PhD course of National Interest in Technologies for Fundamental Research in Physics and Astrophysics

Annual report

Name and surname: Gaurav Rajesh Mota
Cycle and A.A.: 39° cycle 2023/2024
Supervisor: Prof. Nicola Pompeo and Prof. Enrico Silva.

- **Research activity carried out during the year**

Research Topic: Surface Impedance of Superconductors under Conditions of Interest for Fundamental Physics

The research focuses on the experimental characterization and study of the surface impedance of superconductors at radio and/or microwave frequencies in high dc magnetic fields, and at cryogenic temperatures, for the perspective application of these materials in both particle accelerators and in axion detection cavities known as haloscopes. During the first year I have been focused on acquiring several skills related to the operation of an experimental laboratory: handling of cryogenic liquids, operation of vacuum systems, and use of several instruments for dc and rf electrical measurements, in particular vector network analyser (VNA). I also performed surface impedance measurements using dielectric loaded resonators, which involved learning to calibrate the measurement system, to operate and remotely control the VNA, to acquire the microwave line scattering coefficients both manually and through National Instruments Labview control software. I then performed an extensive elaboration on the measurements done on a cuprate superconducting sample. By using high frequency vortex motion models I have been able to extract the relevant vortex parameters for the material, through MATLAB scripts that I specifically prepared. Since the vortex motion dynamics is frequency dependent, it is important to be able to study the material in a broad band frequency range. Hence, I am developing a new measurement setup in the so-called 'Corbino disk geometry'. The initial design I have prepared takes into account several project requirements. The Corbino disk line needs to be operated at cryogenic temperatures and in high magnetic fields, hence mechanical stability is paramount, both to compensate thermal expansion and to ensure good ohmic contact between the sample and the measurement line. The cell must be compact enough to fit in the cryostat (dia. <40 mm). Careful placement of heaters and temperature sensors is needed for good thermalization. Finally, line calibration requires specialized approaches to be developed to account for the unique challenges posed by the cryogenic setup and to yield reliable and accurate surface impedance measurements.

- **List of attended courses and passed exams**

  Applied Superconductivity: Quantum Phenomena and Quantum Systems.

  Advance scientific programming in Matlab.

- **List of attended conferences, workshops and schools, with mention of the presented talks**

  1. Attended Summer School on Superconductivity supported by ESAS Prague, Czech Republic. (24/06 - 28/06/2024)
     - Lab visit to The University of Chemistry and Technology, Prague.
     - Industrial visit to CAN Superconductors.

  2. Scientific visit to University of Stuttgart, Germany at Physikalisches Institut, Dr. Marc Scheffler, Head of the Microwave lab. (01/07 - 05/07/2024)
  3. IEEE Council on Superconductivity Italy Chapter meeting. (University Roma Tre) (28/05/2024)
  4. IEEE Authorship and Open Access Symposium: Tips and Best Practices to Get Published from IEEE Editors. (online, 07/05/2024).

- **List of published papers/proceedings**

  "Microwave Vortex-dynamics Characterization in Nb3Sn under High Magnetic Field" to be presented by **P. Vidal,** submitted to 11th International Workshop on Thin Films and New Ideas for Pushing the Limits of RF Superconductivity - TFSRF2024. 16–20 Sept 2024

- **Thesis title**

  "Development of advanced wideband techniques for the measurement of the surface impedance in Superconductors in high magnetic fields"

Date, 10/09/2024 **Signature** Gaurav

Seen, the supervisor.

Nicola Pompeo