Multiple-period Floquet states and time-translation symmetry breaking in quantum oscillators

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Quantum nonlinear oscillators subject to periodic driving have received substantial attention in the last years, e.g., in the context of nano-mechanical, superconducting, and atomic systems. Their dynamics is described in terms of Floquet states based on the fact that a driven system has discrete time-translation symmetry with the period of the driving. Recently, the breaking of discrete time-translational symmetry has attracted much interest, known as "time crystallization". Nonlinear oscillators provide an ideal platform for studying this effect as they are intermediate between large closed systems and dissipative systems, which both display the symmetry breaking, but have qualitatively different dynamics. Here we show that this phenomenon may also occur in a quantum coherent regime and specifically discuss nonlinear quantum oscillators driven close to three times their eigenfrequencies [1]. This class of oscillators exhibits features which seem to be generic beyond linear and parametric driving. It turns out that time-translational symmetry breaking occurs due to crossings of quasi-energy levels originating from geometric phases. These phases depend on the driving strength and are directly determined by the topology of the corresponding quasi-energy fields. The role of dissipation is also addressed, where with varying detuning a reentrant kinetic transition appears between states of different time-translational symmetry. These findings can be experimentally explored particularly in circuit QED set-ups with voltage biased Josephson junctions [2-4].

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