AC Josephson effect and resonant superconducting transport through vibrating Nb nanowires

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The generation of high-frequency current oscillations when a constant voltage is applied across an insulating tunnel gap separating two superconductors was one of the celebrated predictions made by Brian Josephson in 1962 [1]. These oscillations are ubiquitous to superconducting weak links of various geometries, and their analogues have also been found in other macroscopic quantum systems, such as superfluids [2-4] and gaseous Bose-Einstein condensates [5]. The phenomenon has been confirmed by studying changes in the current-voltage characteristics of superconducting tunnel junctions caused by the interplay of the oscillating current with externally applied microwave radiation of matching frequency (Shapiro steps [6]) or with internal electrodynamic resonances (Fiske effect [7]). We report measurements and theoretical studies suggesting that Josephson current oscillations interact with atomic-scale mechanical motion as well. We generated a niobium dimer (Nb_2) that acts as a weak-link between two superconducting (bulk) niobium electrodes [8]. We find features in the differential conductance through the dimer which correspond to excitations of the dimer vibrational eigenmodes by Josephson oscillations and support our results with theoretical simulations [9].

Research of superconducting transport through microscopic objects with intrinsic vibrational degrees of freedom provides a new research avenue, with the details of the microscopic coupling mechanism between the vibrational degrees of freedom in the weak links and the ac Josephson currents remaining a subject for further experimental and theoretical investigations. Additionally, such systems offer a sensitive spectroscopic method for probing molecular dynamical properties.

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