

Quantum Interference Effects in the Ultrafast Dynamics of a Low Dimensional Mott Insulator

Simon Wall¹, Daniele Brida², Stephen Clark³, Henri Ehrke^{3,4},
Dieter Jaksch³, Hiroshi Okamoto⁵, Giulio Cerullo², Andrea
Cavalleri^{3,4}

¹*Dep. of Physical Chemistry, Fritz Haber Institute of the Max Planck Society,
Berlin, Germany*

²*IFN-CNR, Dipartimento di Fisica, Politecnico di Milano, Italy*

³*Department of Physics, Clarendon Laboratory, Oxford UK*

⁴*Max Planck Research Group for Structural Dynamics, University of Hamburg,
CFEL, Germany*

⁵*Department of Advanced Materials Science, University of Tokyo, Japan*

The competition between electron localization and de-localization in doped Mott insulators underpins the physics of strongly correlated electron systems. Photo-excitation, which re-distributes charge among different sites, can be used to control this cooperative many-body process on the ultrafast timescale. To date, time-resolved studies have mostly been performed in solids in which other degrees of freedom, such as lattice and spin-orbital excitations, come into play. However, the underlying dynamic physics of ‘bare’ electronic excitations has remained out of reach. To date, quantum coherent many-body dynamics have only been detected in the controlled environment of optical lattices, where the dynamics are slower and lattice excitations are absent. By using nearly-single-cycle, sub-10-fs pulses in the near-infrared, we have measured quantum-coherent excitations in the organic salt ET-F₂TCNQ, a prototypical one-dimensional Mott insulator with narrow bandwidth and weak electron-phonon coupling. After photo-doping, a new resonance appears on the low-energy side of Mott gap, which oscillates with a 25 THz frequency. Time-dependent simulations of the Hubbard Hamiltonian reproduce the oscillations at the experimentally observed frequency, showing that electronic delocalization occurs through quantum interference between bound and ionized holon-doublon pairs.