Quantum resonances in ac driven quantum ratchets

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Ratchet or rectification phenomena appear in many different fields ranging from nanodevices to molecular biology [1, 2]. Recent experimental realizations of forced ratchets in weakly dissipative optical lattices [3, 4] have shown a good agreement with the classical model of a Hamiltonian ratchet [5, 6]. With a similar setup one can approach to the quantum regime by using far detuned standing waves. This may lead to new effects, especially for the current rectification, that are not present in the classical counterpart. Hence we study the quantum analog of a driven classical ratchet system [5, 7], where the generation process of a directed current involves a biharmonic driving force. We study the asymmetry properties of the Floquet states as a function of the relative phase of the biharmonic force. This asymmetry induces a nonzero directed current for a plane wave with zero momentum as initial condition. The average current depends on the relative phase as in the classical limit [7]. One new peculiarity of the quantum forced ratchet is the strong dependence on the initial phase of the ac-field. Interestingly, quantum resonances that appear due to avoided crossings between Floquet states, enhance the transport. These resonances persist independently on the initial phase. Our results could be relevant for the experimental realization of quantum ratchets with cold atoms.

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