Radiation Detector Based on Magnetoresistance Induced by Superconducting Vortex Excitations

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Introduction

Superconducting radiation detectors are characterized by high energy resolution and sensitivity to very low signals. In Transition Edge Sensors [1] radiation breaks Cooper pairs causing resistance to increase. In analogous way MKIDs [2] exploits the variation of kinetic inductance. In Superconducting Tunneling Junction [3] quasiparticles created by incident radiation are collected through a Josephson junction (JJ). In Superconducting Nanowire Detectors [4] absorption of a single photon causes a small spot of the wire to go normal. JJ's irradiated with a microwave source show steps in the V-I characteristics called Shapiro Steps [5]. We investigate a possible new detector based on magnetoresistance induced by vortex excitation in nanometric-square array of superconducting islands placed on a normal metal.

1 - Controllable resistance in superconducting metamaterial

Nanotechnologies allow the construction of metamaterials with specific properties that can be both controlled and modified. Superconducting systems, for instance, may be turned into an insulator in nanoperforated TiN films [6].

2 - Proximity superconducting array

We have considered a proximity superconducting array [7] manufactured on a silicon/silicon oxide substrate where a metallic gold template with four contacts has been grown. The size of the array is 80 µm x 80 µm. On this 'template' an array of 300x300=90000 Nb superconducting islands was realized. The device has a period of a=270 nm, the island diameter is 220 nm, thickness of 45 nm and separation of 47 nm (figure 1).

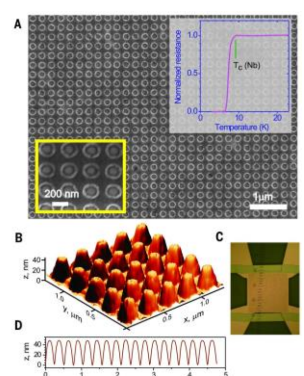

Figure 1: SEM image of a square array of Nb islands.

3 – Tunable magnetoresistance

With the application of a magnetic field, Josephson vortices are induced and localized among superconducting islands. These vortices generate different patterns as a function of $f=B/B_0$, with B the applied magnetic field and $B_0 = \Phi_0/a^2$=28.6 mT. The system will show minima of the differential electrical resistance, dV/dI, for different stable vortex lattices. Reversal of these minima into maxima is induced by increasing the bias AC current (figure 2).

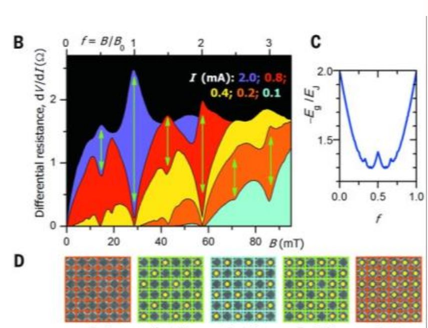

Figure 2: dV/dI and vortex configurations versus B.

4 - Main goal

Investigate the excitation of vortex-array configurations with incident radiation and the resulting resistance variation showing up in a V-I signal. At LNF we designed and constructed a cryostat to host the device with a tunable sc-magnet. A thin window will allow tests with minimum ionizing particles. Optical fiber will be inserted for UV-IR illumination (figure 3).

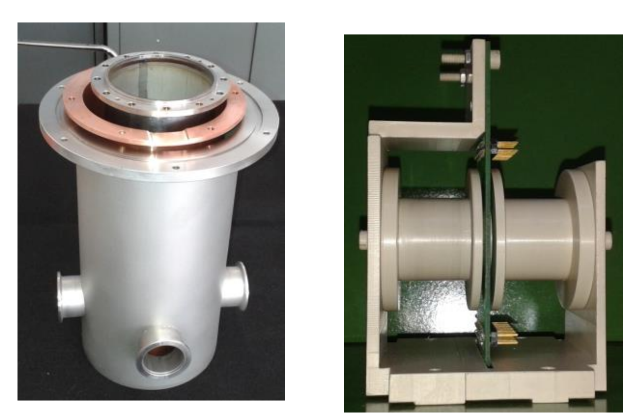

Figure 3: Cryostat and sample holder

Potential Impact: Applications in CMB measurements, X-ray astronomy, Axion and WIMP dark-matter searches.

References

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