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Synopsis Circular dichroism in the two-color XUV + IR ionization of He^+ is considered theoretically in connection with the recent experiment by Ilchen *et al.* [1]. The sharp decrease of the circular dichroism with increasing intensity of the IR field when the XUV frequency is near the $1s-3p$ resonant excitation is studied. It is confirmed that the main source of the effect is the axial component of the polarizability, which has opposite signs for magnetic substates with opposite projections.

In a recent experiment, intense circularly polarized extreme-ultraviolet (XUV) and near-infrared (NIR) laser pulses were combined to double ionize atomic helium via the oriented intermediate $He^+(3p)$ resonance state [1]. Specifically, the first XUV photon with energy $\omega_{\rm XUV} = 48.37\,{\rm eV}$ from the free-electron laser (FEL) FERMI in Trieste (Italy) ionized helium into the ionic ground state $He^+(1s)$. A second FEL photon with the same energy, in combination with a collinear NIR beam with $\omega_{\rm NIR} = 1.58\,{\rm eV}$ ($\lambda = 784\,{\rm nm}$), subsequently produced He^{2+}. The intensity of the XUV pulse irradiating the He atom was estimated as $I \approx 1.0\times10^{13}\,{\rm W/cm^2}$, while the measurements were performed at two intensities of the NIR pulse, $I_{\rm NIR} = 7.3\times10^{11}\,{\rm W/cm^2}$ and $I_{\rm NIR} = 1.4\times10^{12}\,{\rm W/cm^2}$, respectively. The energy of 48.37 eV corresponds to the $He^+(1s)-He^+(3p)$ transition in the field-free case. Therefore, with the above intensities of the photon beams, corresponding to the multiphoton regime, it is expected that the second ionization proceeds predominantly via the $He^+(3p)$ state with subsequent ionization by absorption of a few NIR photons. The measured circular dichroism is defined as ${\rm CD} = ({\rm P}_+ - {\rm P}_-)/({\rm P}_+ + {\rm P}_-)$, where P_+ and P_- are the angle-integrated photoemission probabilities for circularly polarized pulses with the same (+) or opposite (−) helicity, respectively.

An unexpected result of the experiment was a sharp decrease of the CD of the main photoelectron line from $0.98^{+0.02}_{-0.11}$ to $0.169^{+0.06}_{-0.10}$ when the intensity of the NIR beam increased only twice, from 7.3×10^{11} to $1.4\times10^{12}\,{\rm W/cm^2}$. The experimental result reported in [1] was reproduced by TDSE calculations, but possible mechanisms for the effect remained unclear. It was suspected that the reason for the sharp decrease in the CD is a different helicity-dependent shift of the $He^+(3p, m = \pm1)$ states due to the presence of the circularly polarized NIR field: with increasing NIR intensity a magnetic substate $He^+(3p, m)$ with $m \neq 0$ moves out of resonance faster for co-rotating XUV and NIR fields than for the counter-rotating case. A prerequisite for this phenomenon is the axial component of the polarizability, which has opposite signs for the $He^+(3p, m \neq 0)$ magnetic sublevels, depending on the chirality of the NIR field.

We further investigated this subject theoretically on the basis of the corresponding quasienergy curves and confirmed that the proposed mechanism is the principal source of the fast CD decrease with increasing NIR intensity. The mechanism is illustrated by further TDSE calculations. We also explain the main features of the photoelectron resonance structures as function of the NIR intensity. Detailed results will be presented at the conference.

References

[1] Ilchen M *et al* 2017 *Phys. Rev. Lett.* **118** 013002

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