Spin-Orbit Dynamics and a Relativistic Surprise

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Spin is often ignored in strong-field physics, as it couples non-dynamically to the initial states [1], while spin-resolved measurements have only recently become possible [2]. Spin-orbit dynamics are neglected in strong-field ionization, as the photoelectron energies appear too low. However, long wavelengths used in imaging process such as laser induced electron diffraction (LIED), means that spin dynamics could play a role, through high-energy rescattering.

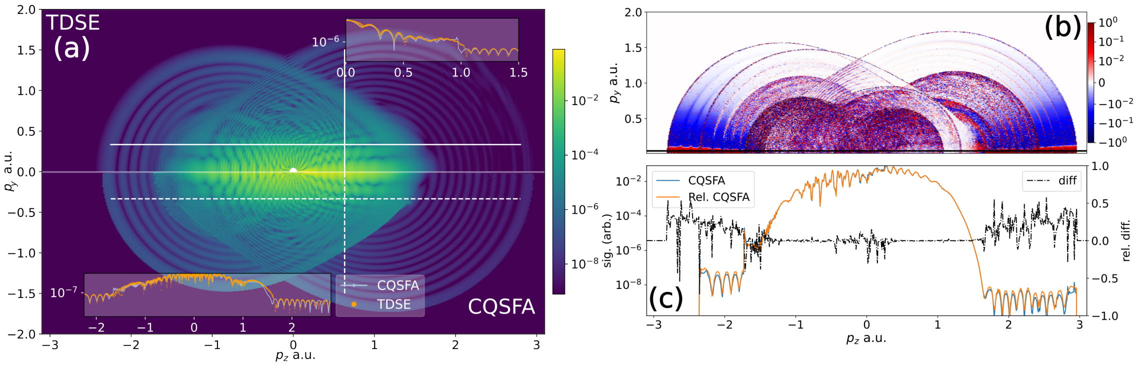

Figure 1: Photoelectron momentum distribution (PMD) for H at 1600 nm, 2.5×10^{13} W/cm^2 for 4-cycle sin^2 pulse. (a) Comparison of CQSFA with TDSE [3]. (b) Difference between relativistic and non-relativistic CQSFA-computed PMD. (c) Cross-section taken from (b).

Using the flexible Coulomb quantum-orbit strong-field approximation (CQSFA) path-integral formalism [4], we include all terms from the fine-structure Hamiltonian. This enables a semi-classical treatment of spin, which is the first of its kind in strong-field physics. We confirm the validity by comparing the non-relativistic model without spin to a TDSE code, with exceptional agreement Fig. 1. Then we are able to show that the most energetically rescattered electrons, undergo huge momentum transfer and briefly reach relativistic velocities. We probe these effects and show that they yield significant differences at 1600 nm wavelengths, see Fig. 1. We also explore dynamical spin and spin-orbit coupling effects and find they are vastly over estimated, if the relativistic corrections are not included, otherwise the effects are quite subtle.

We make a key step in accurate modeling of strong-field ionization at longer wavelengths and highlight important implication for imaging processes such a LIED or photoelectron holography.

References

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