SORBONNE UNIVERSITÉ

Ecole doctorale SMAER
Sciences **M**écaniques, **A**coustique, **E**lectronique, **R**obotique

Thesis subject 2019

Laboratory: **Group of Electrical Engineering - Paris (GeePs)** – UMR CNRS 8507 – CentraleSupélec

University: **Sorbonne Université**

Title of the thesis: **A new generation of ultrafast detectors for the synchrotron radiation in the terahertz range**

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This subject can be published on the doctoral school's web site: **YES**

Thesis's summary (abstract):

Terahertz (THz) electromagnetic waves, the frequency range of which spans from 300 GHz to 10,000 GHz (= 10 THz), currently provide many fields of **practical applications** (biomedical, industrial control, homeland security, etc.). Besides, they offer a great interest in **fundamental research** (astrophysics, condensed matter physics, spectro-chemistry), because of the many entities (atoms, ions, radicals, molecules) that exhibit characteristic frequencies in the THz domain. In the recent years, with the advent of high performance radiation sources available at large instrument sites (synchrotron radiation= light emitted by ultra-relativistic electrons, i.e. of very high energy, in a storage ring), the resurgence in the field of high resolution THz spectroscopy in the pulsed mode has been witnessed, which has created a need for ultrafast THz detectors. This thesis provides an **innovative solution in this field in collaboration with the synchrotron instrument SOLEIL** (AILES beam line).

In this context, we develop specific thermal detectors (i.e., sensitive to the intensity of incident radiation), called Hot Electron nano-Bolometers (HEB). An HEB is a nanoconstriction elaborated in an ultra-thin film (≈ 40 nm) of the high critical temperature superconducting oxide Y-Ba-Cu-O (YBCO, $T_c \approx 92$ K) and coupled to a metal planar micro-antenna. The advantage of YBCO is to exhibit the unique feature of an intrinsic electron-phonon interaction time close to the picosecond, which reflects the ultra-fast response exploitable in the nanodetector (see R. Ladret, A. Dégardin, V. Jagtap, and A. Kreisler, in *Photonics* **6** (2019). DOI:10.3390/photonics6010007). The thesis consists in developing a self-contained demonstrator of ultrafast THz detector. The points to be addressed will be:

a) Evaluation of the potential performance: modeling of physical phenomena occurring in the HEB device (microscopic modeling specific to high T_c superconductors, modeling of heat balance between the sensor and its environment, electromagnetic modeling of ultrafast readout circuits). FTIR measurements range will complement the knowledge on the optical properties of YBCO ultra-thin layers in the THz frequency range.

b) Device design and fabrication: design and fabrication in clean rooms of nanoconstrictions made from YBCO ultra-thin films and coupled to broadband planar micro-antennas. The film nanostructuring is a challenge because of the easy de-oxygenation of YBCO material during the technological process. Electrical and optical tests performed on HEB devices will allow to assess the effects of aging of YBCO ultra-thin films and optimize the manufacturing steps.

c) Implementation of the detector: at this final stage, a THz detector system will be designed and implemented. Extensive THz detection tests will be conducted on the SOLEIL synchrotron site (AILES beam line), according to the various pulse sequence modes delivered by the instrument. Validation of spectroscopy experiments will be further performed in collaboration with concerned physicists.

Required education and skills: Master of Science degree or equivalent degree in Electronics, Photonics or Applied Physics. **Excellent academic results are required.**