Optical Tunnelling Without a Barrier? Tracking Ionization Events in a Bichromatic Field

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Tunnel ionization is a central phenomenon of strong-field physics involved in essentially all intense laser-matter interactions. Strong-field ionization in the tunnelling regime takes place as discrete events which the strong-field approximation describes via saddle points that give rise to the well-established formalism of quantum orbits.

In this work we consider the nonadiabatic above-threshold ionization of a 1D model atom by a bichromatic field. We pose the question of what happens to these ionization events (i.e., saddle points of the action) when we gradually replace a monochromatic beam with its second harmonic (Figs. 1(a) through (d)). Over this replacement, the number of ionization events per cycle of the fundamental changes from two to four. We therefore ask: Which ones are new? And, how did they get there?

The transition comprises two interesting features. Firstly, we identify configurations in which the saddle points describing ionization events fully coalesce in a caustic (triangle in Fig. 1(b)) and form a branch point. Here, continuous labelling of saddle points becomes impossible, the saddle point approximation breaks down and instead uniform approximations have to be employed. In addition, the saddle-point coalescence implies a nontrivial topology for the saddle-point set, which we will explore in detail.

More remarkably, we find that the new saddle points start contributing to the ionization yield long before the field changes sign (Fig. 1(c)). In other words, we present a tunnelling ionization event which occurs when the instantaneous electric field is zero, and hence at a time when there is no barrier. This results purely from a nonadiabatic picture of tunnelling, and presents a situation which cannot be modelled within the semi-classical picture of optical tunnel ionization.

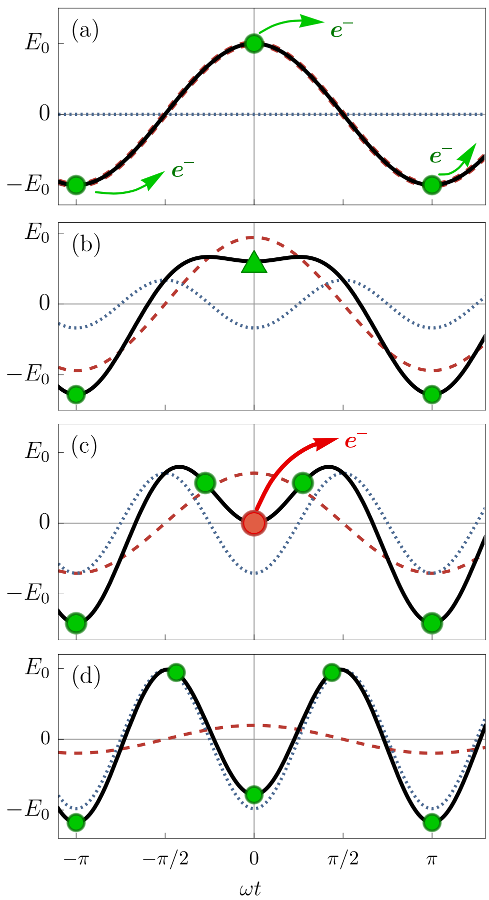

Figure 1: Total electric field formed by superposing a fundamental with its second harmonic. Green disks represent ionization events and the triangle marks the coalescence of solutions. The red disk in (c) shows a tunnelling ionization event when the electric field is zero and there is therefore no tunnelling barrier.

References

[1] Weber A and Pisanty E 2023 *in preparation*