Atom optics simulator of lattice transport phenomena

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We report on a novel scheme for studying lattice transport phenomena, based on the controlled momentum-space dynamics of ultracold atomic matter waves. In the effective tight binding models that can be simulated, we demonstrate that this technique allows for a local and time-dependent control over all system parameters, and additionally allows for single-site resolved detection of atomic populations. We demonstrate full control over site-to-site off-diagonal tunneling elements (amplitude and phase) and diagonal site-energies, through the observation of continuous time quantum walks, Bloch oscillations, and negative tunneling. These capabilities open up new prospects in the experimental study of disordered and topological systems.