Probing Doubly Excited Helium with Isolated Attosecond Pulses

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Synopsis: Single attosecond pulses generated with a neon gas target were used to probe two electron excitation and autoionization in a helium gas target. By adding an intense near infrared laser beam, the population of the excited atoms in the $2s2p\,^1P^0$ state was modified in a controllable manner for the first time.

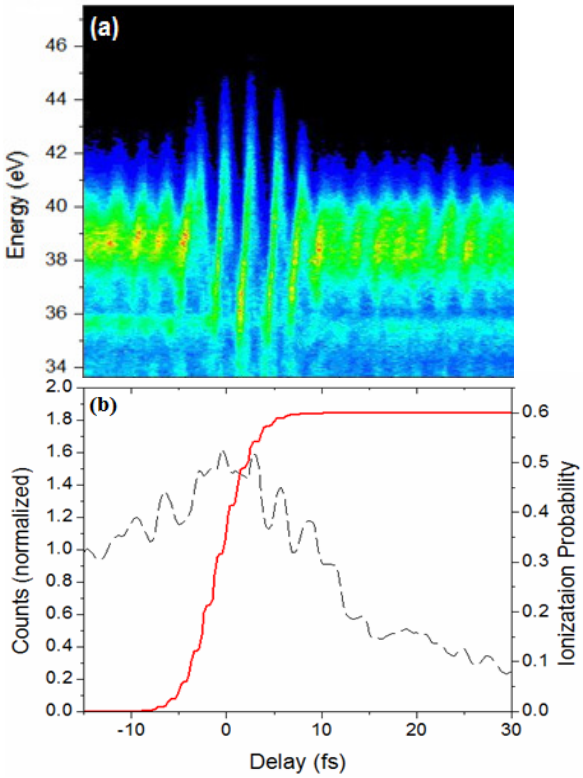
Studying the temporal evolution of electron dynamics is a main application goal of generating single isolated attosecond pulses. Helium is an especially attractive target due to interest in time resolved studies of the Fano profile [1]. When the doubly excited states are formed by using single isolated attosecond extreme ultraviolet (XUV) pulses, it was predicted that the autoionization process could be modified by intense few femtosecond near infrared (NIR) laser pulses overlapping with the XUV pulses [2]. Here we report results of the first attosecond streaking experiments on the He $2s2p\ ^1P^o$ resonance.

The experiments were conducted with a streak camera in an interferometric configuration. An 8 fs, 1mJ laser pulse was split by an 80% transmitting beamsplitter. The high power side was used for attosecond pulse generation in a neon gas target with an ellipticity modulated pulse from double optical gating [3]. This resulted in a single attosecond pulse which was then recombined with the remaining NIR laser pulse at a hole drilled mirror. The mirror transmitted the XUV and reflected the NIR to a two component annular focusing mirror. The inner mirror focused the XUV and the outer mirror focused the NIR to a second helium filled gas target. Here photoelectrons were produced by the XUV, given a momentum shift by the NIR and recorded with a time of flight detector.

Figure (a) shows an experimentally obtained streaked spectrogram with a clearly visible autoionization resonance at 34 eV. The resolution of the detector gives this peak nearly a 0.7 eV width. The streaking of the photoelectrons shows the pulse to be a single attosecond pulse and the intensity of the NIR pulse can be extracted from the degree of streaking. In this case, the NIR intensity was estimated at 5 x 10^{11} W/cm^2.

Figure (b) shows the counts of the autoionization resonance as a function of delay between the XUV and the NIR (dashed line). The decay is attributed to single ionization of the doubly excited state. Since the ionization potential from the 2s2p level is 5.2 eV, the NIR laser has sufficient intensity to deplete this level leaving the helium atom in $He^+(2s)$. The ionization probability calculated from the PPT method is indicated by the solid red line.

In conclusion, the doubly excited state of helium was studied with the attosecond streaking method.



The electron dynamics were also modified by the presence of the NIR laser. The physical process described here is different than what is proposed in other numerical simulations [2, 4]. 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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