Two-photon double ionization of noble gases: First application of the intense HHG beamline at Lund Laser Center

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Abstract
We present the results after recent improvements to the high-intensity high-order harmonic beamline at the Lund High-Power Laser Facility, leading to efficient generation of an attosecond pulse train (APT) in argon with 0.8 µJ pulse energy and a spectrum between 17 and 50 eV. After transmission of the full extreme ultraviolet (XUV) bandwidth through the beamline the APT is focused to an intensity of $3x10^{12}$ W/cm^2 in a neon gas target in which we observe two-photon double ionization.

Nonlinear ionization using high-energy photons is very interesting as a tool for probing electron correlation and dynamics of highly excited systems. It allows, within a XUV-pump XUV-probe approach, to observe ultrafast dynamics intrinsic to the target system. So far such experiments have been limited to free electron lasers [1]. But in the last years intense high harmonic generation (HHG) sources reaching sufficient pulse energies have been developed at Forth [2], RIKEN [3] and recently at the Lund Laser Centre [4]. These are uniquely suited to extend the studies of multiple ionization/excitation dynamics using XUV light on the few to sub-femtosecond timescale. This is an intriguing regime for studies of electron correlation effects, due to the existence of competing pathways for double ionization. Two-photon double ionization can be either a direct or sequential process via the singly charge ion. The two pathways are sensitive to the delay between the absorption of the two photons on the attosecond timescale.

We present first results on two-photon double ionization of neon using the full harmonic spectrum from generation in argon (17 eV to 50 eV). To achieve the high flux needed, we generate in a loose focusing regime that allows to use up to 80 mJ energy from a 10 Hz Titanium:Sapphire laser. We measure the generated XUV energy and the XUV

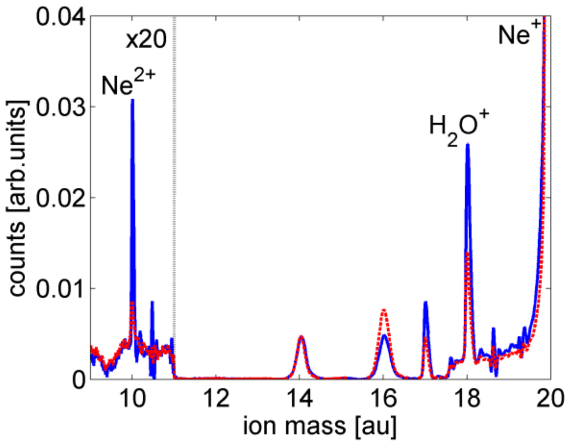

Fig. 1. Ne^{2+} signal for two different XUV photon flux

focal spot size, which gives us an estimation of the intensity in the gas jet target. The whole beamline is optimized for the large bandwidth of the attosecond pulse train so that we can maintain the full spectrum within the Al filter window in the target focus. We detect Ne^{2+} ions and show that the yield is quadratically dependent on the intensity of the XUV pulses [5]. By changing the spectral shape of the generated harmonic radiation, we can change the contribution from the two different double ionization channels and get an indication if the sequential two-photon process or the direct two-photon process is dominant in our conditions.

The observation of two-photon double ionization indicates that the beamline provides a sufficiently high XUV flux to proceed to pump-probe experiments. We are currently implementing a time delay unit in the beamline for performing pump probe experiments. It is based on a split mirror composed of two silica plates mounted on nm-precision piezo actuators. The split mirror setup has been tested using an IR laser, is currently being installed in the beamline in order to perform XUV-pump XUV-probe experiments.

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