PHY543: RF Superconductivity for accelerators

Instructors: Prof. S. Belomestnykh and Dr. S. Posen

The course will be taught remotely via Zoom. A Zoom meeting link will be sent to registered students via email before the first lecture. The students are expected to have access to a computer equipped with a microphone for interaction with instructors and other students. Having a camera is not required.

Purpose and Audience

This graduate level course covers application of radio frequency (RF) superconductivity to contemporary particle accelerators: particle colliders, storage rings for X-ray production, pulsed and CW linear accelerators (linacs), energy recovery linacs (ERLs), etc. The course will address both physics and engineering aspects of the field. It will cover fundamentals of RF superconductivity, types of superconducting radio frequency (SRF) accelerating structures, performance-limiting phenomena, beam-cavity interaction issues specific to superconducting cavities, approaches to designing SRF systems and engineering of superconducting cavity cryomodules. The course is intended for students interested in accelerator physics and technology who want to learn about application of RF superconductivity to particle accelerators.

Prerequisites: Classical mechanics, thermodynamics, electrodynamics, solid state / condensed matter physics and physical or engineering mathematics, all at entrance graduate level.

Objectives

Upon completion of this course, students are expected to understand the physics underlying RF superconductivity and its application to accelerators, as well as the advantages and limitations of SRF technology. The aim is to provide students with ideas and approaches that enable them to evaluate and solve problems related to the application of superconducting cavities to accelerators, as well actively participate in the development of SRF systems for various accelerators.

Instruction Method

This course includes a series of lectures and review sessions. Homework problems will be assigned. Homework will be graded, and solutions provided during the review sessions. There will be a final exam at the conclusion of the course.

Course Content

The course will include a brief introduction of the basic concepts of microwave cavities and fundamental concepts of RF superconductivity. Then it will cover the beam-cavity interaction issues in accelerators: wake fields and higher-order modes (HOMs) in superconducting structures, associated bunched beam instabilities and approaches to deal with these instabilities (HOM absorbers and couplers, cavity geometry optimization, …), bunch length manipulation with SRF cavities, beam loading effects, etc. Following that we will discuss a systems approach and its application to SRF systems for accelerators. We discuss the ways in which the superconducting material, and in particular the surface, can be modified to improve quality factor and accelerating gradient. Finally, we will address issues related to engineering of the SRF system components: cryostats, cavities, input couplers, HOM loads, and frequency tuners.

Recommended Textbook

While all necessary material will be provided during lectures, we recommend the following textbook for in-depth study of the subject:

RF Superconductivity for Accelerators, by H. Padamsee, J. Knobloch, and T. Hays, John Wiley & Sons, 2^{nd} edition (2008).

Other Reading Recommendations

It is recommended that students re-familiarize themselves with the fundamentals of electrodynamics at the level of *Fields and Waves in Communication Electronics* (Chapters 1 through 11) by S. Ramo, J. R. Whinnery, and T. Van Duzer, John Wiley & Sons, 3^{rd} edition (1994) or *Classical Electrodynamics* (Chapters 1 through 8) by J. D. Jackson, John Wiley & Sons, 3^{rd} edition (1999).

Additional reference books: *Handbook of Accelerator Physics and Engineering*, edited by A. W. Chao, K. H. Mess, M. Tigner, and F. Zimmermann, World Scientific, 2^{nd} Edition (2013) and *RF Superconductivity: Science, Technology, and Applications*, by H. Padamsee, Wiley-VCH (2009).

Credit Requirements

Students will be evaluated based on the following performance criteria: final exam (50%), homework assignments and class participation (50%).

Credits earned upon successful completion of this course can be applied toward receiving a Certificate in Accelerator Science and Engineering under the Ernest Courant Traineeship in Accelerator Science & Engineering.

Contact Information

Prof. Belomestnykh: sergey.belomestnykh@stonybrook.edu

Dr. Posen: sposen@fnal.gov

Zoom sessions can be arranged upon request.