Multiphoton Ionization and Photoinjection Rates from *Ab Initio* Simulations

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Strong-field ionization and photoinjection, leading to the formation of electron wave packets, are central to attosecond science. The highly nonlinear nature of these processes confines them to sub-half-cycle time intervals near the middle of a few-cycle linearly polarized laser pulse [1]. This temporal confinement is central to ultrafast techniques such as nonlinear photoconductive sampling [2] and solid-state TIPTOE [3], which enable optical-field-resolved measurements with a petahertz bandwidth [4]. Advancing these techniques requires a deeper understanding of photoinjection dynamics with the following key questions: What is the duration of a sub-half-cycle photoinjection event? How many carriers are photoinjected by each half-cycle? What are the optimal conditions for single subfemtosecond photoinjection within feasible optical waveforms?

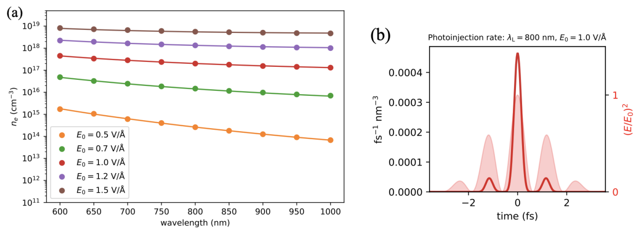

Figure 1: Photoinjection in SiO_2 by single-cycle pulses. (a) The input data, represented by the full circles, consists of concentrations of conduction-band electrons, n_e, obtained in 45 *ab initio* simulations for various values of the pulse's central wavelength, λ_{L}, and peak electric field, E_0. With 9 adjustable parameters, GASFIR accurately reproduces all the input data. (b) Retrieved photoinjection rate (solid curve) for $\lambda_{\mathrm{L}} = 800$ nm and $E_0 = 1$ V/Å

Answering these questions hinges on the availability of accurate and reliable rates of strong-field ionization. We re-examine the problem of defining and calculating such rates by asking: "Can we reconstruct ionization dynamics from ionization probabilities obtained for a set of different laser pulses?" We demonstrate that this is possible, but it requires an ionization model that is not limited by the quasistatic approximation and combines the flexibility required for matching ab initio input data with constraints imposed by the physics of nonlinear light-matter interaction. We present such a model, which we call a General Approximator for Strong-Field Ionization Rates (GASFIR). We have validated this approach for atomic gases and wide-bandgap solids.

References

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