Superconducting Nanoscience Group

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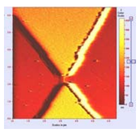
Terahertz Detection



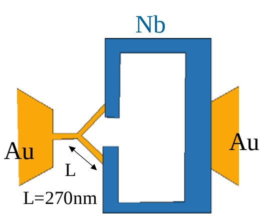
An Atomic Force micrograph of a HEB.

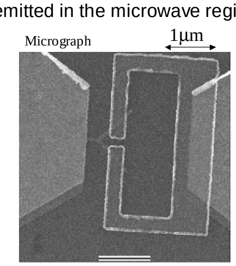
The FIRST (Far Infrared Submillimeter Telescope) satellite is slated to use HEBs

- Hot Electron Bolometers (HEBs) are a promising detector for 1-10 THz in radio astronomy and atmospheric chemistry.
- The HEB is made of a superconducting microbridge connecting two normal metal pads.
- Heating due to the photons increases the resistance and is recorded at GHz frequencies.

Quantum Noise in Mesoscopic Interferometer

- At very low temperature, electrons in a metal behave like waves, subject to interference phenomena.
- Electrons leave the niobium (Nb) superconducting electrode by the two arms and interfere in the normal metal, gold (Au).
- A magnetic flux inside the loop dephases the two paths leading to phase-dependent superconducting properties in the gold (the charge of the carriers is twice the electron charge). We access this by measurement of the electrical noise emitted in the microwave region.





What is SUPERCONDUCTIVITY ?

- Kammerlingh Onnes discovered in 1911 that below a certain transition temperature the dc resistance of certain metals disappeared.
- J. Bardeen, L. Cooper and R. Schrieffer received the Nobel Prize in 1972 for the development of the theory of superconductivity (BCS theory).
- A key conceptual element in the BCS theory is the pairing of electrons close to the Fermi level into Cooper pairs.

Classes of Applications

Based on Different Properties of

the Superconducting State

- Zero resistance ⟶ magnets
- Transition between the superconducting and non-superconducting states ⟶ bolometers for **Terahertz detection**
- Josephson junctions (tunneling of Cooper pairs through a barrier) ⟶ SQUID magnetometers, **interferometers**
- Tunneling of single electrons ⟶ **single photon detectors** – used in biological microscopy

Research Infrastructure

- Yale Nanofabrication Laboratory
- Cryogenic Test systems
- Microwave Test Systems (Hewlett-Packard donation – 1995)

Research done in collaboration with
NASA JPL, NASA Goddard, U. of Arizona and Yale Med. Sc.
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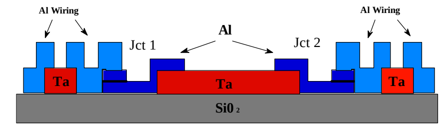
Single Photon Detector



- Photon is absorbed in tantalum (Ta), breaking Cooper pairs and creating quasiparticles.
- Quasiparticles diffuse and are trapped in lower gap aluminum (Al) on either end.
- Total charge collected gives the energy of the incident photon.
- Ratio of charges from each junction gives position along absorber ⟶ imaging.
- This detector can resolve photon energy, unlike a photomultiplier.

Biological Applications

- Single photon detectors for single molecule spectroscopy
- One possible candidate is a PNA (DNA-like structure) molecular beacon with 2 states:

  -closed (fluorescence quenched)

  -open (fluorescence not quenched)
- Trigger mechanism: recognition by the unfolded loop of a complementary sequence

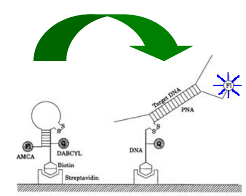


Fig. 1. The chimeric PNA-DNA probe in the "closed" (quenched) state and, after the interaction with the target, in the "open" (fluorescent) state.