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Emergence of light-induced states in the few-photon ionization of atomic helium*

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In this joint experimental and theoretical work [1], photoelectron emission from excited states of laser-dressed atomic helium is analyzed. We successfully demonstrate a method that is complimentary to transient absorption (e.g. [2]) for the assignment of light-induced states (LIS). The experiment is carried out at DESY in Hamburg and uses the FLASH2 free-electron laser to produce an extreme ultraviolet (XUV) pulse to which the helium atom is subjected along with a temporally overlapping infrared (IR) pulse in the multi-photon ionization regime ($\approx 10^{12}$ W/cm^2). Analysis of the experiment occurs at the reaction microscope (REMI) end station [3] at FLASH2. The XUV pulse is scanned over the energy range 20.4 eV to 24.6 eV, corresponding to excited states of helium. The resonant, electric dipole-allowed nP states corresponding to a first step of single XUV photon excitation are shown to lead to ionization, independent of whether or not the lasers temporally overlap. However, dipole-forbidden transitions to nS and nD states corresponding to multiphoton (XUV $\pm$ nIR) excitation are observed during temporal overlap. Studying photo\-electron angular distributions (PADs) in the case where the ionization pathway of a LIS is difficult to resolve energetically allows for an unambiguous determination of the dominant LIS. The IR intensity and relative polarization between the lasers are varied to control the ionization pathway. Numerical solutions of the time-dependent Schr\"odinger equation within a single-active electron model with a local potential completely support the experimental findings in this project.

[1] S. Meister *et al.*, Phys. Rev. A **102** (2020) 062809; Phys. Rev. A **103** (2021) in press.
[2] S. Chen *et al.*, Phys. Rev. A **86** (2012) 063408.
[3] S. Meister *et al.*, Applied Sciences **10** (2020) 2953.
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