tons occur in quadratic nonlinear media and birefringent cubic nonlinear media.

In a series of works, an approach to find families of stationary walking solitons has been reported and the properties of optical walking solitons in two representative and important examples have been uncovered.[1–4] Namely, spatial solitons in quadratic nonlinear media in the presence of Poynting vector walk-off, and temporal vector solitons in birefringent optical fibers. In particular, solitons in second-harmonic generation geometries are made out of the mutual trapping of the fundamental and second-harmonic beams, and when a soliton is formed in the presence of Poynting vector walk-off, the interacting beams drag each other and propagate stuck, or locked together. Under such conditions a walking soliton is formed, opening the possibility to specific applications, some of which have already been experimentally demonstrated.[5] The walking solitons display features different from non-walking solitons, they can exist under different conditions, have different shapes and wavefronts, and carry different energies. Figure 1 (page 44) shows a typical example.

The important result is that the approach reported is intended to be a general tool to uncover new families of walking solitons in other scenarios. Because of their very nature, walking solitons have potential applications to all-optical switching and routing devices and to multiplexing techniques. Beyond optics, walking solitons might be relevant to mechanisms of energy and information transport in a variety of physical, chemical, and biological systems.

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ULTRAFAST TECHNOLOGY

A Compact All-Solid-State Sub-5-fsec Laser

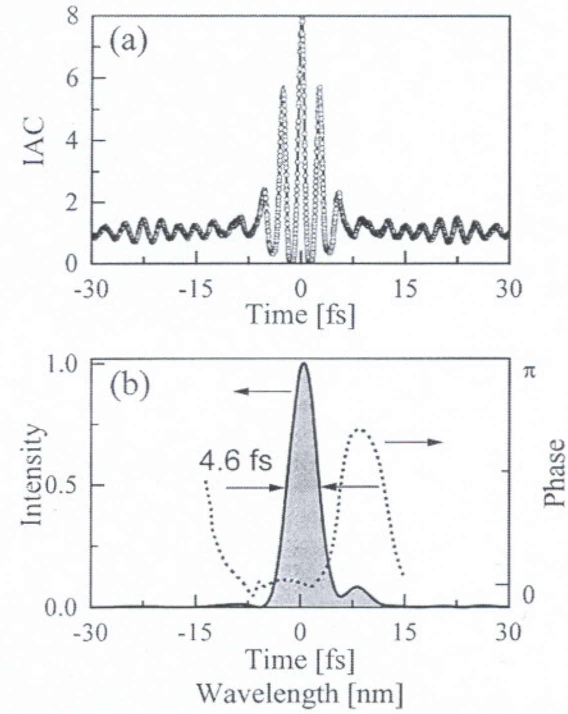
Andrius Baltuška and Maxim S. Pshenichnikov, Ultrafast Laser and Spectroscopy Laboratory, Dept. of Chemistry, Univ. of Groningen, Groningen, The Netherlands; Róbert Szipöcs, Research Institute for Solid State Physics, Budapest, Hungary; and Douwe A. Wiersma, Ultrafast Laser and Spectroscopy Laboratory, Dept. of Chemistry, Univ. of Groningen, Groningen, The Netherlands.

Recent developments in solid-state lasers,[1] chirp-mirror technology,[2] and methods of pulse characterization[3] made it possible to design an all-solid-state laser that delivers sub-5-fsec pulses at a 1-MHz repetition rate.[4] Such extremely short light pulses at a high repetition rate are most suitable for spectroscopic applications in condensed phase, and in particular in nonlinear optical studies of ultrafast chemical reaction dynamics in solutions.

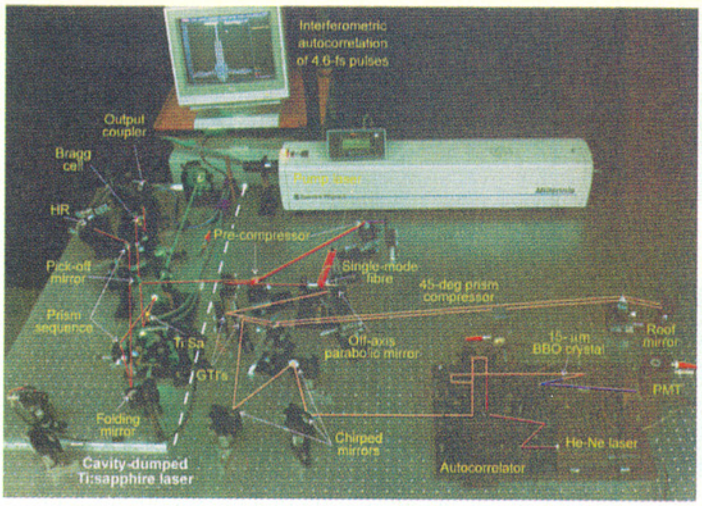
The basic recipe for generating ultrashort pulses consists of four main ingredients:

- Generating a white-light continuum (WLC) with sufficient spectral bandwidth;
- Measuring the spectral phase of the resulting WLC;
- Designing a compressor capable of phase correction over the whole continuum bandwidth; and
- Determining the compressed pulse duration and its phase.

In our setup, the required ultrabroad bandwidth of WLC is produced upon injection of ~13-fsec, 35 nJ pulses from a Millennia-pumped cavity-dumped Ti:sapphire laser into a single-mode fused silica fiber.[4, 5] Due



Baltuška Figure 1. (a) Interferometric autocorrelation (circles are experimental points, and the solid line is the fit). (b) Retrieved intensity profile (filled contour) and phase (dashed line). (c) Measured spectrum of compressed pulse (filled contour) and retrieved spectral phase (dashed line).



Baltuška Figure 2. An all-solid-state sub-5-fsec laser occupies a work space of 1 m x 1.5 m on an optical table.

to self-phase-modulation (SPM) in the fiber, the exiting pulse has a spectrum stretching from 500 nm to ~1.1 µm. Phase resulting from combined action of SPM and dispersion leading to a nearly linear group delay over most of the spectrum was resolved by means of cross-correlation of the white light pulse with a well-characterized reference pulse.[3–5]

Precise knowledge of the group delay that should be corrected constitutes the backbone of pulse compressor design. The matching group delay introduced by the compressor should be provided with a few femtoseconds accuracy over a few hundreds of nanometers. We used a newly designed three-stage compressor consisting of a quartz 45°-prism pair, broadband chirped mirrors, and thin-film Gires-Tournois dielectric interferometers. Dispersive properties of this compressor have been investigated by dispersive ray tracing, balancing dispersion of various elements to fit the target function.[5]

The interferometric autocorrelation of compressed pulses is depicted in Figure 1a (circles). A 15-µm BBO crystal was used to enable simultaneous up-conversion of the entire spectral bandwidth and to minimize material dispersion inside the crystal. To retrieve the pulse shape and, therefore, to determine the pulse duration from the autocorrelation function, a recently proposed iterative algorithm was used.[6] Furthermore, the derived pulse profile combined with the pulse spectrum yields information on the pulse phase thus completing the full characterization of the pulse in both frequency and time domain. The output of the above routines is presented in Figures 1b and c. The retrieved pulse duration is ~4.6 fsec, which corresponds ~2.5 oscillation of the electric field at its FWHM. Excursions of phase across most of the spectrum do not exceed ~$\pi/4$ (see Fig. 1c) and originate from non-smooth phase of used chirped mirrors. The interferometric autocorrelation calculated using obtained phase information is shown in Figure 1a (solid line) and agrees well with the experiment, proving the consistency of the chosen approach.

For the near future, we aim for an all chirped-mirror compressor, having had already demonstrated its preliminary 6-fsec version. Novel chirped mirrors with smooth monotonous group velocity delay over 550–200 nm reflectivity range are currently being designed. According to our calculations, sub-4-fsec pulses from our setup should be achievable. With smaller diode-pumped light sources coming on the market, there is every reason to believe that soon it will be possible to build a sub-5-fsec cavity-dumped laser that fits onto a breadbox of only 1 × 0.5 m.

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Spatiotemporal Shaping of Terahertz Pulses

Jake Bromage, Stojan Radic, G.P. Agrawal, and Carlos R. Stroud, Jr., Institute of Optics, Univ. of Rochester, Rochester, N.Y., and P.M. Fauchet and Roman Sobolewski, Dept. of Electrical Engineering and Laboratory for Laser Energetics, Univ. of Rochester, Rochester, N.Y.

It has been demonstrated in a number of laboratories over the past several years that when a GaAs crystal is subject to a dc voltage bias and simultaneously illuminated by a fsec laser pulse whose photon energy exceeds the crystal's bandgap, a small antenna is formed that radiates a THz pulse. The pulse typically contains only a fraction of a cycle to a few cycles of oscillation. These pulses have found a variety of uses in ultrafast spectroscopy of atoms, molecules, and solids, far-infrared time-domain spectroscopy, study and control of Rydberg atoms, T-ray imaging of optically opaque materials, and impulse ranging studies.[1]

Optical pulse shaping, in which the slowly varying complex envelope of the pulse is controlled, has been widely practiced since the pioneering work of Steacy more than 20 years ago. Pulse shaping takes on an entirely different meaning when the bandwidth is approximately equal to the average frequency, as in these THz pulses. With these pulses, the actual time dependent amplitude of the field can be controlled and shaped. One can tailor fields that might, for instance, be used to control atomic or molecular electrons like a thruster controls an earth satellite.

Although shaped THz pulses have been made by