Time-Dependent B-Spline R-Matrix Approach to Double Ionization of Atoms by XUV Laser Pulses

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Synopsis We present an *ab initio* and non-perturbative time-dependent approach to the problem of double ionization of a general atom driven by intense XUV laser pulses. After using a highly flexible B-spline R-matrix method to generate field-free Hamiltonian and electric dipole matrices, the initial state is propagated in time using an efficient Arnoldi-Lanczos scheme. Example results for momentum and energy distributions of the two outgoing electrons in two-color pump-probe processes of He are presented.

We have developed a general *ab initio* theoretical approach for short-pulse intense laser-atom interactions, which is applicable to complex targets beyond (quasi) two-electron systems. In two recent papers [1, 2], we outlined how field-free Hamiltonian and electric dipole matrices generated with the highly flexible B-spline R-matrix (BSR) [3] suite of codes may be combined with an efficient Arnoldi-Lanczos (AL) time propagation scheme to describe the interaction of short intense laser pulses with a complex atom, leading to multi-photon excitation and *single* ionization. The key points of our method are i) the employment of the BSR code to generate field-free Hamiltonian and dipole matrices, ii) the propagation of the initial state in time by the AL scheme, and iii) the extraction of the physical information by standard projection schemes.

Here we report the extension of this approach to allow for two electrons in the continuum and hence the possibility to describe double ionization processes. In particular, we investigated pump-probe processes involving two XUV laser pulses whose characteristics, including a time delay, are assumed to be controlled separately in the corresponding experiment.

As an example, figure 1 depicts the energy distribution of two escaping electrons from He for the following scenario: Both pulses have a time duration of 10 optical cycles, pulse 1 has a central photon energy of 35.3 eV and a peak intensity of 10^{14} W/cm^2 while the corresponding parameters for pulse 2 are 57.1 eV and 10^{13} W/cm^2, respectively. The time delay between the two pulses is 360 attoseconds. Although sequential double ionization is possible in this scenario, yielding two distinct maxima corresponding to energies around 10 eV and 3 eV for the two outgoing electrons, the central maximum represents a clear signature of a non-sequential double ionization process. This is caused by the lack of time for the He^+ ion to relax into its field-free eigenstates before the second pulse arrives. Qualitatively similar results have recently been obtained by Foumouo *et al.* [4] and Feist *et al.* [5].

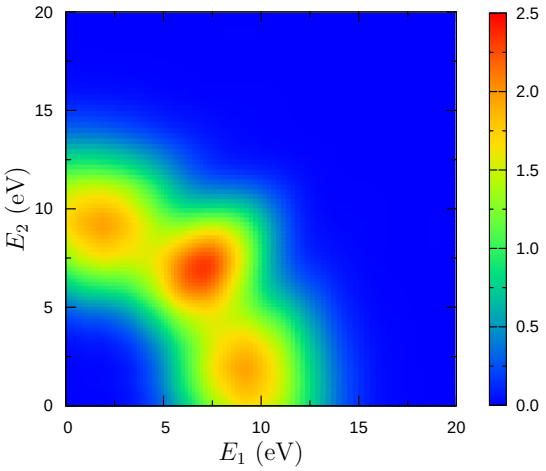

Fig. 1. Energy distribution of two escaping He electrons in a two-color laser pulse (see text). The color bar gives probabilities in multiples of 10^{-4}.

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References

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