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Generation of sub-millijoule-energy and sub-4fs-duration near-infrared laser pulses

Such pulses have controlled waveform comprising approximately 1.5 wave cycles within the full width at half maximum of their temporal intensity profile and their utility for producing high-order harmonic continua of unprecedented bandwidth at photon energies around 100 eV. The generated ultra-broadband coherent continua extend from 90 eV to more than 130 eV with smooth spectral intensity distributions and exhibit dramatic, never-before-observed sensitivity to the carrier-envelope phase of the driver laser pulse. These results suggest the feasibility of sub-100-as XUV pulse generation in the 100 eV range and of a simple and highly sensitive carrier-envelope phase detector with sub-50-ms response time.

The pulses were broadened in a 250µm inner-diameter HCF filled with 1.8 or 2.0 bar Ne. Approximately 50% transmission was achieved. The direct output spectra for the two pressures used in these experiments, which is much broader, smoother and more blue-shifted than that obtained in previous efforts, is plotted in Fig. 1.

These spectra generated with 1.8 bar and 2.0 bar Ne both support 3fs (FWHM) transform limited pulses, although the pulse envelope is not as nice in the case of 1.8 bar. The supercontinuum was next compressed in a negative-GDD chirped-mirror compressor, which, however, was not designed to handle such broad bandwidth. The chirped mirrors used in our compressor were instead designed for high reflectivity and well-controlled dispersion between 550-1000nm. As a result, we cannot expect that the spectral components below 550nm (the continuum extends to near 400nm) can contribute to a shortening of the compressed pulse. In spite of the limited capacity of the chirped mirror compressor, remarkably good compression was achieved.

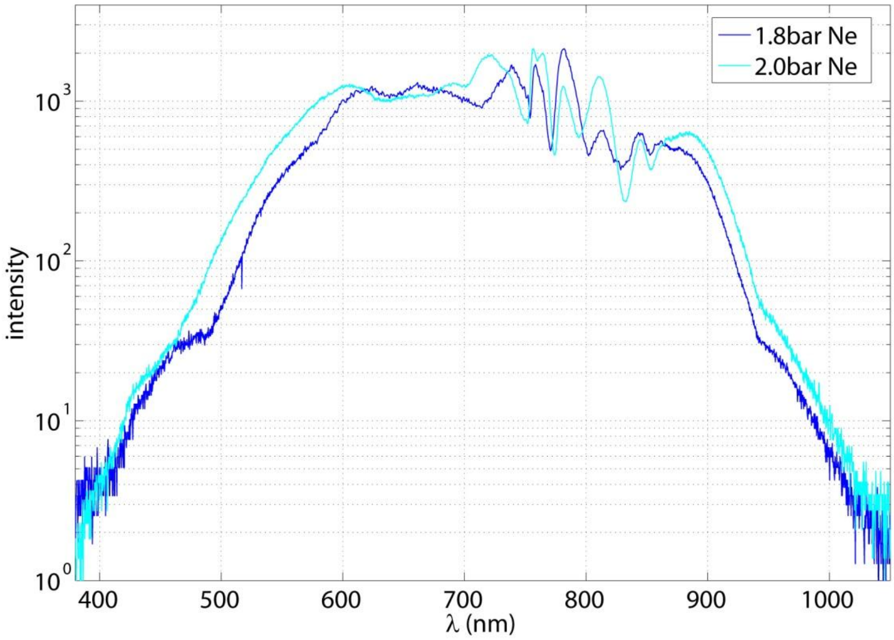

Fig. 1: Broadened supercontinuum spectra from the HCF using shorter input pulses from the hybrid chirped-mirror/prism compressor. The blue curve shows the spectral broadening achieved using 1.8 bar of Ne while the cyan curve shows that achieved using 2.0 bar of Ne. The best SHG autocorrelation was achieved using 2.0bar Ne, while the best THG autocorrelation was achieved using 1.8bar Ne. Neither the SHG or THG autocorrelators were completely suitable for such a broad input spectrum. As a result, measurements made with these devices can only be considered as upper-bounds on the compressed pulse duration.

Measurements using a second-harmonic generation (SHG) interferometric autocorrelator as well as a third-harmonic generation (THG) interferometric autocorrelator were made to characterize the compression of our supercontinuum. Our SHG autocorrelator, containing a 20-µm thick BBO crystal suffers from phase-matching limitations below 5 fs, therefore, SHG AC traces were obtained primarily for comparison with other published results, rather than for absolute pulse duration determination. The shortest SHG autocorrelations were obtained using the supercontinuum generated with 2 bar of Ne. A typical result is shown in Fig 2. The transform-limited autocorrelation function was calculated based on the supercontinuum spectrum and is superimposed on the measured autocorrelation. It corresponds to a pulse duration of 3.0 fs FWHM. Remarkably, with a carrier wavelength of 720nm, this pulse duration corresponds to a 1.25-cycle pulse.

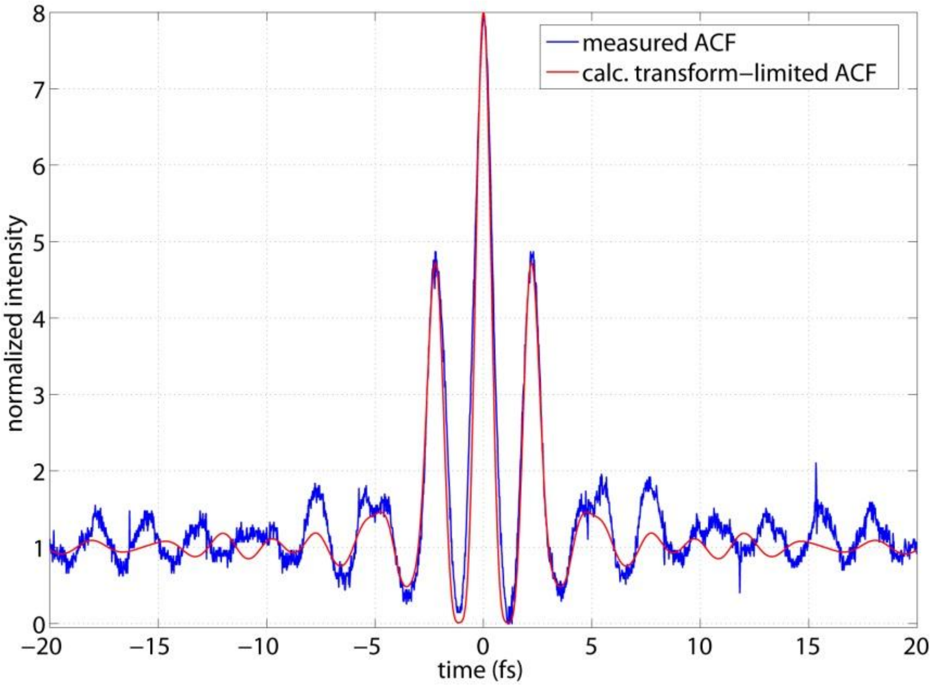

Figure 2: SHG interferometric autocorrelation of the compressed HCF output supercontinuum generated in 2.0bar of Ne. The blue curve is the measured autocorrelation function. The red curve is the calculated transform limited autocorrelation function based on the input spectrum. The calculated pulse duration is 3.0fs (FWHM), or with a carrier wavelength of ~720nm, 1.25 optical cycles.

Reference:

A. L. Cavalieri, E. Goulielmakis, B. Horvath, W. Helm, M. Schultze, M. Fieß, V. Pervak, L. Veisz, V. S. Yakovlev, M. Uiberacker, A. Apolonski, F. Krausz and R. Kienberger. "Intense 1.5-cycle near infrared laser waveforms and their use for the generation of ultrabroad-band soft-X-ray harmonic continua", New J. Phys. 9, 242-1 (2007).

Recommended mirror designs:

PC52, PC70