Attosecond electronic transport on atomic scales at low temperatures

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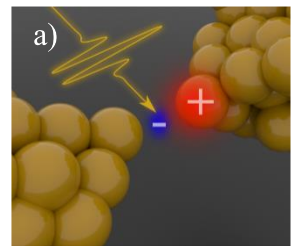
Atomic-scale tunneling junctions combined with attosecond resolution in the time domain by phaselocked single-cycles of light offer an access to ultrafast dynamics in electron-electron interaction and quantum transport phenomena. Exceedingly, the combination of the nonlinear tunneling junction and the symmetry break of a phaselocked single-cycle laser pulse (Fig. 1a) is contributing the fundamental feature to optically driven net currents.



In our previous experiments at room temperature, the relation between intensity, carrier envelope phase of the single-cycle pulse and the net current at the tunneling junction has been investigated [1,2]. Nevertheless, phonon-assisted processes, changes of the atomic structure and contaminations of the junction might establish features in the transport characteristic which complicate the physics involved.

In this work, we implemented a nanoantenna with a tunneling junction consisting of two atomic-sharp tips in an evacuated environment and at a temperature below 5 K. The optically driven tunneling current is depicted as a function of the Keldysh parameter

$$\gamma \propto \frac{1}{E_0},$$

where E_0 denotes the peak electric field of the biasing pulse. Consistent with Keldysh theory, the development is continuous with a smooth transition from multiphoton emission transport, relevant for small electric field amplitudes, to light-induced tunneling transport at high pulse intensity.

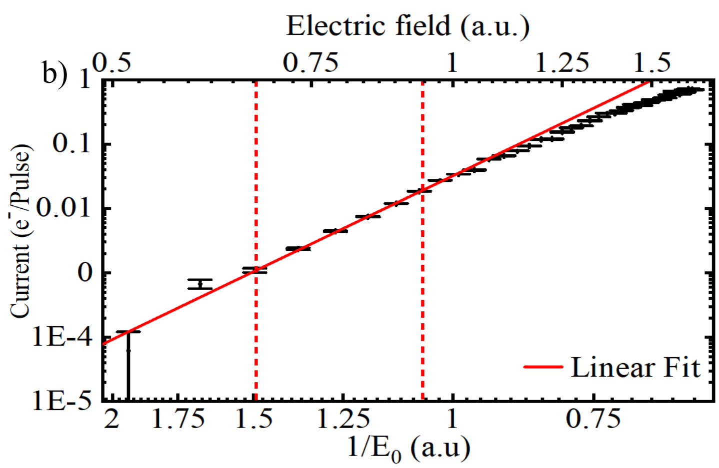


Fig. 1: *(a) Sketch of light-driven charge transport in atomic-scale tunneling junction. (b) Optically induced electron current per pulse versus peak electric field amplitude.*

In conclusion, our results extend the accessible parameter range for ultrafast electron transport measurements to atomic-scale tunneling junctions at kryogenic temperatures biased on sub-cycle optical timescales. An adiabatic transition from multiphoton to field-induced tunneling transport is found.

References:

[1] T. Rybka, *et al.*, *Nature Photonics* **10**, 667 (2016)
[2] M. Ludwig, G. Aguirregabiria, *Nature Physics* **16**, 361 (2020)