Direct Determination of Spatial Electric Field Variations Using Isolated Attosecond Pulses

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Synopsis: Using single isolated 276 attosecond pulses of extreme ultraviolet radiation, the transverse electric field of an 8 femtosecond Bessel-Gaussian beam was directly measured for the first time. A photoelectron replica of an attosecond burst was generated to act as a probe for the electric field of the Bessel-Gaussian beam. By monitoring the momentum shift of the photoelectrons, the direction reversing field of the laser was accurately mapped.

By placing an attosecond burst of electrons in the field of an ultrashort laser, the electric force, via a momentum shift, can be directly measured to reconstruct the electric field oscillations of the pulse [1]. Here we extend this technique to measure the electric oscillations of the Bessel beam in space.

A Bessel-Gaussian laser pulse has a non-trivial transverse profile. These pulses can, in principle, be indirectly mapped since the direction reversal of the adjacent rings can be treated as a π phase shift. This is indirect however since even scalar Bessel beams also exhibit this property [2]. A true verification should be demonstrated by the first principle of electrodynamics, namely that the field is defined as the force exerted on a point charge.

To conduct the experiment, an interferometric streak camera was used. An 8 fs, 1mJ laser pulse was split by an 80% transmitting beamsplitter. The transmitted portion passed through double optical gating optics to generate an ellipticity dependent pulse [3]. The pulse was then focused onto an argon filled gas cell to generate the extreme ultraviolet (XUV) single attosecond burst. Meanwhile, the reflected near-infrared (NIR) portion of the initial laser pulse recombined with the XUV at a hole drilled mirror. The mirror allowed the XUV to pass and reflected the NIR. The two beams then were reflected and focused by a double mirror assembly consisting of an Mo/Si mirror and a silver mirror concentric to it. The two beams were temporally locked and spatially overlapped at a second gas target to generate photoelectrons from the XUV burst and to give a momentum shift from the NIR.

In the reflected portion of the interferometer, a thin lens was installed on a movable translation stage for overlap of the two beams at the second target. Since the double mirror assembly truncated the NIR beam, a Bessel-Gaussian beam was produced as shown in figure 1(a). Also shown is a lineout of the intensity profile (b).

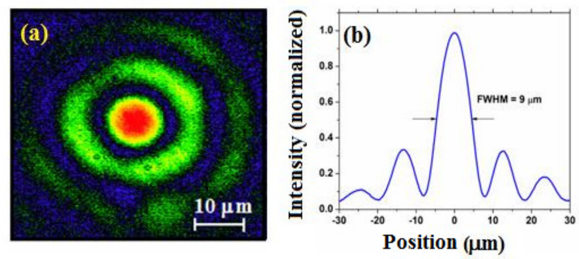

Fig. 1 (a) CCD image of the laser image. (b) Lineout of the center of (a).

The NIR beam was moved over a range transverse to the stationary attosecond burst thereby giving a spatially dependent momentum shift to the photoelectrons as seen in figure 2. This method allows for the spatial varying field strength of the pulse to be calculated directly.

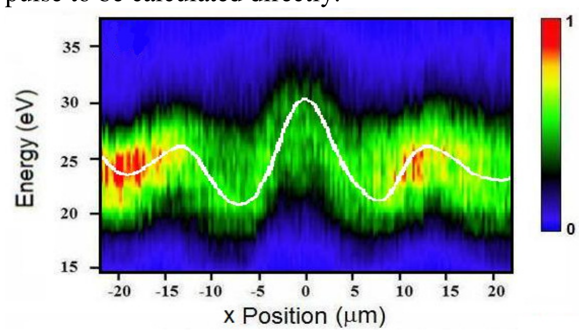

Fig. 2. Photoelectron spectrum as a function of position.

In conclusion, the transverse electric field of a Bessel-Gaussian laser beam was directly measured with single attosecond pulses. Coupling this with an accurate temporal scan of the pulse gives a full classification of femtosecond laser pulses. 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.

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