17a-F7-9

High-order above-threshold ionization spectroscopy of noble gases using few-cycle carrier-envelope phase-stabilized pulses in the infrared spectral range

ISSP, °Henning Geiseler, Nobuhisa Ishii, Keisuke Kaneshima, Teruto Kanai, Jiro Itatani

E-mail: geiseler@issp.u-tokyo.ac.jp

Above-threshold ionization (ATI) is a fundamental process that occurs through tunnel ionization when matter is exposed to intense laser fields. When the liberated electrons collide with their parent ion in the optical cycle following the ionization step, even higher final kinetic energies of these electrons result (high-order ATI). We report on the spectroscopy of electrons resulting from this process using a previously unavailable source of light, namely, 1.7-cycle optical pulses in the infrared (IR) spectral range at a center wavelength of λ = 1600 nm from a BiB_3O_6 optical parametric chirped-pulse amplifier [1]. The maximum kinetic energy of ATI electrons is about 10 times the ponderomotive energy U_p, which is proportional to λ^2, and thus the long wavelength enables the extension of the generated electron spectrum to kinetic energies in the keV range. In addition, the capability to stabilize and manipulate the carrier-envelope phase (CEP) of the IR optical pulses allows to control the motion of the recolliding electron wave packet, and to identify individual half cycles of the optical field in which ionization occurs.

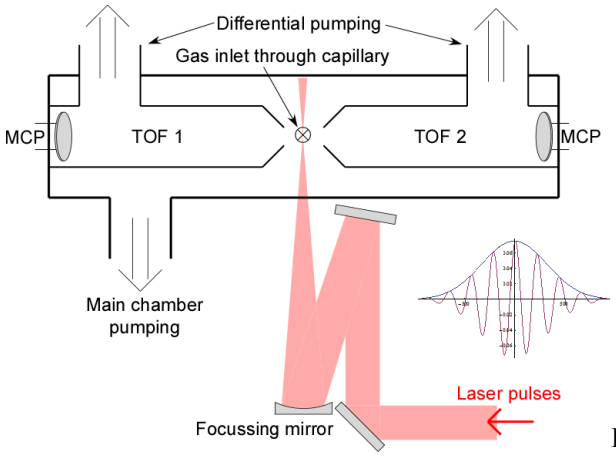

Fig. 1: Sketch of setup for electron spectroscopy

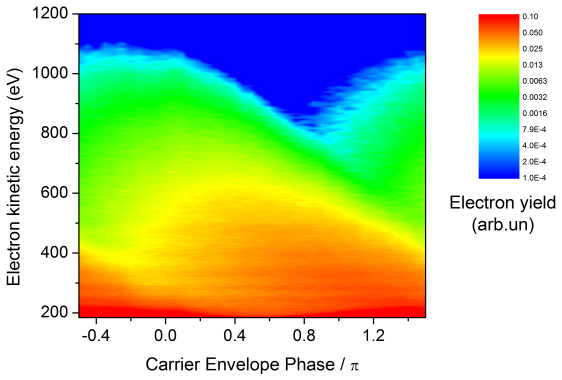

Fig. 2: Contour plot of energy-resolved electron yield from argon atoms for varying CEP

The setup we employ is shown in Fig. 1. The IR beam is focused (focal length f = 37.5 cm) into a vacuum chamber, where two opposing time-of-flight spectrometers (free flight path length s = 48 cm) detect the energy distribution of electrons that are emitted from the focal point in a small cone of 1.2 msr. In our experiments, the spectrometer axis coincided with the polarization direction of the optical pulses. Figure 2 shows the recorded electron spectra after ionization of argon, scanned over a full cycle of the CEP, where individual half-cycle cut-offs can easily be identified. The pronounced dependence of the high energy cut-off on the CEP illustrates the sensitivity of the spectrometer, as well as the stability of the light source. For a cosine-like pulse (CEP = 0.0 π), the cut-off energy reaches its maximum of more than 1 keV. Following the well-established semi-classical model, we deduce a kinetic energy of these electrons at the moment of recollision of more than 300 eV. The energy of this recolliding wave packet can easily be reduced and tuned in a wide range by attenuating the optical pulse energy. Since the employed light source allows for CEP-stable operation for more than 24 hours, also very low pulse energy measurements are feasible. Thus, the recolliding wave packet provides an ideal tool to probe electron collision characteristics of the parent ion in an unprecedented energy range. As the electron collision process is mapped on the final kinetic energy distribution, careful analysis will facilitate its further investigation. This type of spectroscopy constitutes a complementary method to high-harmonic spectroscopy. In contrast, our method is sensitive to electron collision phenomena, and does not suffer from phase matching issues.

[1] N. Ishii, *et al.*, Opt. Lett. **37**, 4182 (2012)