The two separate methods for controlling high-harmonic generation — two-colour control[4] and polarization gating[5] — both use longer pulses to obtain isolated attosecond pulses. Two-colour control uses a second-harmonic field on top of the fundamental field to provide a means of breaking the half-cycle symmetry, thus generating attosecond pulses only at every full cycle of the driver wave. Polarization gating exploits the extreme sensitivity of high-harmonic generation to the polarization state of the driving laser pulse.

The slightest ellipticity in the driving field expels the electrons to the side, which prevents recombination from occurring. Thus, the initial idea was to use a driving field that is cylindrically polarized except for a single linearly polarized half-cycle serving as the 'gate' to allow creation of an isolated attosecond pulse. Unfortunately, it turned out that this method was not able by itself to break the few-cycle pulse requirement because of another fundamental optical limit: the speed at which a pulse's polarization can change is fundamentally tied to the bandwidth, and thus to the duration of the pulse[6]. Therefore, to switch the polarization from circular to linear and then back to circular within half an optical cycle, a few-cycle driver pulse is still needed.

Combining both the two-colour and polarization gating methods in GDOG, as demonstrated by Chang and colleagues, is an important step towards the goal of relaxing the requirements on pulse duration. The schemes work well together because the two-colour field doubles the permissible polarization gating time, and thus allows twice-as-long driving pulses to be used for generating isolated attosecond pulses. Importantly, only standard optical components (two waveplates, a standard nonlinear crystal and a glass plate at the Brewster angle) are needed to generate the twisted pulse shapes (Fig. 1) necessary for experimentally implementing GDOG. The glass plate — the simplest of these elements — improves the permissible driver pulse duration by yet another factor of two over the earlier DOG method. The crucial idea here was to give up the purely cylindrical polarization on the leading and trailing edges of the driver pulse, thus allowing the same polarization gate width using a longer pulse. The team obtained spectrograms of their isolated attosecond pulses and employed the widely used FROG-CRAB (frequency-resolved optical gating for complete reconstruction of attosecond bursts) phase-retrieval technique to measure a pulse duration of 160 as.

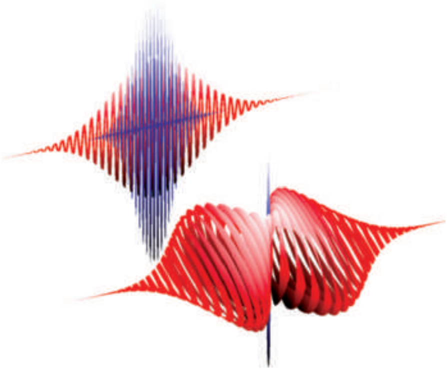


Figure 1 | A twisted pulse does the temporal squeeze. Top: A traditional linearly polarized 25 fs laser pulse (red) generating a train of attosecond pulses (blue). Bottom: The same laser pulse after GDOG optical manipulation (two waveplates in combination with a second-harmonic crystal and a glass plate) generates a single, isolated attosecond pulse.

The scientific merit of this technological advance is also more than just convenience. Isolated attosecond pulse generation has so far been limited to rather low-energy (mJ level) driver pulses that can be pre-compressed to pulse durations of 5 fs and below. This in turn limited the maximum achievable attosecond pulse energy to a few nJ (at a typical conversion efficiency of 10^{-6}), rendering high-intensity nonlinear experiments with isolated attosecond pulses almost impossible. In principle, GDOG now opens the door to high-power attosecond pulse generation using multicycle, multijoule driver pulses with durations longer than 20 fs. This may open up a whole new era of optical and chemical physics, potentially making attosecond pump–probe extreme-UV and soft-X-ray experiments feasible for exploring electron dynamics in the gas and condensed phases.

Attosecond technology is now set to make the final transition from being an exotic science to a routine laser tool. Because 25-fs-duration laser pulses are available in practically any ultrafast laser lab in the world, the field of attosecond science is about to become far more accessible than ever before.❐

Thomas Pfeifer leads the INTERATTO Max-Planck Research Group at the Max-Planck Institute for Nuclear Physics, Saupfercheckweg 1, 69117 Heidelberg, Germany.
e-mail: tpfeifer@mpi-hd.mpg.de

References

1. Goulielmakis, E. *et al. Science* **320,** 1614–1617 (2008).
2. Feng, X. M. *et al. Phys. Rev. Lett.* **103,** 183901 (2009).
3. Gilbertson, S. *et al. Phys. Rev. A* **81,** 043810 (2010).
4. Pfeifer, T., Gallmann, L., Abel, M. J., Neumark, D. M. & Leone, S. R. *Opt. Lett.* **31,** 975–977 (2006).
5. Corkum, P. B., Burnett, N. H. & Ivanov, M. Y. *Opt. Lett.* **19,** 1870–1872 (1994).
6. Brixner, T. *Appl. Phys. B* **76,** 531–540 (2003).

VIEW FROM... SPIE PHOTONICS EUROPE 2010

Champion innovations

Europe has always been a hub of innovation for photonics, and this year's Photonics Europe conference has shown that young inventors are still coming up with great ideas for commercialization.

Rachel Won

Photonics, designated as one of the five 'key enabling technologies' by the European Commission in September 2009, has undisputed value for a wide variety of applications. Nowhere was this more evident than at the recent Photonics Europe conference in Belgium, which featured a 'Photonics Innovation Village' section to showcase emerging photonic technologies that have strong potential for commercialization.

On 12–16 April, around 2,150 researchers, industrialists and policy-makers convened in Brussels — the *de facto* capital city of Europe — for Photonics Europe to discuss the role of photonic technologies in areas such as healthcare, solar energy, bio-, micro- and nanotechnology, lighting, communications and multimedia, among others.

The Photonics Innovation Village — a showcase of creative technology demonstrations developed by universities and research centres — was notably well-visited by attendees. Sponsored by SPIE (the International Society for Photonics), the European Commission's Photonics Unit and Brussels Capital Region, and co-organized by the Brussels Photonics Team of Vrije University of Brussels, it aimed to provide broad exposure and publicity to young innovators, as well as to encourage the technology transfer of photonics research into new and useful products.

Among the 21 demonstrations on display from 12 countries (see Table 1), the three that received critical acclaim in an associated competition were a tunable visible organic laser for spectroscopy (VISOLAS), an image-steering integrated screen for 3D imaging (ISIS3D), and photosensitive materials for two-photon polymerization.

Table 1 | List of contestants at the Photonics Innovation Village

3D Metrics	'3D Metric' software tool for image analysis and on-screen measurement
VUB	ISIS3D: image-steering integrated screen for 3D viewing
VUB	New software for the characterization of historical glass
VUB	Transverse laser mode switching devices and subsystems for *Q*-switching lasers with enhanced figures-of-merit
Optrima	3D camera
KIT	Tunable visible lasers for spectroscopy
Multitel	Optical instrument for interrogating high-sensitivity and multiparametric photonic biochips for future point-of-care diagnostics
SMARTHIES	Test station for microelectromechanical systems based on exchangeable micro-optical probing wafers
OSIRIS	3D rear projector without glass and a liquid-crystal-on-silicon laser projector
Galway University	Low-cost kilohertz wavefront sensor prototype
IESL/FORTH	Photosensitive materials for two-photon polymerization
Photonics Technology Laboratory Thailand	Data-non-intrusive photonics-based credit card verifier
Tampere University	Yellow–orange high-brightness semiconductor disk laser
Trinity College	Optical signal-to-noise monitoring using two fibre interferometers
HOES Photonics	Spectroref: a spectrometer that measures the refractive index of fluids
P4L	Electro–photonic biochip
KIT	MicroMops: an active modular micro-optical system
Belarusian State University	Compact, mobile fibre optical and thermal sensor for non-invasive measurement of blood biochemistry
Photonics Research Centre	A high-speed passive wavelength measurement system
Nanyang Technological University	Compact digital holography system

First place in the competition was given to VISOLAS, a continuously tunable visible laser made from solid-state organic gain materials, presented by Thomas Woggon from the Karlsruhe Institute of Technology in Germany. The system uses specially designed laser chip cartridges, based on a distributed feedback resonator design, which are optically pumped with a UV microchip laser. "The on-chip integration of all components crucial for laser operation makes the system very compact and robust," said Woggon.

Optical confinement and gain are provided by a wedge-shaped layer of tris(8-hydroxyquinoline)aluminium (Alq3) doped with the laser dye 4-dicyanomethylene-2-methyl-6-(p-dimethylaminostyril)-4H-pyrane (DCM). Different emission wavelengths can be obtained by pumping positions on the chip that have varying thicknesses.

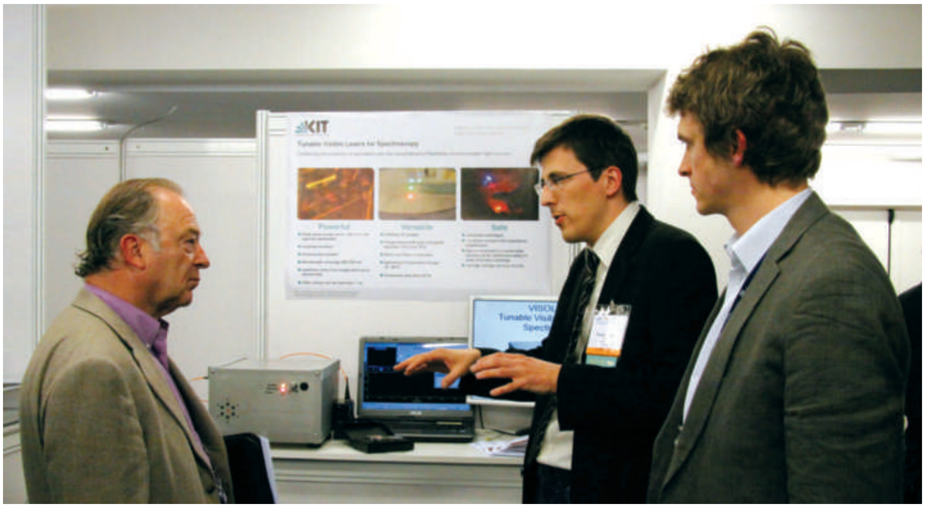
According to Woggon, the laser pulses are subnanosecond in duration and can be emitted at rates ranging from single shots up to several kilohertz with jitter of less than 1 ns, enabling time-resolved measurements. Compared with conventional dye lasers, VISOLAS avoids the need to handle irritating or toxic solvents, and its ability to combine different gain media on a single chip gives a wide tuning range of emission. The prototype presented in the conference was the first step towards commercialization, offering a seamless tuning range of 610–650 nm. "The final product will cover the tuning range of 400–700 nm and so will be perfectly suitable for spectroscopy applications in the visible spectral range," said Woggon.

The first runner-up in the competition was ISIS3D, a multiview projection display that allows 3D visualization without the need for special glasses, showcased by Lawrence Bogaert from Vrije University of Brussels in Belgium. The display has a 25-inch screen and generates 19 different viewing zones, each presenting one view of the 3D image in XGA resolution (1,024 × 768 pixels). The system uses a special projection screen that consists of two large microlens arrays. The exact position between the lenses determines the projection direction of light. Images are time-sequentially projected onto the rear of the projection screen and steered into different directions. Thus, two different views are seen by both eyes at every viewing position. The parallax between both images simulates 3D vision; when the viewer moves around, different views of the 3D image are seen, thus making it possible to look around 3D objects.

"ISIS3D is a low-cost and compact system that enables 3D viewing at high spatial and angular resolutions without the need to wear special glasses," said Bogaert. "It can be used in medical imaging, scientific and technical visualization, and also in entertainment."

The second runner-up was the development of photosensitive materials with superior mechanical and optical properties for one- and two-photon lithographic applications. Showcased by Maria Farsari from the Foundation for Research and Technology in Hellas, Greece, the materials are designed for use with direct laser writing — a technology based on two-photon absorption. "Essentially, when the beam of an ultrafast infrared laser is tightly focused into the volume of a transparent photosensitive material, the polymerization process can be initiated by two-photon absorption within the focal volume," explained Farsari. By moving the focused laser beam in a 3D manner through the resin, 3D structures can be fabricated. The only processing required afterwards is the washing and removal of the non-illuminated (and therefore non-photopolymerized) material.

According to Farsari, this technique has previously been implemented with a variety of acrylate and epoxy materials, and several components and devices such as photonic crystal templates, mechanical devices and microscopic models have been fabricated as a result. "In our work we have made materials that have superior structuring properties, such as high resolution and no shrinkage, but we have also made materials that have functional groups



RACHEL WON

Thomas Woggon from the Karlsruhe Institute of Technology in Germany showcasing his work on VISOLAS in the Photonics Innovation Village.

in them, such as metal-binding groups for metamaterial and sensor fabrication, quantum dots and nonlinear optical groups," said Farsari. The main features of the materials are that they do not suffer from distortion during polymerization, can be readily functionalized or metalized, and are biocompatible. Submicrometre resolution can be achieved through this technique, allowing the fabricated materials to be used for applications in nanophotonics, microelectromechanical systems, microfluidics, embedded waveguides, optoelectronic components, medical implants and devices, and scaffolds for cell migration and tissue engineering studies.

Other demonstrations that received recognition were Multitel's optical instrument for interrogating photonic biochips, Ghent University's stretchable optical waveguide and Optrima's 3D camera.

All in all, innovation is clearly alive and well in Europe. Those wishing to see it in person should attend the next Photonics Europe conference, which will be held again in Brussels on 16–20 April 2012. ❐

Rachel Won is at Nature Photonics, *Chiyoda Building, 2-37 Ichigayatamachi, Shinjuku-ku, Tokyo 162-0843, Japan.*
e-mail: r.won@natureasia.com