Quantum-resonance ratchets: experimental realizations and prediction of stronger effects

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Classical low-dimensional Hamiltonian systems may exhibit the chaotic *"ratchet effect"* only for a *mixed* phase space. However, the corresponding quantized systems generally feature significant quantum-ratchet effects also under *full-chaos* conditions. We shall consider here particularly strong such effects, i.e., quantum momentum currents (*ratchet accelerations*), occurring in kicked systems for *quantum-resonance* (QR) values of a scaled Planck constant. These effects were studied in work [1] for kicked-rotor systems and variants of them under most general conditions.

Experimental realizations of simple QR ratchets in Ref. [1] were performed in works [2,3] using atom-optics methods. Bose-Einstein condensates (BECs) were exposed to a pulsed standing light wave approximating a *completely symmetric* (cosine) kicking potential. Also, the BEC was initially prepared in a superposition of two momentum states corresponding to a state with well-defined *point symmetry*. Despite these symmetries and in accordance with predictions in Ref. [1], a QR ratchet effect was observed due to the *relative asymmetry* associated with the generic non-coincidence of the symmetry centers of the symmetric potential and the initial state [3]. The experimental results were found to agree well with theoretical ones [1] after taking properly into account the finite quasimomentum width of the BEC; in particular, this width was shown to cause a suppression of the ratchet acceleration for exactly resonant quasimomentum, leading to a saturation of the directed current [3].

Quite recently [4], a new, *statistical* approach to the quantum-chaotic ratchet effect was proposed, featuring natural initial states that are *phase-space uniform* with the *maximal possible* resolution of one Planck cell. It was shown that the average strength of the effect over these states, under QR conditions, is *significantly larger* than that over usual momentum states or superpositions of few momentum states such as those used in the experiments above. By increasing the number of momentum states in the superpositions, the average strength of the effect gradually increases, approaching that for the maximally uniform states. These results were obtained for the kicked Harper models which are equivalent to kicked harmonic oscillators. The latter systems, as well as superpositions of many momentum states, are experimentally realizable. Thus, the very strong quantum ratchet effects predicted should be observable in the laboratory.

References:

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