In another bio-related work, Brian Pogue at Dartmouth discussed the imaging of radiation dose and molecules in humans receiving radiation cancer therapy. The idea employs optical capture of Cherenkov light that can be used to image radiation therapy delivery and map radiation dose delivered to tissue.

"Using specifically designed sheets of radiation, Cherenkov light in tissue can be used to excite molecular probes within the tissue, and thereby use sweeping of the radiation and Cherenkov sheets to create images of molecular reporters in tissue," Pogue told *Nature Photonics*. "This approach to sheet illumination in radiotherapy provides a very-high-resolution method to do optical molecular imaging *in vivo*. Mapping of luminescence from an oxygen-sensing probe contained within rodent lymph nodes and tumours has been done, demonstrating this high-resolution capability for *in vivo* imaging."

We look forward to seeing the wide-ranging advances at the next OSA Imaging and Applied Optics Congress. ❐

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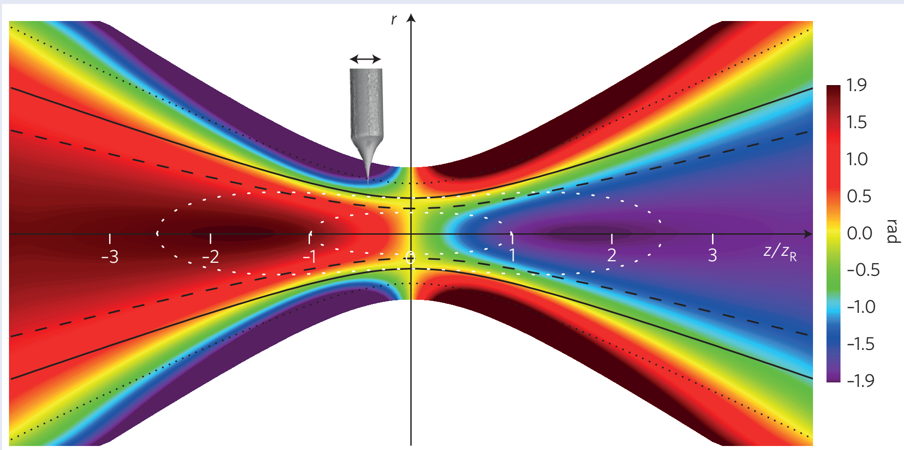
ULTRASHORT PULSES

# Phase in focus

Ultrafast, nonlinear light-matter interactions such as high-harmonic generation take place at the focus of a beam of laser pulses and rely strongly on the phase of the optical carrier field with respect to the pulse envelope's maximum — the carrier-envelope phase (CEP). For a focused monochromatic beam, it has long been known that the on-axis spatial dependence of the phase around the focus is described by the Gouy phase, which follows a simple arctangent curve. However, the situation for focused, ultrashort broadband pulses is more complex and recent theoretical studies have suggested a significant deviation from the Gouy phase.




Now, Dominik Hoff and co-workers from Germany and Israel have experimentally performed three-dimensional mapping of the CEP evolution of a focused broadband Gaussian laser beam (pictured) and elucidated its complex behaviour (*Nat. Phys.* http://dx.doi.org/10.1038/nphys4185; 2017).

The experimental system was composed of a nanotip-based focus characterization set-up and a xenon-gas-based, stereographic, above-threshold ionization CEP meter. A train of 4-fs-duration, 700-nm central wavelength pulses from a laser system with a hollow-core fibre compressor was split into two paths: one path for individual characterization of the random CEP of each shot and the other for recording electron spectra from the laser–nanotip interaction. The beam of laser pulses was focused using a 90° off-axis parabolic mirror onto a metal (tungsten or gold) nanotip placed inside an ultrahigh-vacuum chamber ($10^{-9}$ mbar).

The key point for success in the three-dimensional mapping is the capture of ejected photoelectrons from the nanotip: the large kinetic energy obtained by these electrons strongly depends on the CEP. A time-of-flight spectrometer recorded the flight time of photoelectrons using a microchannel plate and determined their kinetic energy. In the other path, the CEP meter measures the randomly varying CEP of each and every shot.

The metal nanotip was positioned at several points in the beam path. Strong-field-induced photoemission happened almost exclusively in the enhanced optical near-field region at the apex of the sharp tip, with a radius of 10 nm. The spatial and CEP resolutions were consequently obtained as 10 nm and 80 mrad (corresponding to 60 as), respectively.

The measured CEP showed extrema (darkest red and darkest purple regions) at 1.7 times the Rayleigh length ($z_R$) both before and after the focus ($z$ is the laser-propagation direction and $r$ the radial position). Although the phase evolution exhibited a much more complex spatial dependence than the Gouy phase, it opens the opportunity for novel ways to improve phase matching in high-order harmonic and attosecond pulse generation.

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