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Photoionization microscopy: linear polarization rotation effects

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Synopsis Photoionization microscopy (PM) aims at imaging the flux of slow (meV) electrons released by atomic photoionization in the presence of a static electric field. We discuss the rotation of the linear light polarization with respect to the electric field direction. Two-photon ionization out of an $m=0$ initial state allows for the population of $|m|=0,1,2$ Stark states. The resulting $|m|$ -beating effects in the PM images are demonstrated theoretically (in hydrogen atom) and experimentally (in Mg atom). Implications on the applicability of tomographic techniques for slow electrons are also discussed.

The purpose of photoionization microscopy (PM) is the measurement of the electron current probability density j in the case of photoionization of an atom in the presence of a static electric field [1]. The low (meV) energy of the outgoing electrons and the high spatial resolution of PM allows for the observation of the radial quantum interference patterns exhibited by j . For simplifying the analysis of these patterns PM experiments were so far restricted to the excitation of final Stark states of a single magnetic quantum number $|m|$. Here we study the simultaneous excitation of multiple- $|m|$ final Stark states. We examine a two-photon excitation scheme out of an $m=0$ ground state. The employed geometry is shown in Fig. 1(a). The field \mathbf{F} is directed towards the positive z -axis, the laser beam propagates along x -axis and the linear laser polarization vector $\boldsymbol{\varepsilon}$ lies in the yz plane. The angle between $\boldsymbol{\varepsilon}$ and \mathbf{F} is Θ . The 2D position sensitive detector is placed at the macroscopic distance $z_{\text{det}} \ll 0$.

Figure 1(b) shows theoretical images (computed along the lines described in [2]) for several values of Θ and fixed strength F and electron excitation energy E (with respect to the zero-field limit, $E=0$). For $\Theta=0^\circ$ only $m=0$ states are excited, while for $\Theta=90^\circ$ excitation of both $|m|=0$ and 2 is allowed, but the latter dominates the image. The more interesting $\Theta=45^\circ$ image shows a quasi-horizontal nodal line signaling the additional excitation of $|m|=1$ states. Experimental PM images obtained by two-photon ionization of Mg atom reproduce qualitatively these effects. In addition, multiple- $|m|$ excitation is also evident in other observables, such as the total ionization cross section.

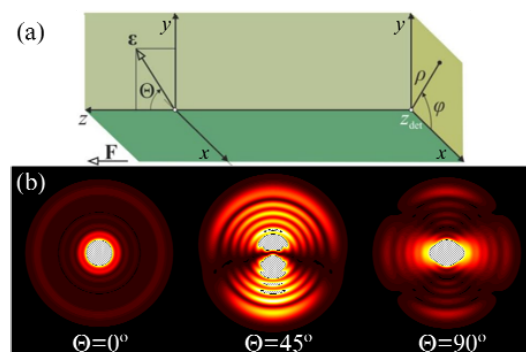


Figure 1. (a) Geometry of the present calculations and experiment. (b) Calculated hydrogenic PM images for $F=680$ V/cm, electron excitation energy $E \approx -15.3$ meV and different angles Θ . Linear colorscale, common for all images. Intensity cuts allow for better visualization of the Θ -dependent radial quantum interferences.

Note finally that the Θ -dependence of the relative contributions of different- $|m|$ states poses new challenges on the applicability of tomographic reconstruction techniques [3] when meV electrons are involved, because these techniques assume the reconstruction of a *single* 3D object, rotated (by rotating $\boldsymbol{\varepsilon}$) and projected on the 2D detector by a field \mathbf{F} assumed to be weak enough that its influence can be ignored.

References

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