Direct Transition from Quantum Escape to a Phase Diffusion Regime in YBaCuO Biepitaxial Josephson Junctions

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The remarkable development of superconductive systems in the field of quantum information processing and the expertise gained on manipulating coherent entangled states and different coupling regimes with the environment have boosted research on several complementary aspects of coherence and dissipation. Because of their design scalability and their flexibility in controlling the level of damping, Josephson systems have proven to be a fantastic test bench for studying fundamental physics problems such as the quantum superposition of alive and dead states of Schrodinger's cat, the behavior of an artificial atom in cavity quantum electrodynamics experiments, or measurements of quantum coherence in macroscopic systems. Dissipation encodes the interaction of a quantum system with the environment and regulates the activation regimes of a Brownian particle.

In this Letter, we demonstrate a direct transition from a running state, obtained following a quantum activation, to diffusive Brownian motion in YBaCuO Josephson Junctios (JJs) (see Fig. 1).

Multiple retrapping processes in subsequent potential wells characterize phase regimes where diffusive phenomena play a relevant role. The relevant parameters driving the occurrence of these phenomena are the operational temperature T, the damping factor Q, and the critical current Ic. The various operation scenarios for a JJ can be condensed in a phase diagram (see Fig. 2). By spanning the (E_J, k_BT) parameter space it is possible to engineer all different regimes ranging from phase diffusion (PD) and thermal activation (TA) to macroscopic quantum tunneling (MQT). MQT takes place not only for low values of dissipation (Q _>>1), but also for intermediate levels of dissipation (1<Q<5). We explore a new region of this phase diagram, made available by the different ranges of Ic and of the standard deviation of the switching distribution offered by YBaCuO biepitaxial junctions when compared with most low temperature superconductor JJs. The moderately damped systems are particularly significant and promising to address and quantify interactions of a quantum system with the environment which is, apart from the its intrinsic interest for fundamental physics, a cornerstone for the development of whatever quantum hybrid technology.

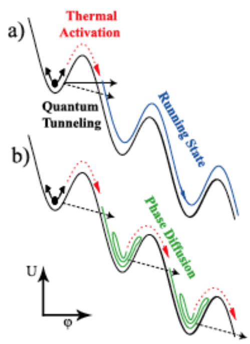

Fig. 1
(a) Thermal (red dashed line) or quantum activated escape in the tilted periodic potential. Quantum escape is represented for both very low ideal (Q _>> 1, continuous black line) and high (1<Q<5, dashed black line) levels of dissipation, respectively. (b) Diffusive motion due to multiple escapes and retrapping in subsequent potential wells.

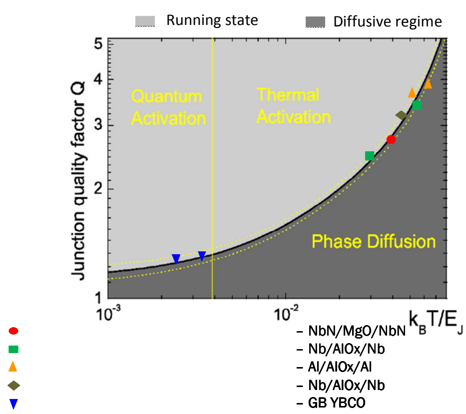

Fig. 2
($Q, k_BT/E_J$) phase diagram, showing the various activation regimes. The transition curve (black line) between the PD regime and the running state has been extrapolated through numerical simulations, the sideband curves (yellow dashed lines) mark the uncertainty in our calculation and are due to the temperature step size. The symbols refer to various works reported in the literature in the last ten years. The proximity of experimental data to the simulations suggests the validity of such approach and the universal nature of the transition curve. This phase diagram constitutes a guideline for moderatey damped systems over a large range of junction materials, geometry and dissipation level.