

Josephson diode effect in superconducting circuits

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We investigate the superconducting diode effect in circuits composed of two Josephson junctions in series, connected to three superconductors. This circuit was implemented experimentally by S. Matsuo et al, with Josephson junctions where a semiconductor was embedded in order to change the transmission with a gate. Here we embed quantum dots - which are here considered as resonant energy levels - in the two junctions in order to optimize the Josephson current. The diode effect occurs because of the two fundamental Cooper pair processes occurring at the central superconductor: double crossed Andreev reflection and Cooper pair cotunneling through the latter. We use the Masubara formalism is employed and the partition function can be written as a simple sum over Masubara frequency of a determinant which incorporates tunneling processes to all orders between the dots and the leads. The diode behavior is studied as a function of the parameters of the system such as the ratio of the tunneling rates of the dots to the gap energy and the position of the levels of the two dots.