TERA - CSN5 - Annual Report

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1 Summary

Terahertz radiation (1 THz = 33 cm-1 = 4 meV = 300 um = 48 K = 1 ps) represents a cutting-edge scientific and technological tool in various physics fields of interest to INFN. These range from new particle acceleration techniques (from acceleration to their diagnostics), to medical physics, to detectors for dark matter, to opto-electronic devices for manipulating the properties of radiation (phase, amplitude, polarization), to innovative materials. The TERA (Terahertz ERA) project is based on the development of a THz laser source with unique characteristics (high intensity, associated electric field 10-50 MV/cm; short duration 50 fs, high rep rate 1 KHz, polarization modular, beam-shaping), and which was assembled in a dedicated laboratory at the Department of Physics of La Sapienza. Various researches will be developed around this source, in synergy with the participating sections (LNF, Turin, Naples) and the other research institutes (La Sapienza, CNR, IIT):

– acceleration techniques
– detectors
– innovative materials
– devices to control the properties of THz radiation.

The Frascati National Laboratories participate in the project with two activities:

WP2: study of the dynamics of the electron beam in THz accelerating structures for the optimization of acceleration processes from single-stage to multistage linac; start-to-end simulations to demonstrate the acceleration of high brilliance electron beams such as to drive a free electron laser (FEL) (Resp. E. Chiadroni); A possible scheme for terahertz-based acceleration of high brightness electron beams has been identified. The accelerating structure has been characterized both from a theoretical point of view and by means of electromagnetic simulations. The resulting 3D electromagnetic fields have been used to perform beam dynamics simulations with GPT, showing the preservation of the high brightness of a high charge electron beam for user applications [2)].

WP3: development of detectors with superconductive, passive and tunable metamaterials; spectroscopic characterization in intensity, polarization and electric field; development of superconducting detectors; spectroscopic characterization in intensity, polarization and electric field (Resp. A Marcelli).

2 Experimental activity

The apparatus was modified to facilitate insertion of the radiofrequency source simple dipole.
The 80x80 micron device was tested exposed to the RF radiation in the range of 7-10 GHz and the radiation power of 0-45 dbm for which a 1x10-6 is received by sample.
Another sample holder was manufactured to house the 2x2 mm junction arrays. Three large area samples were fabricated (in the framework of collaboration with INRiM) using colloidal lithography with the Nb islands of dimensions of 200 nm over a 30 nm layer gold film.
The tests were performed on two of the large area sample at 4.2 K while the it was observed that that due to slight disorders, present in the sample due to the large area, it is was not possible to reach the fully coherent state. Accordingly samples with higher precisions of the islands order should be fabricated.
The large area samples with higher precision in the island distance orders are in preparation within the collaboration with CNR-IFN.
The cryostat was modified in order to fabricate a cryogenic arm with in built optical lens with the focal length of the 20 and 30 mm.
The Sample holder was also modified to remove the mechanical vibrations of the samples.
The optical apparatus was installed and tested for mechanical and temperature endurance of the cryostat.
Test were performed on the two different available sources of 300 GHz and 4 THz. The generated beams were mapped using pyroelectric detector and a hot electron bolometer. The sources characterizations are still ongoing.
A new apparatus to perform rapid signal measurements is under development employing a signal generator applying a current to the sample via a hot resistor. . We have introduced a new low noise amplifier to the measurement apparatus in order to increase the signal to noise ratio of the signal measured across the proximity array.

3 Experimental Activity within out collaboration with CNR-IFN

A high sensitivity hot electron bolometer with possibility to evidence pulses in a broad THZ range and with high repetition rates were designed and fabricated.
The bolometer is tested via quantum cascade laser and the response is characterized based on the HEB biasing.
A portable cryostat working at 4.2 K (liquid helium) is settled. The cryostat employs a low noise amplifier working at 4.2 K to significantly increase the S/N ratio.

4 Milestones

1. SMMD:Design and realization of a second superconducting meta-material based detector with 2-3 millions of islands.

2. Sample holder was manufactured to house the 2x2 mm junction arrays. Three large area samples were fabricated (in the framework of collaboration with INRiM) using colloidal lithography with the Nb islands of dimensions of 200 nm over a 30 nm layer gold film.

3. The tests were performed on two of the large area sample at 4.2 K while the it was observed that that due to slight disorders, present in the sample due to the large area, it is was not possible to reach the fully coherent state. Accordingly samples with higher precisions of the islands order should be fabricated.

4. Other large area samples with higher precision in the island distance orders are in preparation within the collaboration with CNR-IFN.

5 Collaborations

INRiM: Fabrication of PAD devices with large are of 2x2 mm . (Three devices)
CNR-IFN: Characterization of the portable THz sources. Design and fabrication of the HEB its compatible cryostat.
Dresden: Fabrication of the 80x90 micron PAD device.

6 Publications

References

1. J S. J. Rezvani, D. Di Gioacchino, S. Tofani, A. D'Arco, C. Ligi, S. Lupi, C. Gatti, M. Cestelli Guidi and A. Marcelli. A cryogenic magneto-optical device for long wavelength radiation. Review of Scientific Instruments 91 (075103)(2020).

2. M. Marongiu, E. Chiadroni, M. Croia, M. Ferrario, L. Ficcadenti, S. Lupi , V. Martinelli, A. Mostacci, R. Pompili, S. Tofani, Electromagnetic and Beam Dynamics Studies for High Gradient Accelerators at Terahertz Frequencies. Journal of Physics: Conference Series, 2020, 1596(1), 012029