PHY543.01: RF Superconductivity for accelerators

Instructors: Prof. S. Belomestnykh, Prof. I. Petrushina, Dr. S. Verdú Andrés

The course will be taught remotely via Zoom on Mondays, 6:05 pm – 9:00 pm. 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 as 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

All necessary materials will be provided during lectures and via the course website https://sites.google.com/view/srfsbu2023/home. However, 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, 2nd 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, 3rd edition (1994) or *Classical Electrodynamics* (Chapters 1 through 8) by J. D. Jackson, John Wiley & Sons, 3rd 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, 2nd 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%). The total scores will be weighted at the end of the semester to account for variation in the class average. The following thresholds will be applied after weighting: A+ > 0.97, A > 0.93, A- > 0.9, B+ > 0.87, B > 0.83, B- > 0.8, C+ > 0.77, C > 0.73, C- > 0.7, D+ > 0.67.
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

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Individual Zoom sessions can be arranged upon request.

Student Accessibility Support Center Statement

If you have a physical, psychological, medical, or learning disability that may impact your course work, please contact the Student Accessibility Support Center, Stony Brook Union Suite 107, (631) 632-6748, or at sasc@stonybrook.edu. They will determine with you what accommodations are necessary and appropriate. All information and documentation is confidential.

Academic Integrity Statement

Each student must pursue his or her academic goals honestly and be personally accountable for all submitted work. Representing another person's work as your own is always wrong. Faculty is required to report any suspected instances of academic dishonesty to the Academic Judiciary. Faculty in the Health Sciences Center (School of Health Professions, Nursing, Social Welfare, Dental Medicine) and School of Medicine are required to follow their school-specific procedures. For more comprehensive information on academic integrity, including categories of academic dishonesty please refer to the academic judiciary website at http://www.stonybrook.edu/commcms/academic_integrity/index.html

Critical Incident Management

Stony Brook University expects students to respect the rights, privileges, and property of other people. Faculty are required to report to the Office of Student Conduct and Community Standards any disruptive behavior that interrupts their ability to teach, compromises the safety of the learning environment, or inhibits students' ability to learn. Faculty in the HSC Schools and the School of Medicine are required to follow their school-specific procedures. Further information about most academic matters can be found in the Undergraduate Bulletin, the Undergraduate Class Schedule, and the Faculty-Employee Handbook.