Exploring symmetries in ultrafast photoelectron holography with two-color linearly polarized fields

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Synopsis We investigate ultrafast photoelectron holography in bi-chromatic linearly polarized rω-sω fields of commensurate frequencies and relative phase ϕ, focusing on the existing symmetries and for which parameters they are kept or broken. Using group theory, saddle-point methods and the Coulomb quantum-orbit strong-field approximation, we discuss the symmetries of the ionization times and of the driving field for r+s even and odd, provide general expressions and analyze the consequences on the prominence and contrast of specific holographic patterns, such as the fan, the spider and the spiral.

Due to the high electron currents and ultrafast time scales involved, photoelectron holography has established itself as a powerful imaging tool [1]. However, there are several open questions about how different types of holographic interference behave in the presence of tailored fields and/or more complex targets, especially in the presence of residual binding potentials. In this work, we investigate photoelectron holography in bichromatic linearly polarized fields using group-theoretical methods, with emphasis on existing symmetries and for which parameters they are kept or broken [2].

We show that, for a rω-sω field, there are three relevant symmetries: the well-known half-cycle symmetry, which is broken for r+s odd, and reflections around the field crossings and maxima, which may or may not be kept depending on how both waves are dephased. The three symmetries are always present for monochromatic fields, while for bichromatic fields this is not guaranteed, even if r+s is even and the half-cycle symmetry is retained. Breaking the half-cycle symmetry automatically breaks one of the other two, while if it is retained, the other two symmetries are either both kept or broken. We analyze how this affects the ionization times and saddle-point equations. We provide a general expression for what relative phases ϕ the symmetries are retained, for an arbitrary (r,s) field, which can be generalized to n-color fields.

As an application, we compute photoelectron momentum distributions for bichromatic fields with the Coulomb Quantum Orbit Strong-Field Approximation (CQSFA) [3] and assess how holographic structures such as the fan, the spider and interference carpets behave, focusing on the reflection symmetries. We discuss how the Coulomb distorted orbit classification changes with the inclusion of the weak second driving wave, taking into consideration the field gradient, extrema and their relation with the broken symmetries. The features encountered can be traced back to the field gradient and amplitude affecting ionization probabilities and quantum interference in different momentum regions.

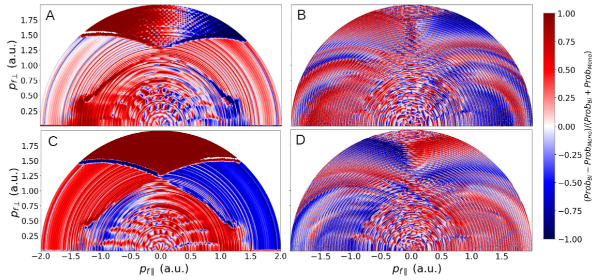

Figure 1. Normalised difference between the transition probability for a (1,2) bichromatic field and its monochromatic counterpart, computed for hydrogen. The monochromatic field has wavelength 800m and intensity 7.0 x 10^{14}W/cm^2. The upper and the bottom row were calculated for the relative phases ϕ = 0 and ϕ = π/4 respectively, and the left and the right columns correspond to the CQSFA and the time-dependent Schrodinger equation (TDSE), respectively.

We hope our study will pave the way for orbit-based investigations in tailored fields for which the residual binding potential and the driving laser field are included on equal footing.

References

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