
Novel manifestations of the Josephson effect in a high-impedance environment

Résumé

Dynamics of Josephson junctions can be heavily influenced by the properties of the embedding electrical circuit. In particular, a low-impedance circuit would favor small fluctuations of the superconducting phase-difference variable, leading to semi-classical dynamics. A high-impedance case is more intriguing, as it is required to observe deviations from the semi-classical dynamics. We introduce two recently studied cases, a junction shunted by a (very) high inductance and a junction embedded into an ideal Ohmic environment of a high wave impedance transmission line. The former circuit is known as Blochonium (quasicharge qubit), a dual of transmon qubit, the low-energy spectrum of which can be understood by replacing the Josephson element with a non-linear (periodic in charge) capacitance. The latter circuit generally belongs to a class of many-body problems and cannot be readily simulated on a computer. We show that the junction scatters microwaves in a high-impedance transmission line elastically and inelastically. The sign of the elastic phase-shift changes as the line's wave impedance crosses resistance quantum for Cooper pairs (6.5 kOhm), that is to say the junction changes from inductance to capacitance. This behavior is in agreement with a dissipative localization quantum phase transition (Schmid transition), predicted for a particle in a periodic potential with friction three decades ago. Inelastic scattering is a more subtle effect, which has never been encountered in circuit QED. It makes the junction act as an ideal resistor at the critical wave impedance, a property required to continuously transform an inductance into a capacitance at any finite frequency.