Magnetic field induced 2D to 1D crossover in SNS Josephson junction arrays as revealed by mutual phase locking

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The Josephson effect arises when two superconductors are coupled by a weak link forming a Josephson junction (JJ). JJs have extraordinary properties when subjected to a high frequency radiation field (e.g. the Shapiro effect). However, the use of a single junction for practical high frequency applications is limited due to its low response. Coupling JJs into an array provides a natural alternative for the enhancement of the response.

We fabricated prototypical overdamped JJ arrays (JJAs) containing over 2000 superconductor-normal-superconductor (SNS) junctions as shown in figure 1a. The devices consist of a rectangular lattice of superconducting islands, which are deposited on a normal metallic gold film, having very different lattice parameters (defined by d_x and d_y).

The observation of pronounced Shapiro steps in the measured IV-characteristics when the fabricated JJAs are irradiated with a radiofrequency (RF) field indicates they present a self-synchronised and phase locked response, robust against intrinsic disorder within the array [1].

We demonstrate that the phase–locked response depends highly on the anisotropy $(d_y/\,d_x)$ parameters of the array, the properties of the RF drive, temperature and magnetic field induced frustration. For instance, we observe a field induced crossover from a 2D response, characterized by the presence of Shapiro steps only at matching conditions, to a 1D response, characterized by field independent Shapiro steps, in a device having a small anisotropy (Figure 1b). Whereas, a highly anisotropic device shows a pure 1D response modulated by flux quantization in the weak link area itself (Figure 1c). The obtained responses show excellent agreement with numerical simulations using an extended resistively shunted Josephson junction model.

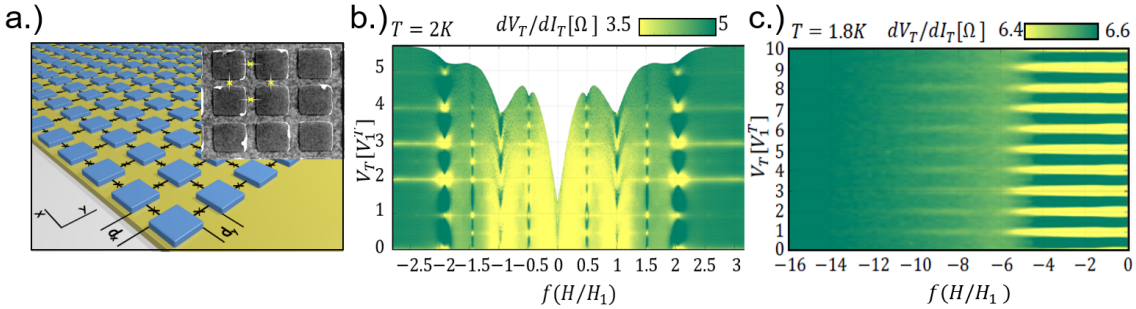

Fig 1(a). Schematic illustration of a JJA together with scanning electron microscopy image of an Au/MoGe based JJA with d_y/d_x=0.8. Fig 1(b). Frustration (Magnetic field) dependence of the Shapiro step response (corresponding with zones of reduced differential conductance, yellow) at low temperatures for Device 1 having d_y/d_x=0.8 and for Device 2, having d_y/d_x=4 (shown in Fig 1(c)).

References

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