Attosecond Spatial Control of Electron Wavepacket Emission Dynamics and Electron-Electron Correlation in Double Ionization

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Abstract

Using orthogonally polarized two-color (OTC) laser fields on neon and coincidence momentum imaging we gain access to the Coulomb influence in single ionization on sub-cycle times, and demonstrate control over the two electron-emission dynamics in double ionization. We show that tuning the relative phase of the OTC fields allows dictating whether the two electrons are predominantly emitted in a correlated or anti-correlated manner.

Angström and attosecond control of free electron wave packets is one of the pinnacles of attosecond science. Orthogonally polarized two-color (OTC) laser fields allow to control the motion of field-ionizing electronic wave packets both in time and space [1]. In OTC pulses time and space are connected and thus an attosecond time scale is established in the polarization plane for both the emitted and the recolliding wave packets [2].

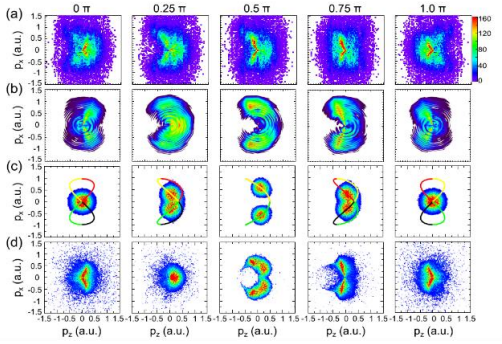

Figure 1. Comparison of experimental (a) and calculated (b)-(d) electron-momentum distributions. (b) Solutions of the TDSE. (c),(d) CTMC simulations without (c) and with (d) inclusion of the ionic potential. Intensity I_{800nm} = I_{400nm} = 1×10^{14} W/cm^2 in all panels.

We report on experiments that use OTC pulses for studying single and double ionization of neon using the COLTRIMS technique. In our experiments OTC pulses were produced by combining an 800 nm laser pulse, frequency ω, and its second harmonic pulse, frequency 2ω, in a collinear geometry at a rate of 5 kHz with an adjustable relative phase, Δφ, between the two colors.

Measured electron spectra correlated with singly ionized neon [Fig. 1] show that the electron emission direction is highly sensitive to the shape of the OTC field, featuring asymmetric emission patterns that vary with Δφ. By exploiting the time to momentum space mapping provided by OTC fields (in combination with simulations) we found [3] that depending on their sub-cycle birth time the trajectories of photoelectrons are affected differently by the ion's Coulomb field. While recollision trajectories are focused, direct trajectories are defocused or strongly scattered. This results in a timing failure of the mapping provided by the OTC filed on the order of $2\pi/(32\omega)$.

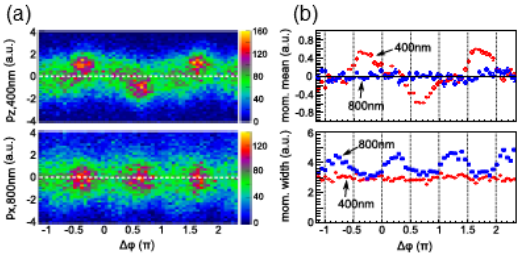

Figure 2. (a) Ne^{2+} p_z momentum (other directions integrated over) as a function of relative phase Δφ (upper panel). Ne^{2+} px momentum (lower panel). (b) Δφ - dependent mean value of p_z (red dots) and p_x (blue squares). lower panel: width of pz (red dots) and p_x (blue squares). Intensity I_{800}nm = I_{400}nm = $(2\pm0.2)\times10^{14}$ W/cm^2.

Turning to non-sequential double ionization (NSDI) with OTC pulses we analyze spectra of the electron sum momentum vector in terms of its mean values and widths along p_x and p_z as a function of Δφ. We find that for those relative phases where the spectral width is large [Fig. 2], the emission happens in a correlated manner with emissions alternately into both hemispheres [4]. In contrary, the small momentum width measured when the total double ionization probability maximizes [Fig. 2] is due to the fact that the two electrons are emitted into opposite $p_{x,800nm}$ hemispheres in a strongly anti-correlated emission scenario [4]. Thus, our measurements demonstrate that by using OTC laser fields it is possible to control the electron-electron (anti-)correlation during NSDI by using Δφ as the control parameter.

References

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