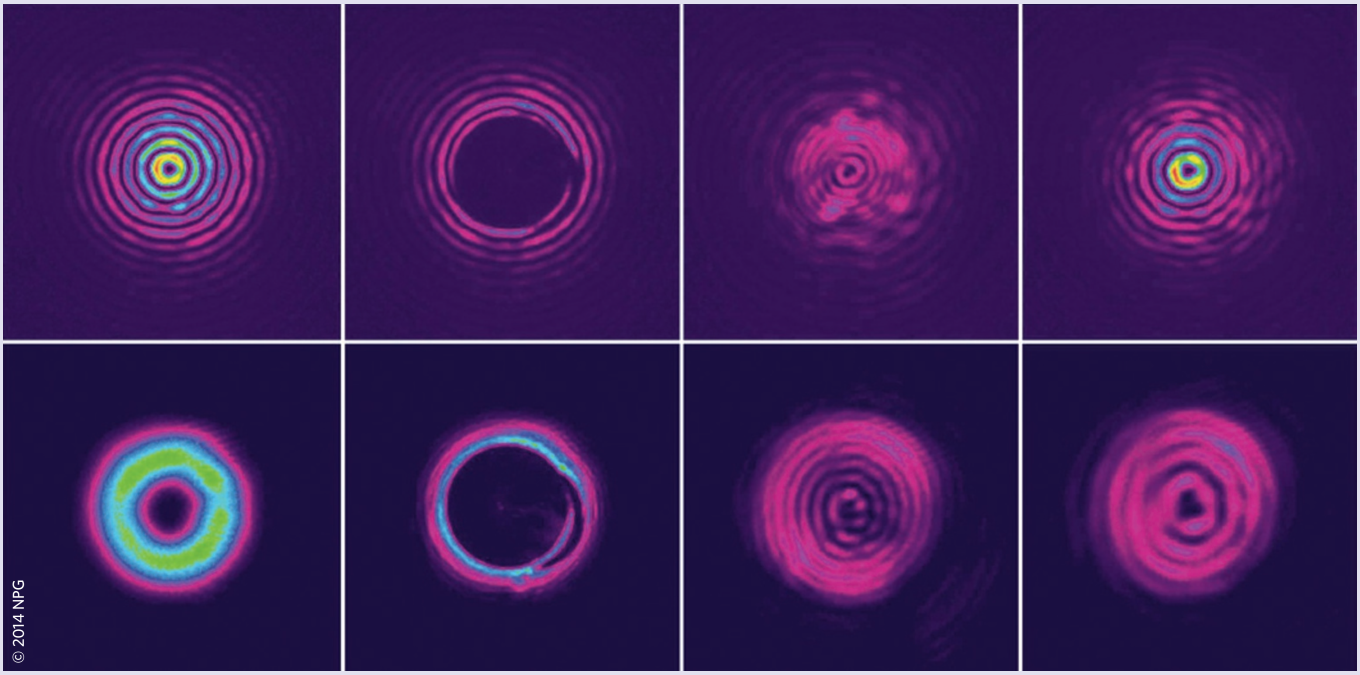
QUANTUM OPTICS

Entanglement, heal thyself



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Bessel beams are unusual. They are non-diffracting, have an infinite number of concentric rings and can reform after crossing an obstacle — a property known as self-healing. Of course, these are ideal Bessel beams, beautiful mathematical objects, but quasi-Bessel beams with similar properties can be created in the lab from light, sound or even matter waves — as reported in *New Journal of Physics* by Changhyun Ryu and colleagues, from experiments using a rotating, toroidal atomic Bose–Einstein condensate (*New J. Phys.* **16,** 013046; 2014).

Bessel beams of light are also interesting from a practical point of view — as optical tweezers, for example. Such beams can also carry orbital angular momentum that can be used to encode information. Compared with the more common Laguerre–Gaussian modes, Bessel–Gaussian modes offer more dimensions to play with, as well as unusual properties such as self-healing — which turns out to be a very useful feature for quantum technologies. Entangled Bessel beams can be created using spontaneous parametric down-conversion in a nonlinear crystal, and Melanie McLaren and colleagues have now demonstrated that such entanglement persists even after the beam has traversed some obstacle (*Nature Commun.* **5,** 3248; 2014). This robustness is particularly appealing for free-space communication.

McLaren *et al.* placed a circular obstacle (of radius 200 μm) in the path of an entangled down-converted photon. Optical loss would normally compromise the entanglement, but, by measuring in the Bessel–Gaussian basis, the self-healing property of Bessel beams means that the signal is recovered and entanglement is revived. The authors imaged both the Bessel–Gaussian and Laguerre–Gaussian modes (pictured in the upper and lower panels respectively) for different obstacle positions, starting with no obstacle, then placing it in the plane of the crystal, then at a distance of 20 mm and 50 mm (left to right). Whereas at 50 mm the Bessel–Gaussian modes recovered, the Laguerre–Gaussian modes did not.

This demonstration of self-healing is beautiful, but not unexpected — neither is the energy loss seen when the beam recovers after the obstruction, which agrees with classical Bessel beam theory. What is perhaps more surprising, and potentially useful, is the recovery of entanglement witnessed by the violation of a Bell-type inequality. Even for single photons, the resilience of Bessel beams ensures the survival of quantum correlations despite the optical losses.

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