SIMULATION OF CURRENT-VOLTAGE CHARACTERISTICS OF LARGE-AREA JOSEPHSON JUNCTIONS AND SPACE-TIME DYNAMICS FOR VARIOUS VORTEX-FLOW MODES

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High-frequency applications of Josephson contacts require single-valued current-voltage characteristics which are usually achieved by using an external low-resistance normal-metal shunt in parallel with each junction. In this contribution, we propose a new approach for realizing internal shunting in Josephson heterostructures where a barrier itself contains the desired resistive component. We also study the space-time vortex-flow dynamics in elongated Josephson junctions by solving the related sine-Gordon equation with a Baecklund transformation.

Superconducting digital electronics may be an attractive candidate for the replacement of the semiconductor technology with many potential advantages. It is using Josephson junctions as ultrafast switches and magnetic-flux encoding of information and offers a combination of high speed and very low energy consumption, fast as well as lossless interconnects between circuit elements and thus allows to develop small-scale circuits that dissipate more than one thousand times less power than state-of-the-art silicon CMOS devices. Unfortunately, conventional Josephson metal-insulator-metal heterostructures are inherently underdamped and exhibit hysteretic current-voltage response. The usual way to overcome such behavior is to place an external low-resistance normal-metal shunt in parallel with each junction. Such solution results in a considerable complication of the circuitry design and introduces significant parasitic inductance through the junction. In the talk, we propose possible ways towards creating internally shunted Josephson multilayers able to eliminate the need for external-shunt resistors.

We consider a situation when transmission characteristics of a weak link between two superconducting (S) electrodes are strongly disordered in the interface plane so that the main part of the transition region between the superconducting leads has very low transmission coefficient $D << 1$ whereas a very small portion of the interface is well transparent with $D \leq 1$. Moreover, the latter one is distributed more or less uniformly in the form of filaments having a diameter much less than the superconducting coherence length ξ_S in the junction electrodes while the distance between them exceeds ξ_S. In this case, the inverse proximity effect on the S layers should be very small and the superconducting order parameter (even near the NS interface) remains almost the same as in the bulk. The supercurrent that flows through the low-transparent (and thus tunnel-like) part of the weak link will follow the conventional Ambegaokar-Baratoff theory whereas the transport of Cooper pairs across high-transparent filaments will realize internal shunting by following the SNS scenario.

A Josephson junction with a comparatively large area where the total transmission coefficient across a weak link is defined by a sum of independent local transparencies D_i for concerned eigenchannels. We show that under certain conditions two simple (in spite of the different physics origin) distribution functions, a Lorentzian and a hyperbolic cosine to the minus two power, are expected. We suppose that the arguments in the two functions are very smooth random variables uniformly distributed from zero to infinity and get a universal bimodal probability-distribution function of local transmission coefficients D in disordered weak links. Some experimental realizations of the self-shunted Josephson junctions are discussed.

The second part of the contribution is devoted to long Josephson junctions where the space-time vortex-flow dynamics is described by the sine-Gordon equation, a nonlinear hyperbolic partial differential equation involving the d'Alembert operator and the sine of the unknown function. Their soliton-solutions defined Josephson vortices (fluxons), circulating currents across the insulator due to the phase difference between the wave functions in the superconductors. The fluxon, a robust and stable object, can be forced to move along the junction by applying an exterior bias current to the junction S electrodes. The dynamics of long Josephson junctions in the presence of a rapidly varying driving force modelled by a periodically driven sine-Gordon equation was studied and obtained numerical data are discussed from an applied perspective. We have investigated the coupled mode oscillations in the presence of an ac-drive as well.

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