Compared with unseeded ASE beams, which exhibit divergences of up to 10 mrad, the beam divergence of the injection-seeded laser-induced plasma is reduced to 0.7 mrad. As the gain bandwidth of the plasma amplifier is a good deal narrower than that of the high harmonics, the amplified output pulses have a duration of approximately 1 ps. Moreover, they are essentially fully coherent in time thanks to the narrow linewidth of the plasma amplifier. In addition, there is a very high degree of spatial coherence across the amplified beam, as illustrated by high-visibility interference fringes that can be observed in a simple double-slit experiment, even for slit separations of up to 100 μm. The results show dramatic bandwidth narrowing as the seed pulse propagates along the gain channel in the plasma amplifier until saturation is reached. The laser system produces pulses with energies approaching 75 nJ, and peak intensities of about 75 kW.

This work has emerged at an interesting point in the evolution of EUV optics, which is rapidly growing into a burgeoning area of research and application. The EUV extends from approximately 1 nm to 50 nm and is hence, in a sense, the natural nanotechnology waveband. As a result significant efforts are now being made to design and build very efficient optical systems in the EUV. Many, if not most, of the familiar UV–visible optical configurations can now be realized using multilayer EUV optical elements that are highly reflective. This is especially true in the EUVL band around 13.5 nm, driven of course by the imminent need to reduce the computer-chip feature size down to the next node on the International Technology Roadmap for Semiconductors[8] (ITRS). Combining phase-coherent sources with efficient EUV optical systems and cameras will bring many new scientific and technological opportunities, for example, holographic imaging and matter probes based on phase-controlled transmission and photo-ionization. In addition, for phase-coherent light in the biologically relevant water window, around 3 nm, it may even be possible to apply these techniques to *in vitro* and even *in vivo* targets.

There is of course one other EUV amplifier design that competes with the plasma-based amplifier, namely the free-electron laser (FEL). Free-electron lasers use a relativistic electron beam as the lasing medium, and build up their radiation fields from shot noise through a process termed self-amplified spontaneous emission (SASE). Mikhail Yurkov and colleagues recently reported, in this journal[9], continuously tunable laser-like EUV radiation from FLASH (the FEL in Hamburg). FLASH can provide pulses of up to 150 μJ with less than 30 fs duration, at repetition rates short of 1 kHz at present but, pushed to its ultimate design values, rates of up to 10 kHz will be achieved. It is immediately clear that such SASE-FELs would benefit greatly from injection seeding with high-order harmonics, and indeed such a project has been approved for implementation at the Deutsches Elektronen Synchrotron (DESY). Such a system could potentially produce fully coherent radiation at peak pulse powers of many gigawatts and average powers at the 1-W level.

In summary, Yong Wang and co-workers have combined the best of many years of research in the arena of high harmonics and laser-plasma-based amplifiers to develop a neat, laboratory-scale coherent EUV laser with average powers in the microwatt range and peak pulse powers that could approach 1 MW with some additional effort. The SASE-FEL is rapidly maturing as a technology and also looks set to benefit from clever use of high-harmonic injection seeding and, indeed, other less tried, but nevertheless potentially very effective, continuous-wavelength seeding techniques.

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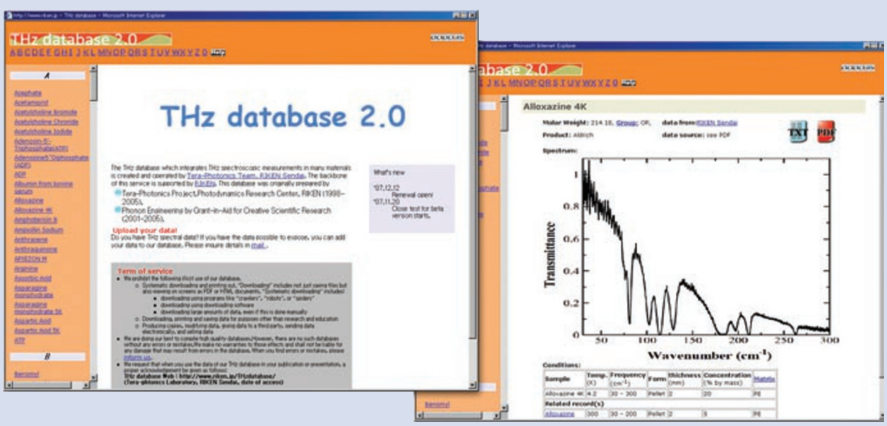
TERAHERTZ SPECTROSCOPY

RIKEN database goes live

An online database containing terahertz spectroscopic data for nearly 200 materials has now gone live and is free to access. Compiled by researchers at RIKEN, a Japanese research organization, the terahertz database provides downloadable data in ascii and pdf format for research and educational purposes. The database is located at www.riken.jp/THzdatabase.

At present, it features 164 organic materials, including amino acids, saccharides, polymers, agrichemicals and medical compounds, as well as 18 inorganic materials, such as semiconductors and dielectrics. Several of the materials are widely used in the photonics community, for example silicon, sapphire, carbon nanotubes and lithium niobate. In each case transmission spectra (typically between 30 cm^{-1} and 200 cm^{-1}) and the measurement conditions, such as sample thickness, temperature and concentration, are provided. RIKEN says that it plans to grow the database and welcomes external parties to upload information they have collected themselves.



"We believe that it is very important to collect this information and share it with the terahertz community and materials scientists," explained Hiromasa Ito, leader of the Teraphotonics research team at RIKEN. "We will routinely be adding more data ourselves and will be accepting data from others as well."

Oliver Graydon