Scanning tunneling microscopy of superconducting single photon detectors

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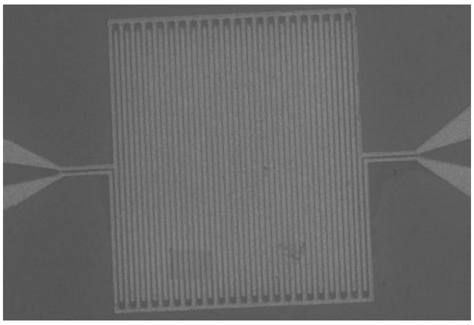
Superconducting single photon detector (SSPD) technology has recently emerged as a building block for numerous novel applications, including quantum communication, optical quantum computing or space-to-ground communications [1]. Such devices are made of nano-patterned ultrathin superconducting films (in our case – 3-5nm-thick NbN elaborated on sapphire substrate). The detector is a long (about 10-100 micron) folded superconducting nanowire (typically 10-100nm wide) (see figure); the wire is biased by a super-current which intensity is kept just below the critical current value, that holds the superconducting wire very close to the transition to the normal (resistive) state. When an incident high-energy particle (photon, electron etc.) hits the wire and gets absorbed, it locally destroys already weakened superconductivity and creates a resistive region, generating a voltage drop across the detector [2].



While such ultra-sensitive detectors become widely used, the microscopic picture of the particle-to-signal conversion is far from being understood. How the presence of strong supercurrents before the particle absorption modifies the superconducting properties of the wire? Are there “preferential locations” where the conversion takes place? How the film structure, intrinsic and extrinsic inhomogeneities [3], wire edges and bends affect the detector efficiency? Are there vortices, and do they influence the detection process? At least some of these open questions will be addressed during this thesis, using the new ultrahigh vacuum low-temperature Scanning Tunneling Microscopy / Scanning Tunneling Spectroscopy / Atomic Force Microscope (STM/STS/AFM) equipment recently installed at LPEM-ESPCI, and unique in France. It will allow for studying both the distribution of supercurrents and vortices when biasing the superconducting nanowire and give relevant information to understand the conversion process. This study may potentially have a strong impact since it could give ideas for optimizing design and improving efficiency of SSPDs.

Nanofabrication will be carried out using electron beam lithography at ESPCI and using clean room facility at ENS. Then the real current-biased device will studied at low temperatures with the STM/STS/AFM equipment. As a second step, the device will be triggered using a local current pulse produced by STM tip or by a photon delivered by a laser connected to an optical fiber, and its local and global responses will be analyzed.

[1] Nature Photon. 3 696–705 (2009) [2] Supercond. Sci. Technol. (2012) [3] C. Carbillet PhD Thesis, Paris. (2014)

Techniques utilisées : transport électronique DC, nano-fabrication (lithographie, gravure....), cryogénie basse température, techniques ultra-vides, microscopie à effet tunnel et microscopie à force atomique.

Qualités du candidat requises : Etudiant motivé ayant une solide formation en physique quantique et physique de la matière condensée et attiré par la physique expérimentale.