Symmetry breaking in a parametrically modulated quantum oscillator

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A weakly damped nonlinear oscillator modulated close to twice its eigenfrequency has two stable states, which have the same vibration amplitudes but opposite phases. The states are equally populated due to classical or quantum fluctuations. This is reflected by the two symmetric wells of the rotating wave energy g (Fig. 1).

Coupling to a thermal reservoir leads to transitions between the states of the system. For zero temperature the energy of the system decreases in each transition. However, the rotating wave energy may decrease or increase with unequal probabilities. Relaxation corresponds to a decrease of g towards either of the two classical stable states which are at the minima of g. Due to the finite probability of an increase of g during a transition the relaxation is accompanied by diffusion. Ultimately, this diffusion results in overbarrier transitions between the wells [1, 2].

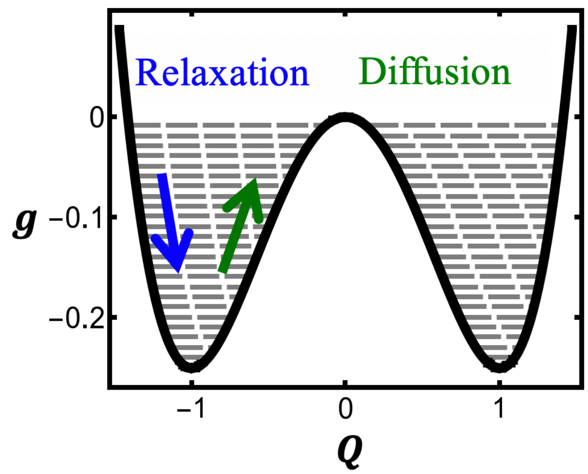

Fig. 1: *Relaxation and Diffusion over the rotating wave energy states.*

An extra force at half the modulation lifts the symmetry of the wells and therefore the symmetry of the states, generally (Fig. 2). In the classical regime the change of the transition rates between the two wells due to such an extra force has already been investigated [3,4].

We study how the symmetry breaking effects the transitions between the states in the quantum regime. As we show, a significant change of the state populations can take place already for a weak extra force. The mechanism is the force-induced change of the rates of interstate switching. The change is exponential in the ratio of the force amplitude to the appropriately scaled quantum length. It is large even where the effect of the force on the mean-field oscillator dynamics is small. This provides a mechanism for a transition to the time-crystal phase in coupled quantum oscillators.

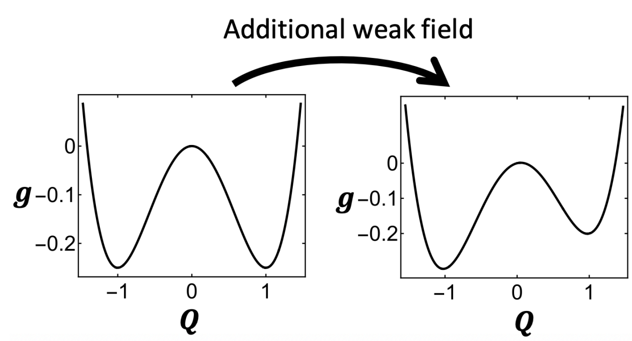

Fig. 2: *Symmetry breaking of the rotating wave energy g due to an extra force at half the modulation frequency.*

References:

[1] M. Marthaler *et al*., Phys. Rev. A **73**, 042108 (2006)
[2] V. Peano *et al*., New J. Phys. **16**, 015011 (2014)
[3] D. Ryvkine *et al*., Phys. Rev. E **74**, 061118 (2006)
[4] I. Mahboob *et al*., Phys. Lett. **96**, 213103 (2010)