One probable influence is the duration of the drought: Zhou *et al.* studied a chronic and increasingly severe water shortage, whereas whether the Amazon is also experiencing a long-term drying trend remains an open question[9]. However, analysis[8] using improved data for EVI and for the normalized difference vegetation index do in fact show large-scale 'browning' (reduction in greenness) in the Amazon in the mega-drought years of 2005 and 2010, and these observations are consistent with reduced microwave backscatter[6]. Thus, it seems plausible that the Amazon, like the Congo, has experienced large-scale structural responses to drought events, but that this was masked by remote-sensing artefacts.

Another crucial question is: what actually happens in the forest to cause these remotely sensed signals? The sensors generally respond to changes in the upper forest canopy, and those signals are not simple proxies for whole-ecosystem responses. To cause shifts in forest structure that drive climate-relevant atmospheric exchanges of carbon, water and energy, reductions in photosynthetic capacity must also cause other changes, such as reduced biomass production and elevated tree mortality.

One expected response to a long-term drying trend is a transition from high-biomass, closed-canopy forests to more-open, low-biomass forests and savannahs. However, the thresholds in water stress, carbon starvation, elevated temperature and increased vapour-pressure deficit at which this transition will occur are not well understood[13]. Response to drought is also not limited to upper-canopy effects, and other tools, such as tower-based measurements of evapotranspiration and net ecosystem productivity[14], coupled with field investigations of key ecosystem processes[15], are needed for complete assessments of the effects of drought on net forest–atmosphere fluxes.

Thus, a key constraint on our ability to interpret signals acquired by remote-sensing platforms is a lack of ground-based data with which to validate them. Obtaining such data will require extensive fieldwork using an array of methods at varying scales. As our climate continues to warm, quantifying the effects of drought on forests will become increasingly important, so ground-validated remote-sensing investigations must also be designed that best inform the development of Earth-system models. ■

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APPLIED PHYSICS

Bright electron twisters

A new holographic method has been used to convert ordinary electron beams into helical beams. These beams show promise in applications such as the spectroscopic analysis of materials with intrinsic handedness and nanoparticle manipulation.

JUN YUAN

Electron vortex beams, also known as electron twisters, are quantum waves of electrons that have a rotational motion akin to that of the notional electron clouds orbiting atomic nuclei — except that there is no central Coulomb force to hold the electrons, so the quantum wave can travel along its axis of propagation as it rotates. These beams remained a theoretical novelty[1] until their experimental demonstration four years ago[2–4]. They have many interesting physical properties, including potentially high magnetic moments and their interaction with matter and electromagnetic fields[5]. To investigate them experimentally, the beams must be bright. In a paper published in *Applied Physics Letters*, Grillo *et al.*[6] show how this can be achieved.

In the framework of quantum mechanics, the rotational velocity of an electron vortex beam, and the related angular momentum, are proportional to the angular gradient of its quantum phase (a measure of the local amplitude of the quantum wave as it swings back and forth between its maximum and minimum values). Because of this phase gradient, the crest of the quantum wave rotates about the beam axis, tracing out a perfect helical wavefront. For comparison, lines of white froth on ocean waves approaching a beach mark the planar wavefronts of the waves.

The helical-wavefront nature of electron vortex beams suggests that they can be obtained by adding an angular phase gradient to an ordinary planar-wavefront electron beam. A technically challenging approach to making such a conversion is to use an optical element known as a phase plate whose thickness varies in a spiral fashion (a spiral-thickness profile)[2]. A more robust method[3,4] is to use a hologram, which was invented by physicist Dennis Gabor[7] in the late 1940s for reproducing three-dimensional images of objects. Holograms change the phase of an incoming light beam by altering the direction of travel of its wavefront by diffraction through a fringe-patterned mask.

First-generation holographic masks for producing electron vortex beams typically involve a simple 'black and white' (binary) fringe pattern, with the relative position of the fringes encoding information about the phase of the vortex beam. The 'white' areas of the mask are micro-machined away to allow the electron beam to pass through unimpeded, and the 'black' areas are filled with a beam-stopping material. However, the maximum efficiency of such a binary-amplitude hologram — defined as the percentage of the incident non-vortex beam that is converted into a vortex beam of a particular orbital angular momentum — is just some 10% (ref. 6). This is because not only is about half of the non-vortex beam stopped by the black areas, but also the remaining transmitted half is distributed among many diffracted beams.

Enter Grillo and colleagues. The authors report a device for creating electron vortex beams with an efficiency of 25%. They attained this value by combining the advantages of the holographic and phase-plate approaches. In this hybrid approach, the conventional binary mask is replaced by one that does not contain beam-stopping areas and which has a sawtooth-thickness structure (Fig. 1) that acts as a phase plate and directs the electrons preferentially in one direction. In optical science, such a device is called a blazed phase hologram, and has a theoretical efficiency approaching 100%.

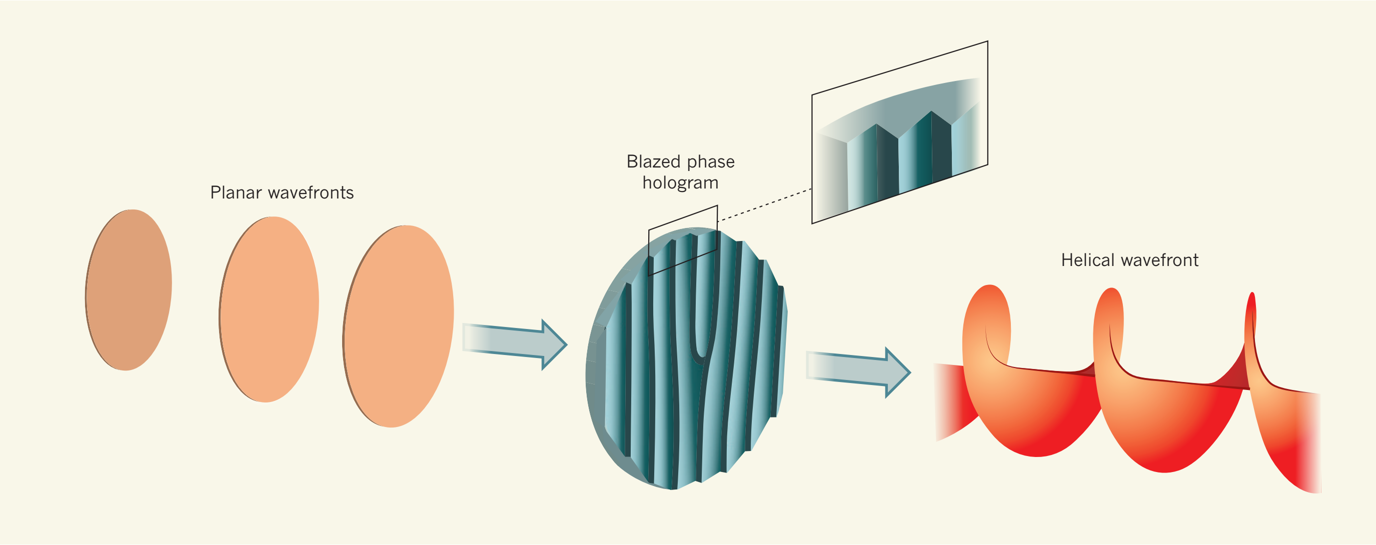

Figure 1 | Converting wavefronts. Grillo *et al.*[6] have designed a blazed phase hologram that has a sawtooth-thickness structure. The device converts an electron beam in which the wavefronts form planes into a beam with a wave crest that rotates about its axis of propagation, tracing out a helical wavefront.

But there are caveats to this approach. Obtaining bright electron vortex beams by this method is challenging because it requires the thickness profile of the blazed phase hologram to be controlled with nanometre-level accuracy. Also, part of the electron beam passing through the hologram will inevitably lose energy through a process called inelastic scattering, which leads to a non-vortex background signal. For beam diagnostics, this inelastic component of the beam can be removed using energy-filtering methods. However, the use of purely phase-shifting devices, such as those that exploit an effect known as optical aberration[8], instead of a blazed phase hologram, might be preferable for applications such as spectroscopy based on the chirality (handedness) of the vortex beams.

The helical form of an electron vortex beam's wavefront means that the exact phase of the beam is ill-defined at its centre, resulting in a doughnut-shaped beam-intensity structure that can be less than 1 nanometre in diameter[9]. This length scale is about 1,000 times smaller than that of existing optical vortex beams, which are used to trap and move micrometre-sized particles. Bright electron vortex beams produced using Grillo and colleagues' method may therefore allow nanoparticles and even individual atoms to be easily manipulated. In fact, existing, rather 'dim' electron vortex beams have already been used to transfer orbital angular momentum from the beams to nanoparticles[3,10,11].

The authors' method will also allow the production of bright electron vortex beams of very high orbital angular momentum, which will enable the investigation of subtle quantum effects associated with the giant magnetic moments of such beams. Finally, owing to the beams' intrinsic chirality, intense electron vortex beams could be used for the spectroscopic study of chiral materials[3,12], such as magnetic materials, certain polymers and biological macromolecules. The future of electron vortex beams is undoubtedly getting brighter. ■

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NEUROSCIENCE

Feedback throttled down for smooth moves

A group of regulatory neurons in the spinal cord has been found to reduce sensory feedback to muscles in mice. Removal of these neurons leads to repetitive limb oscillations during reaching. SEE ARTICLE P.43

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Sensory signals from our limbs allow us to interpret a wealth of information, from perceiving the objects we touch to correcting errors during movement. But despite their importance, the signals are turned down (throttled down) when we move[1]. How does this happen, and why? On page 43 of this issue, Fink *et al.*[2] report that, in mice, the signals are throttled down by a set of neurons in the spinal cord, and that removal of these neurons causes the animals' limbs to oscillate dramatically whenever they reach for food.

Although motor control involves many pathways and circuits in the spinal cord and brain, Fink and colleagues' study focused on the simplest: the feedback between muscle sensory afferent neurons (which carry impulses from the muscle towards the spinal cord) and efferent motor neurons (which carry signals from the spinal cord to the muscles; Fig. 1a). Your doctor examines this pathway when she or he taps your tendon: contact between the hammer and the tendon excites sensory afferents in the stretched muscle, and the impulses are then transferred from the axon terminal