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Discrete-Time Quantum Walks in Momentum Space

Abstract: Quantum walks differ from their classical analogue by the fact that the state of the walker is in a superposition of positions. This is the consequence of applying at each step of the walk a 'coin toss' operator that creates a superposition of two quantum states in an internal degree of freedom, followed by a conditional position displacement depending on this internal state. In our case, the walkers are atoms of a spinor Bose-Einstein condensate kicked by a periodic optical lattice, for whose description we can exploit the quantum kicked rotor dynamics. The kicks will act as the conditional displacements. Fora simple zero-momentum initial state, the walker will just symmetrically diffuse in momentum space. We break the spatial-temporal symmetry by using a directed ratchet motion. The direction of the movement is controlled by the sign of the kicking potential. The sign difference in the kick potential corresponds to a sign difference in the detuning of the kicking laser between two hyperfine levels of the ground state. Additionally, we consider the conditions for quantum resonance to be fulfilled, so that the free evolution of the atoms vanishes, and we only have changes in the momentum at discrete moments in time. The mixing of the internal states is in practice performed with microwaves. A concrete realization of this scheme with a Bose-Einstein condensate of Rubidium atoms is currently worked out at Oklahoma [1]. We investigate how the analytic theory of the temporal evolution of the quantum kicked rotor at quantum resonance can be transferred to two internal spin states that are mixed at each step.

References

[1] G. Summy and S. Wimberger, Phys. Rev. A 93, 023638 (2016)