

Single-photon detectors based on High Tc superconductors

Laboratoire de Physique et d'Étude des Matériaux, ESPCI Paris -PSL

Contact : cheryl.feuilletpalma@espci.psl.eu, yanko.todorov@espci.fr,
djamal.gacemi@phys.ens.psl.eu

The capacity to detect photons one by one is at the heart of quantum technologies, such as secure quantum communications. For photons in the near-infrared range (telecom wavelengths), superconducting nanowires provide advanced technology for single photon detection and counting [3]. In these devices, a thin nanowire of superconducting material is biased just below its critical current. Each photon absorbed heats locally the nanowire, creating a hotspot where superconductivity is suppressed, potentially triggering a transition to the normal state. A voltage peak is then generated that indicates a single photon detection event (Fig. 1a). Typically, such devices are realized with conventional superconductors, such as NbN that have typical critical temperature around 14K. Using high-temperature superconductors such as YBCO ($T_c=85K$) would open completely new perspectives in the field, rendering such devices suitable for widespread applications, and would even allow to extend their operation in the Mid-Infrared and even THz spectral region. A first proof of concept was demonstrated by Chararev et al. using cuprate superconducting nanowires, establishing single-photon sensitivity at telecommunications wavelengths [2]. However, these devices rely on exfoliated cuprate flakes, which remain challenging for large-scale fabrication. YBCO offers a promising alternative, as scalable nanofabrication processes have already been demonstrated [3]. A key challenge for YBCO-based single-photon detectors is controlling heat diffusion and thermal relaxation following photon absorption. Indeed, in YBCO nanowires, the energy deposited by the incident photon can dissipate too fast into the underlying substrate, preventing the formation of a sufficiently long-lived resistive region capable of generating a detectable voltage pulse. This problem could be overcome by using suspended YBCO nanowires recently produced at Thales (Fig. 1b).

We propose a Master 2/ PhD project that is a joint collaboration between Thales, LPEN and LPENS funded by the French ANR (Project BRIGHT). The objective of this project is to study and control the vibration properties of suspended YBCO bridges in order to understand and optimize the physics of heat transfer in such structures. To that end, jointly with LPENS we will build a setup to probe the mechanical oscillations of nanoobjects [4,5]. For the Master 2 internship, this setup will be implemented at room temperature and probed with GaAs cantilevers that are already available in the consortium [4,5]. In these devices, electrostatic driving allows reaching highly nonlinear regimes of mechanical vibrations and characterizing the photothermal effects [4,5] (Fig. 1c). The PhD work will be dedicated to systematic study of YBCO bridges provided by Thales, with an extension of our setup to cryogenic conditions, allowing in operando characterizations of the devices. A candidate with strong experimental aptitudes is required.

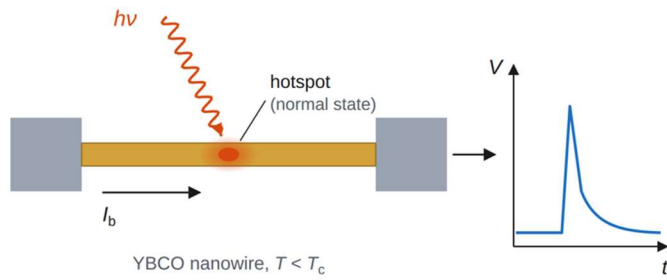
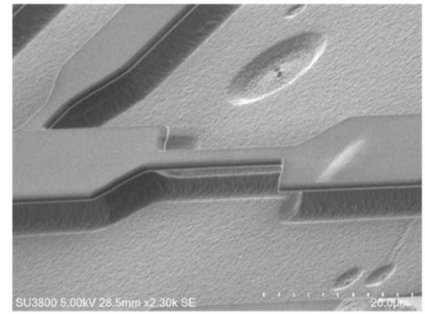
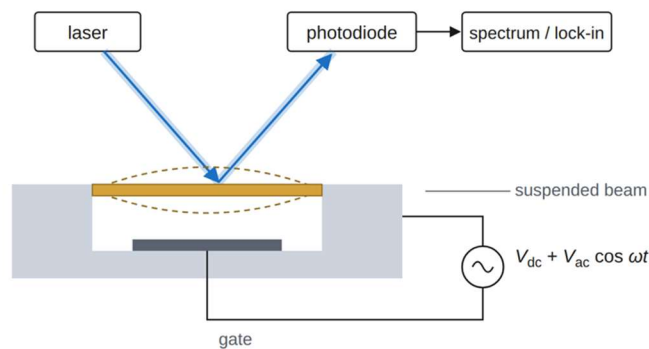
a Single-photon detection**b Suspended YBCO bridge form Thales****c Probing the mechanical vibrations**

Figure 1 | Suspended YBCO nanobridges for high- T_c single-photon detection. (a) Principle of a superconducting nanowire single-photon detector: an absorbed photon creates a resistive hotspot in the current-biased nanowire, which produces a voltage pulse. (b) Electron microscope picture of a suspended YBCO nanobridge (courtesy of Thales) (c) Principle of the setup to be developed: the suspended structure is driven electrostatically by a gate electrode and its vibrations are read out optically by a probe laser reflected onto a photodiode.

References:

- [1] C. Feuillet-Palma, "Transport et interaction matière-rayonnement dans des matériaux corrélés," *Comptes Rendus Physique* **26**, 129–180 (2025).
- [2] I. Charaev et al., "Single-photon detection using high-temperature superconductors," *Nature Nanotechnology* **18**, 343–349 (2023). DOI: 10.1038/s41565-023-01325-2.
- [3] P. Amari et al., "Scalable Nanofabrication of High-Quality $\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$ Nanowires for Single-Photon Detectors," *Physical Review Applied* **20**, 044025 (2023).
- [4] J. Liu et al., "Ultrafast Detection of TeraHertz Radiation with Miniaturized Optomechanical Resonator Driven by Dielectric Driving Force", *ACS Photonics*, **9** (5): 1541–1546 (2022).
- [5] C. Belacel et al., "Optomechanical terahertz detection with single meta-atom resonator", *Nature Communications*, **8**, 1578 (2017).