Spontaneous Symmetry Breaking in Coupled Nanomechanical Electron Shuttles

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Spontaneous symmetry breaking is one of the fundamental ideas in elementary particle physics when unified gauge field theories are applied, e.g. breaking the gauge symmetry leads to the difference in the electromagnetic and the weak interaction. Commonly, one refers to a classical mechanics example to visualize symmetry breaking, such as a thin bar under pressure from both its clamping points. Obviously, the equations of motion are invariant around the symmetry axis along the beam. Once the force reaches a critical level the compressed bar will buckle and thus break the initial symmetry. Although, in the buckled state the bar will be in an energetic minimum, the symmetry of this configuration is reduced. From a quantum mechanical point of view the key question is into which of the many degenerate energetic minima the compressed bar will collapse to and what kind of fluctuation will have caused this transition. Naturally, for a large bar governed by classical mechanics it would be hard to associate the buckling with a quantum mechanical states. The situation changes drastically when one considers quantum electro-mechanical systems (QEM), such as buckled nanomechanical beams which have been theoretically discussed by Carr~{\it et al.}. In other words nanomechanical devices have the potential to address fundamental quantum mechanics. We present spontaneous symmetry breaking in a nanoscale version of a setup prolific in classical mechanics: two coupled nanomechanical pendulums. The two pendulums are electron shuttles fabricated as nanopillars and placed between two capacitor plates in a homogeneous electric field. Instead of being mechanically coupled through a spring they exchange electrons, i.e. they shuttle electrons from the source capacitor plate to the 'drain plate'. Thus a direct current will flow over both islands, if a small bias voltage is applied {\it and} if both nanopillars are in mechanical resonance.