Advancing Superconducting Undulator Technology: Exploring New Frontiers with Nb_3Sn and Beyond at the Advanced Photon Source

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Superconducting undulators (SCUs) are pivotal in x-ray radiation production for storage rings and free electron lasers, offering enhanced radiation brightness and tunability range through generation of higher undulator fields in shorter periods.

The Advanced Photon Source (APS) at Argonne National Laboratory, a storage ring-based x-ray synchrotron radiation facility, has operated four NbTi-based SCUs in the last 10 years. Recently, we successfully installed the first Nb_3Sn-based SCU into APS's storage ring, in collaboration with Fermi National Accelerator Laboratory and Lawrence Berkeley National Laboratory. This new SCU has demonstrated a stable magnet operation, with no spontaneous quenches, and has delivered x-ray beams to users uninterrupted.

To develop this technology, we implemented a systematic approach, beginning with the use of 8 cm model magnets for design validation and performance testing, along with heat treatment optimization to ensure stable operation. Subsequently, the design was scaled up to an intermediate length of 0.5 m, at which point extensive testing of coil-to-ground insulation was carried out. Following confirmation of satisfactory performance, we scaled the design to its final length of 1.1 m. In parallel, an existing cryogenic system was modified to accommodate the Nb_3Sn magnets and to improve cryogenic performance. A rigorous quench analysis of these final magnets enabled us to refine operational boundaries. High-risk tests were prudently deferred to the end of the user run, aiding in demonstrating the potential of Nb_3Sn technology. The device has achieved an undulator field that exceeds that of its NbTi counterparts by over 20%.

In this seminar, we will discuss SCU technology, particularly our experience with the Nb_3Sn SCU, its challenges, and the future potential of next-generation superconductors to elevate SCU performance.

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