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High Harmonic Generation and Strong Field Dynamics in a Wannier Basis

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High harmonics generation (HHG) in solids is a decade old field and yet the understood mechanisms leading to HHG is still an incomplete picture. They fail to capture real-space motion like lateral tunneling ionization. We investigate theoretically high harmonic generation in solids using a localized basis of Wannier states. Wannier states are localized wavefunctions overcoming the infinite nature of Bloch states in real space. We develop a semi-classical model for interband generation, which allows the characterization of HHG in terms of classical trajectories. Our semi-classical approach is in quantitative agreement with quantum calculations. The success of the model completes the single-body picture for HHG in semiconductors. It reveals a complete picture of the mechanisms shaping HHG. Both the ionization and recombination events are altered by real-space processes that are intuitively explained by the Wannier-Stark ladder. An electron tunnel ionized by a strong electric field undergoes a diagonal transition on an energy vs position diagram. The angle of that transition depends on two competing terms: the reduced energy gap due to the Stark effect which favours more horizontal transition and the dipole coupling matrix element, which favours vertical transition. We find that for the recombination, the electron prefers to align in real space with its parent hole. The importance of our semi-classical theory extends beyond HHG; it enables modeling of dynamic processes in solids with classical trajectories, such as for coherent control and transport processes, potentially providing better scalability and a more intuitive understanding.

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