Floquet engineering of tight binding Hamiltonian in momentum space lattices

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Recently, significant efforts have been devoted to simulating condensed matter systems using cold atom experiments. Floquet engineering provides a powerful framework for realizing momentum-space lattices (MSL), which are well suited for emulating a wide range of tight-binding models [1].

In this talk, I present a generalization of such momentum-space lattices based on the quantum resonances of the kicked rotor model [2]. I will describe how modulation functions for the phase and amplitude of the lattice can be designed to simulate various tight binding models. First-order time-dependent perturbation theory and optimal control algorithms are employed to precisely tune the two key parameters of the models: the tunneling coefficients and the on-site energies.

We have implemented these concepts in our experimental setup with a Rubidium-87 Bose-Einstein condensate. This approach has enabled us to explore various aspects of the Rice-Mele model—including quantum walks, edge states on topological defects, and double energy band phenomenology—as well as other models with different periodicities. Furthermore, by introducing an effective force, we directly observed Bloch oscillations in momentum space within the first-nearest neighbor tunneling lattice.

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References

[1] B. Gadway, Phys. Rev. A, 92 (2015) 043606 .
[2] F. Izrailev, D. Shepelyanskii, THEOR MATH PHYS-ENGL TR, 43 (1980) 553-561

Figures

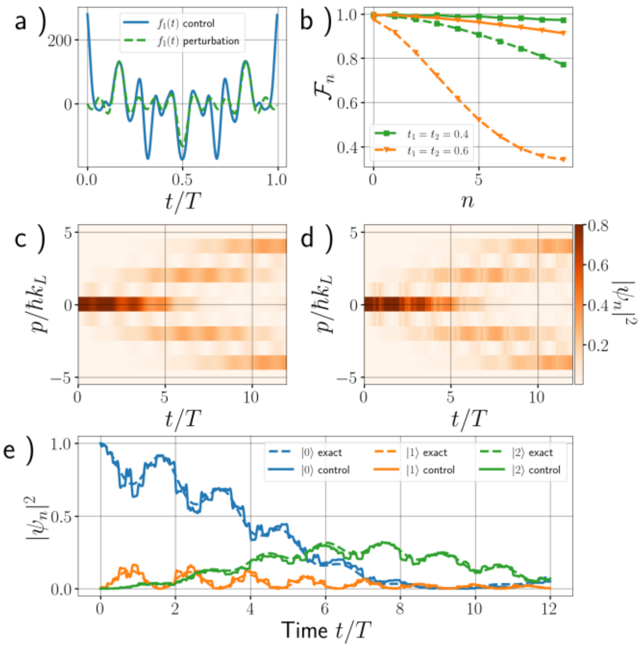

Figure 1: Modulation function, fidelity and quantum walk in a Rice-Mele model in MSL (exact vs optimal control).

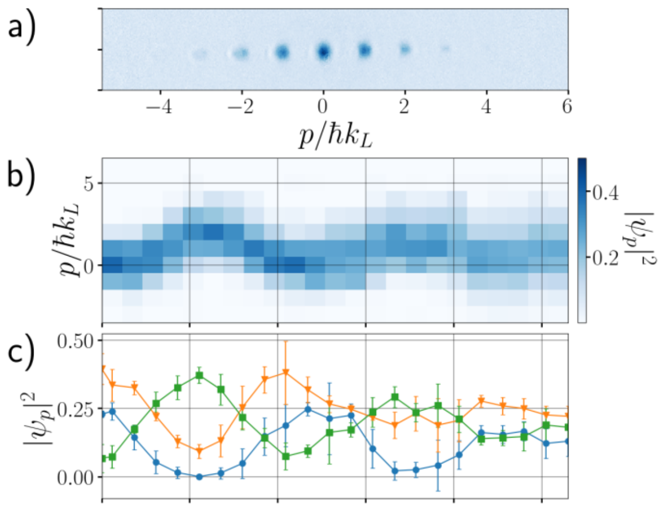

Figure 2: Experimental measurement of a Bloch oscillation in MSL.