Sequential ejection of the two valence electrons of beryllium by ultrashort laser pulses

S. Laulan, M-A. Albert, S. Barmaki[1]

Laboratoire de physique computationnelle et photonique, Université de Moncton, Shippagan, E8S 1P6, N-B, Canada

Synopsis We numerically investigate the sequential two-photon double ionization of beryllium by an ultrashort laser pulse with a photon energy of 19 eV. The two valence electrons can be sequentially ejected via the $Be^+(2s)$ ion or via excitation ionization through the $Be^+(2p)$ ion. We probe the contribution of each of the two possible sequential pathways to the ionization dynamic.

We investigate the two-photon double ionization of the two valence electrons of beryllium atom $Be([1s^2]2s^2)$ subjected to an ultrashort laser pulse with a photon energy of 19 eV, a peak intensity of 10^{13} W/cm^2 and a FWHM time duration of 1.3 fs. To reduce the computational difficulty of the problem, we treated the atom as a two-active electron system with two outer electrons in the field of a frozen core that includes the nucleus and the $1s^2$ inner shell electrons. The frozen $1s^2$ electronic core is represented by a model potential. The electrostatic interaction potential $1/r_{12}$ is treated without any approximation, by using the multipole expansion of the Coulomb repulsion between the two electrons. We solve the time-dependent Schrödinger equation with a spectral method of configuration type that includes the electron-electron correlation in the initial state and during the laser propagation [1, 2].

The sequential two-electron ejection by the laser pulse with $\hbar\omega = 19$ eV photons can occur through two possible pathways as depicted in Figure 1. In the sequential process that involves the $Be^+(2p)$ ion in the intermediate step (Seq(A) process), the absorption of a single photon ejects one of the two electrons with an energy $E_1 = E_{Be([1s^2]2s^2)} + \hbar\omega - E_{Be^+([1s^2]2p)}$ while the second remains bound to the $Be^+(2p)$. The second photon absorption releases the bound electron that leaves with an energy $E_2 = E_{Be^+([1s^2]2p)} + \hbar\omega$. In the sequential process that involves the $Be^+(2s)$ ion (Seq(B) process), the two electrons are ejected with energies $E_3 = E_{Be([1s^2]2s^2)} + \hbar\omega - E_{Be^+([1s^2]2s)}$ and $E_4 = E_{Be^+([1s^2]2s)} + \hbar\omega$.

We extract, at the end of the pulse, the population of the continuum states accessible by the Seq(A) and Seq(B) processes. We present in Figure 2 the contour plots of probability density distribution of the electrons of energies E_1, E_2 ejected following the Seq(A) process and the electrons of energies E_3, E_4 ejected following the Seq(B) process. The two-photon absorption gives the two electrons an excess energy $E_{ex} = E_{Be([1s^2]2s^2)} + 2\,\hbar\omega = 10.5$ eV to carry away. In the Seq(A) process, the two valence electrons are ejected with close kinetic energies ($E_{int} = E_1 - E_2 < 1$ eV) and are hence highly correlated, whereas in the Seq(B) process they are released with distinct kinetic energies and are thus lowly correlated in energy sharing.

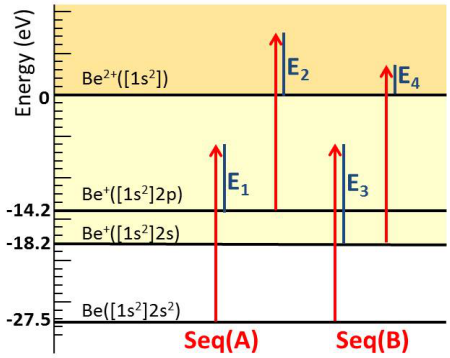

Figure 1. Schematic energy level diagram of the frozen-core beryllium atom, indicating the two possible sequential pathways to double ionize the atom.

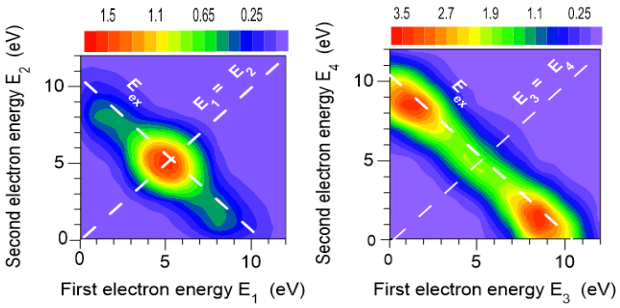

Figure 2. Contour plots of probability density distribution of the two ejected electrons following the Seq(A) (left) and Seq(B) (right) process.

References

[1] S. Barmaki *et al.* 2014 *Phys. Rev. A* **89** 063406

[2] S. Laulan *et al.* 2004 *Phys. Rev. A* **69** 033408

[1]E-mail: samira.barmaki@umoncton.ca