# Generation of CE Phase Stabilized 5 fs, 0.5 mJ, Pulses from Adaptive Phase Modulator


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**Synopsis:** By improving the throughput of the 4*f* system and by increasing the input laser pulse energy, milli-joule level two cycle pulses were produced with a liquid crystal spatial light modulator. The carrier-envelope phase of the two-cycle pulses was measured directly by using its over-one-octave output spectrum and stabilized by feedback controlling the grating separation of the stretcher in the chirped pulse amplifier. To the best of our knowledge, this is the first time that carrier-envelope phase locked few-cycle, milli-joule level pulses were generated by using phase modulator compressors. When the pulses were used in high harmonic generation, it was found that the harmonic spectra depended strongly on the high order spectral phases of the driving laser fields.


Few-cycle laser pulses with milli-joule level energy are crucial for attosecond pulse generation and many other strong field physics studies. So far, such pulses have been produced by compressing white light with chirped mirrors. However, the high order dispersions are not compensated resulting in poor pulse contrast. Adaptive pulse compression has been demonstrated before to generate sub-4 fs light pulses. Unfortunately, the compressed pulse energy was only 15 μJ [1], which is too low for high field applications such as high harmonic generation (HHG). We focused on resolving the pulse energy problem associated with the phase modulator pulse compressor.

The experiment was performed using the Kansas Light Source laser system. The 1.1 mJ pulse from the neon fiber covered the spectrum from 400nm to 1000 nm. By the combination of high input white light energy and high throughput, we obtained 0.5 mJ output pulse energy from the phase modulator.

We adopted the Multiphoton Intrapulse Interference Phase Scan (MIIPS) [2] to measure the spectral phase of white-light pulses. The chirp compensation was done by applying a corrective phase to the SLM. The pulse duration was measured by the Frequency Resolved Optical Gating (FROG). The retrieved pulse duration was 5.1 fs as shown in Fig. 1. We performed coherent control of high harmonic generation with such pulses by independently changing the GDD and high order spectral phases [3].

The modulator was designed to perform spectral phase correction in the range of 500nm to 1000nm. However, the light around 460nm could go through the 4*f* system by the second order diffraction of the grating, overlapped with the fundamental component of 920nm. With such an octave spanning spectrum, an *f*-to-2*f* interferometer was used to measure and stabilize the CE phase after the adaptive phase modulator. The RMS of the CE phase was 184 mrad.

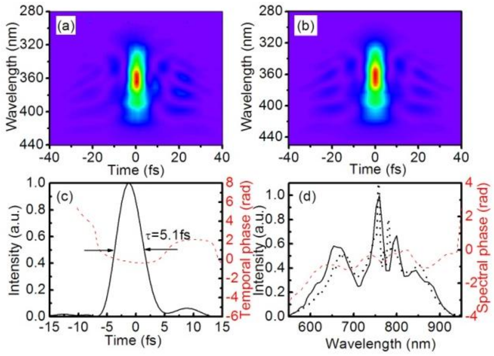


**Fig. 1.** Characterization of the laser pulse by the FROG. (a) The measured FROG trace. (b) The reconstructed FROG trace. (c) The retrieved pulse shape and phase (dashed curve). (d) The retrieved power spectrum (solid curve), phase (dashed curve) and independently measured spectrum (dotted curve).

In conclusion, CE phase locked, 0.5 mJ, 5fs laser pulses were generated from an adaptive phase modulator for the first time. It was found that the harmonic spectra depended strongly on the high order spectral phase. The ability to generate high energy, CE phase controllable, few-cycle pulses provides a new tool to study attosecond science and perform other coherent control experiments in high field physics. This material is supported by the U.S. Army Research Office under Grant No. W911NF-07-1-0475, and by the Chemical Sciences, Geosciences, and Biosciences Division, U.S. Department of Energy.


**References**

[1] B. Schenkel, et. al. *Opt. Lett.* **28**, 1987 (2003).
[2] B. Xu, et. al. *Opt. Exp*. **14**, 10939 (2006).
[3] H. Wang et. al. *Opt. Exp*. **16**, 14448 (2008).



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