Watching the emergence of a Fano resonance in doubly-excited helium

Alexander Blättermann[*] [1], Andreas Kaldun[*], Veit Stooß[*], Stefan Donsa[†], Hui Wei[‡], Renate Pazourek[†], Stefan Nagele[†], Christian Ott[*], Chii-Dong Lin[‡], Joachim Burgdörfer[†] and Thomas Pfeifer[*] [2]

[*] Max Planck Institute for Nuclear Physics, 69118 Heidelberg, Germany, EU
[†] Institute for Theoretical Physics, Vienna University of Technology, 1040 Vienna, Austria, EU
[‡] Department of Physics, Kansas State University, 66506 Manhattan KS, USA

Synopsis We report the experimental observation of the buildup of the 2s2p Fano resonance in helium, which has been under theoretical investigation for more than a decade. The emergence of the absorption line is temporally resolved by interrupting the natural decay of the excited state via saturated strong-field ionization at variable time delay.

Asymmetric Fano line shapes occur in a variety of research fields ranging from nuclear and atomic physics to condensed matter physics and photonics. Among the most well-known examples are the resonances in the extreme ultraviolet (XUV) absorption spectrum of doubly excited helium. From the early works on attosecond dynamics until today, theorists have been investigating how these spectral lines emerge and evolve after the transition is triggered and the subsequent process of autoionization takes place.

Here, we report for the first time the experimental observation of the ultrafast formation of a Fano resonance, namely the helium 2s2p spectral line via high-resolution XUV absorption spectroscopy [1]. In order to monitor the buildup of the absorption line, we apply an intense few-cycle near-infrared (NIR) laser pulse, which rapidly depletes the excited state via strong-field ionization. This in turn terminates the optical response of the atom, and therefore limits the atom's contribution to the measured absorption spectrum to a temporal gate between XUV excitation and NIR depletion. By establishing rise/fall times of the gate much shorter than the lifetime of the state, and by controlling the time delay between the XUV and NIR pulses with sub-femtosecond precision, we are able to sample the transient buildup of the 2s2p line.

A complementary study by an independent team of researchers allowed to observe the formation of the Fano resonance in the photoelectron spectrum of the very same transition, which has been reported simultaneously [2].

Figure 1 depicts the formation of the 2s2p spectral line. For small time delays, the measured spectrum is very broad since the XUV-optical response of doubly excited helium contributes only very briefly to the formation of the line. Extending the duration of the gate by increasing the NIR delay the excited atom is allowed to

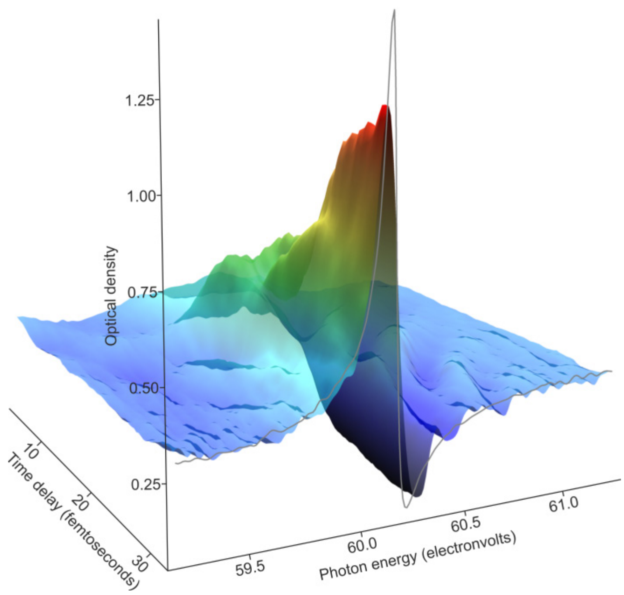

Figure 1. Experimental buildup of the 2s2p absorption line in terms of the time-resolved absorption spectrum (colored surface). The reference (gray line) was recorded with minimum NIR laser influence.

contribute to the absorption spectrum for longer and longer times, causing the resonance line to become more and more pronounced. At the maximum experimentally accessible delay of 32 fs, the observed line shape already closely resembles the natural Fano resonance line. Our measurements are compared with and confirmed by *ab-initio* calculations and an analytic theory of Fano resonances [1].

The presented method of establishing a temporal gate by excitation and laser-driven saturated ionization is also a promising technique for future studies of ultrafast phenomena, e.g. the creation of quasi particles in solids and the emergence of electron—electron or electron—internuclear correlations in molecules.

References

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[1] E-mail: blaetter@mpi-hd.mpg.de

[2] E-mail: thomas.pfeifer@mpi-hd.mpg.de