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The Advanced Photon Source

Superconducting Undulators for X-ray Sources above 20 keV

Increasingly, experiments with high-energy (>20 keV) x-rays are on systems undergoing dynamic processes. Examples include measuring the strain rate response of composite materials under tension or compression, determination of metastable phases that briefly appear during amorphous-to-crystalline phase transformations, and response of materials to dynamic loading (e.g., shock waves). Such experiments are inherently "flux hungry" and users engaged in these types of experimental programs are requesting higher photon fluxes at higher energies.

The emerging superconducting undulator (SCU) technology potentially outperforms all other technologies in terms of peak magnetic field at small periods (near 1.5 cm), thereby resulting in higher photon brilliances at higher energies. The expected brilliance of superconducting devices is shown and compared with Advanced Photon Source (APS) Undulator A (UA) in Fig. 1 [1].

After detailed magnetic modeling analysis, refining of the winding geometry, and development of winding techniques, a magnetic structure design was chosen. The core must be potted in epoxy resin to hold the windings firmly; a technique for this epoxy vacuum impregnation was developed in a collaboration with the Technical Division of Fermilab. A 42-pole prototype is shown in Fig. 2. Grooves between the poles hold the winding, and the winding is arranged so the current goes in opposite directions in adjacent winding packs. To provide a smooth trajectory entrance into and exit from the undulator, there are fewer windings of the main current coil in the last two grooves at each end. The extra space allows separate windings, which will be connected to separate power supplies for trajectory correction at the ends.

Test measurements of the field are very encouraging. The quality of the coil winding is such that, without magnetic field corrections in the body of the undulator, the magnetic field phase error requirement of 8 degrees is met, with a 7.1-degrees phase error at the current needed for 20-keV photons, and a 3.3-degrees phase error at the current for 25 keV. For comparison, today's permanent magnet undulators routinely achieve 4-degrees phase error after tuning. Lower phase errors have their strongest impact on the higher harmonics in the photon spectrum; so for users who want to work at higher energies and higher harmonics, reducing the phase error would be desirable.

Now that a magnetic structure has been successfully tested, the work is focusing on a cryostat that will complete the SCU and result in a device that could be installed on the APS storage ring. A collaboration with Budker Institute in Novosibirsk is under way. The plan is to complete the undulator and have it ready for installation and testing in the APS storage ring in two years. After that, the length of the magnetic structure will be increased from the initial 42-pole length (at 1.6-cm period) to about 1.1 m, to achieve a corresponding increase in brilliance. Eventually, after additional R&D on manufacturing and field correction techniques, and construction of a larger test facility, the magnetic length will increase to something closer to the APS-standard 2.4 m.

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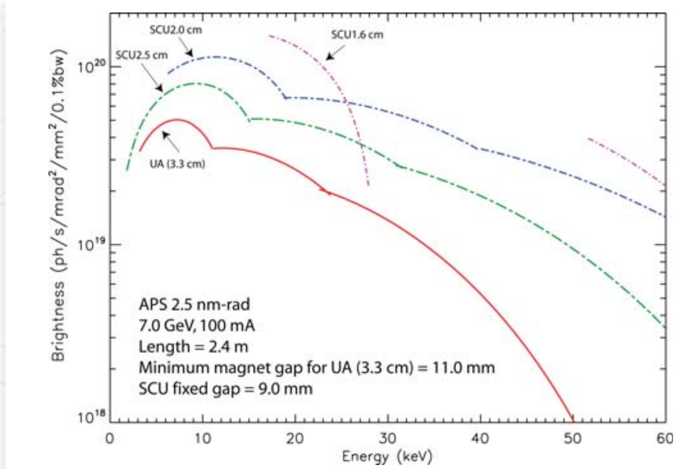

Fig. 1. Tuning curves for UA and some shorter-period SCUs. Note that the shorter periods give higher brightness, especially at higher photon energies. The advantage of SCUs and their stronger field is that the tuning range extends to lower photon energy for each harmonic, giving the user more flexibility in choice of photon energy. Also, gaps in the tuning range, such as that seen for the 1.6-cm-period SCU, occur even for much longer period lengths with permanent-magnet undulators. The SCU1.6 cm is five times brighter than the Undulator A at 20 keV.

Fig. 2. Left: A single SCU core, after winding. The superconductor is wound in the grooves between poles. The current travels in opposite directions in adjacent coil packs. Right: A pair of cores, assembled as for an undulator magnetic structure with a gap between for the beam tube. Here they are ready to go into a vertical dewar for cold testing.

Reference

[1] R. Dejus, M. Jaski, and S.H. Kim, "On-Axis Brilliance and Power of In-Vacuum Undulators for the Advanced Photon Source," ANL/APS/LS-314, formerly Technical Note MD-TN-2009-004.

Call for APS General-User Proposals

The Advanced Photon Source is open to experimenters who can benefit from the brightest hard x-ray beams in the Western Hemisphere.
General-user proposals for beam time during Run 2010-1 are due by Friday, July 9, 2010.
Information on access to beam time at the APS is at http://www.aps.anl.gov/Users/apply_for_beamtime.html or contact Dr. Dennis Mills, DMM@aps.anl.gov, 630/252-5680.

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