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Higher-order and unconventional low-energy structures

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Synopsis Atoms or molecules exposed to intense near-infrared laser pulses produces a considerable amount of slow electrons forming peaks in measured photo-electron spectra. We show that these peaks, namely the so called low-energy structure (LES), higher-order variants and the very-low-energy structure (VLES), can be understood as different solutions of the same soft-recollision mechanism. Additionally we explain the formation of a "zero-energy structure" ("ZES") as a consequence of the release of Rydberg electrons by a static electric field.

Since the first observation [1] of the so-called low-energy structure — a strong peak at a few eV in the photo-electron spectrum of atoms or molecules exposed to linearly-polarized strong near-infrared laser pulses — a number of further measurements [2, 3, 4, 5] and theoretical investigations [6, 7, 8, 9] have been reported. The initially surprising observations has been reproduced by numerical propagation of the Schrödinger equation [1]. More importantly, in view of revealing the underlying mechanism, it became quickly clear that the observed structures can also be obtained by classical calculations [6].

By means of a proper analysis [7] of the underlying deflection functions, which directly determines the spectrum, it could be shown that *soft recollisions* (see the figure below for a sketch) are responsible for a bunching effect, which results in the formation of peaks. Apart from uncovering the mechanism this analysis revealed that there is a series of peaks, from which the 2nd one was seen in experiment recently [10]. Furthermore, there is another branch which induces a peak at even lower energies. Such a peak has also been found experimentally [4].

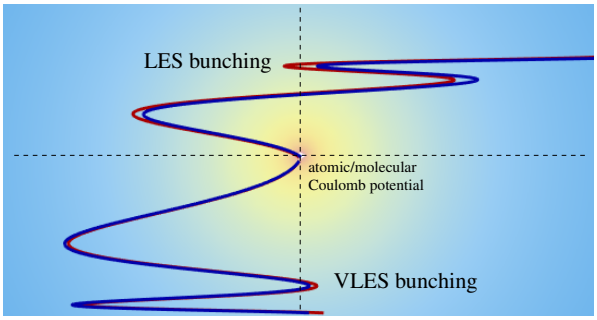

Figure: Characteristic trajectories forming the LES (upper half) and VLES (lower half). Bunching makes trajectories starting a *different* phases (blue vs. red) of the electric field to acquire *identical* final drift momenta.

To disentangle the underlying dynamics we study the peak formation in real time during the laser pulse recording the electron distribution in phase spaces. Neither the LES nor the VLES depend in the simplest non-trivial approximation on details of the potential rendering the respective peak positions universal and only dependent on the averaged vector potential of the laser field.

The recently observed "zero-energy structure" [5] differs from the before-mentioned features. It is shown that the ZES is due the extraction-field induced Stark dynamics of Rydberg electrons, i. e. the release of weakly bound electrons by a static field. The dynamical characteristics of this process are discussed.

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