Quantum Synchronization Blockade: Energy Quantization Hinders Synchronization of Identical Oscillators

JournalArticle (Originalarbeit in einer wissenschaftlichen Zeitschrift)

ID 4493556
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Year 2017
Title Quantum Synchronization Blockade: Energy Quantization Hinders Synchronization of Identical Oscillators
Journal Physical Review Letters
Volume 118
Number 24
Pages / Article-Number 243602
Classically, the tendency towards spontaneous synchronization is strongest if the natural frequencies of the self-oscillators are as close as possible. We show that this wisdom fails in the deep quantum regime, where the uncertainty of amplitude narrows down to the level of single quanta. Under these circumstances identical self-oscillators cannot synchronize and detuning their frequencies can actually help synchronization. The effect can be understood in a simple picture: Interaction requires an exchange of energy. In the quantum regime, the possible quanta of energy are discrete. If the extractable energy of one oscillator does not exactly match the amount the second oscillator may absorb, interaction, and thereby synchronization, is blocked. We demonstrate this effect, which we coin quantum synchronization blockade, in the minimal example of two Kerr-type self-oscillators and predict consequences for small oscillator networks, where synchronization between blocked oscillators can be mediated via a detuned oscillator. We also propose concrete implementations with superconducting circuits and trapped ions. This paves the way for investigations of new quantum synchronization phenomena in oscillator networks both theoretically and experimentally.
Publisher AMER PHYSICAL SOC
ISSN/ISBN 0031-9007
edoc-URL https://edoc.unibas.ch/68061/
Full Text on edoc No;
Digital Object Identifier DOI 10.1103/PhysRevLett.118.243602
PubMed ID http://www.ncbi.nlm.nih.gov/pubmed/28665640
ISI-Number 000403341900004
Document type (ISI) Journal Article