High accuracy, real time, single-shot measurement of absolute carrier-envelope phase and pulse duration for few-cycle laser pulses

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Synopsis: We develop a novel approach which allows for the simultaneous *a priori* single-shot measurement of carrier-envelope phase (CEP) and pulse duration for each and every few-cycle laser pulse in a kHz pulse train, virtually instantaneously. This technique builds upon the previous work of Wittmann *et al.* [1], which outlines a technique for determining CEP using a stereographic ionization measurement [2]. However, our approach allows for real-time assessment of these parameters, thereby permitting the signal to be used as a laser-feedback control mechanism or as an auxiliary measurement providing shot-by-shot pulse characterization for other measurements.

A pulse's electric field asymmetry depends upon its absolute carrier-envelope phase – CEP (φ) and is exaggerated as the pulse length (τ) decreases, where the pulse's electric field is defined as $E(t)=\exp(-(t/\tau)^2)\cos(\omega t+\varphi)$. This asymmetry is reflected in above-threshold laser-induced ionization (ATI) distributions produced from atomic target, e.g. see references [1–3]. Furthermore, as the ATI distribution is dependent upon the absolute CEP and pulse duration, one can work backwards using the measured distribution to determine these quantities, thereby providing an improved alternative to the customary optical methods available that measure only the relative CEP.

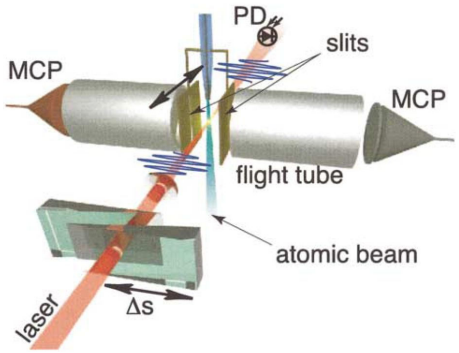

Fig. 1. Stereographic CEP meter [2].

This type of inversion technique was recently employed by Micheau *et al.* [3] to determine the aforementioned parameters using 3D momentum images of high-energy photoelectrons. However, this method requires multiple laser pulses with a constant CEP to generate a clear momentum image, which is then analyzed using rescattering theory.

In contrast, our method utilizes a stereographic ATI measurement, see Fig. 1, and the left / right asymmetry of the two energy regions in the ATI energy spectra to allow for a single-shot real-time determination of the absolute CEP at kHz rates even without CEP stabilization. Fig. 2 shows a parametric plot of the asymmetry coefficient for the two aforementioned energy regions where the polar angle, θ, is roughly equivalent to the absolute CEP. Additionally, this technique allows for the measurement of the pulse duration and intensity along with other laser properties via a comparison to calculated distributions.

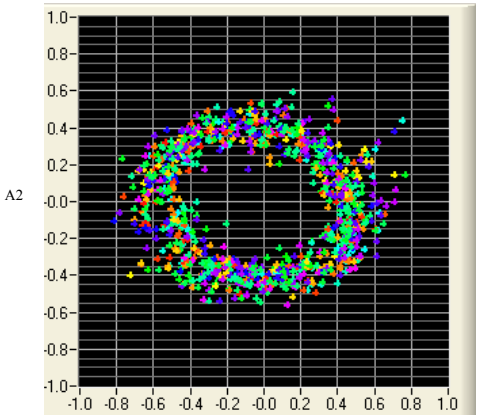

Fig. 2. A typical plot of asymmetry parameters for a non-CEP stabilized ultrashort pulse.

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References

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