Design and optimization of a YBCO based superconducting bolometer

Summary

This thesis deals with the optimization of a Transition Edge Bolometer (TEB) and the preliminary design of a Hot-Electron Bolometer (HEB), both based on optimally doped $YBa_2Cu_3O_{7-\delta}$ (YBCO) films. This work partly fulfils the milestones of the INFN-TERA project.

The introduction provides a general overview of the phenomenology and theories of superconductivity, emphasizing aspects such as vortex dynamics and the difference between type I and type II superconductivity. Then, the most promising technological superconducting materials are summarized before focusing on the YBCO films, whose crystal structure and phase diagram are presented. Finally, the application of the THz frequencies and the detectors working in this spectrum are introduced, before directing the attention to the working principle of a TEB: responsivity, noise, and time constant are presented, namely concepts that will be used in the following parts of the work.

Section 4 focuses on the YBCO based TEB and its optimization. The choice of the MgO substrate based on the optimal lattice matching with YBCO and its both electrical and thermal properties is explained. Then, the irradiation through high-energy heavy-ions for modifying the RvsT curve are described before the presentation of a portable cryostat in which the bolometer is held. Using the experimental data, the optimization of the working conditions is carried out, in terms of temperature, on the basis of the general study of the interplay between responsivity and noise, which will be the starting point for the simulation work. The bolometer is then reproduced with the finite element method employing the software COMSOL Multiphysics®. The first simulations helped in determining the most suitable materials for the sensor housing, which will be used for a detailed study of the response of the detector. Finally, a preliminary study of a new layout is realized and compared with the original geometry.

The last section is devoted to the design of an YBCO based HEB and the theory behind it. The high-frequency response is studied employing the SONNET® simulation software, mainly for matching the 50 Ω of the input impedance. The final configuration is then manufactured through Electron Beam Lithography (EBL) after the deposition of the YBCO film by means of Pulsed Laser Deposition (PLD), still on a MgO substrate. The fabricated devices are characterized, then the results are used for calculating the performance of the detector.