

STATUS OF THE FIRST PLANAR SUPERCONDUCTING UNDULATOR FOR THE ADVANCED PHOTON SOURCE*

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Abstract

Superconducting technology offers the possibility of building short-period undulators for synchrotron light sources. Such undulators will deliver higher fluxes at higher photon energies to the light source community. The Advanced Photon Source (APS) team is building the first superconducting planar undulator to be installed in the APS storage ring. The current status of the project is presented in this paper.

INTRODUCTION

The potential advantage of superconducting technology over existing pure permanent magnet and hybrid technologies for insertion devices was recognized at the APS and led to a long-term R&D project to develop a superconducting undulator for the APS. During recent years, a number of magnetic structure prototypes were built and successfully tested, leading to the present development of the first full-scale superconducting undulator, SCU0. The goal of this undulator is to verify several key concepts in the design as well as to gain practical experience in running such a novel device in the APS storage ring. Three more superconducting undulators are planned to be built and installed at the APS as a part of the APS Upgrade project [1].

PARAMETERS OF THE FIRST UNDULATOR

The goal of our first test device is to gain experience in building an installable undulator complete with cryomodule, so SCU0 contains a relatively short magnet in a full-scale cryostat. Extending the length of the magnetic structure was deferred to the next device (SCU1), which will use the same cryostat and a longer version of the magnet. While the SCU0 magnet has only 42 magnetic poles, the SCU1 magnet will have 144 poles as does the APS-standard 33-mm-period hybrid Undulator A. The parameters for SCU0 were chosen to provide first-harmonic photons in the range of 20-25 keV. Calculations predict that at photon energies near 100 keV, a 0.33-m-long SCU0 magnet operating in the 5th harmonic will produce higher photon flux than a 2.4-m-long Undulator A at the same energy. Parameters of SCU0 are summarized in Table 1.

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Table 1: SCU0 Specifications

Electron beam energy	7 GeV
Photon energy at 1 st harmonic	20-25 keV
Undulator period	16 mm
Magnetic gap	9.5 mm
Undulator peak field	0.4-0.65 T
Magnetic length	330 mm
Cryostat length	2063 mm

MAGNET

The SCU0 magnetic structure consists of a pair of identical magnets (“jaws”) separated by a gap where a beam chamber is accommodated. Each jaw is a series of racetrack superconducting coils wound into grooves that are precisely machined into a steel former. Several such magnetic structures were built and tested at the APS. The SCU0 magnet is shown in Fig. 1.

After winding and resin impregnation, the magnet was

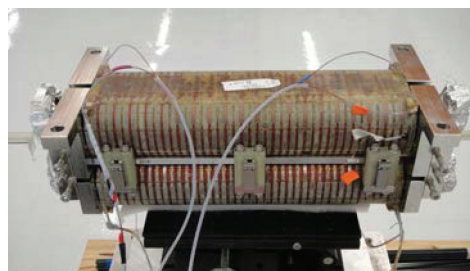


Figure 1: SCU0 magnet.

tested in a vertical liquid helium (LHe) bath cryostat. After training, the magnetic performance of the magnet was measured. It achieved the design field of 0.64 T at a nominal current of 500 A. The measured first and second field integrals were about 50 G-cm and 1200 G-cm², respectively. The measured magnetic field phase error was 1.5° rms. The magnet was then installed into the SCU0 cold mass.

COLD MASS

The SCU0 cold mass includes the magnetic structure described above, a liquid helium tank with LHe circuit piping, a beam chamber assembly, and a stainless steel support frame. The design of the SCU0 cooling system is

described in [2]. It is worth noting that the magnetic jaws are cooled by LHe that passes through the channels in the magnet cores while the beam chamber is conduction-cooled by the two bottom cryocoolers. A vacuum gap of 0.4 mm between the magnet cores and the beam chamber, together with carefully designed beam chamber supports, will minimize heat leak into the 4 K circuit from the 20 K beam chamber. Such a small gap required careful assembly of the cold mass; this was accomplished with the help of the APS Survey and Alignment Group specialists. After assembly, the cold mass was leak-checked and instrumented. About a dozen temperature sensors will monitor the temperature of the LHe circuit, of the superconducting magnet jaws, and of the beam chamber. The magnet is also equipped with several



Figure 2: Assembled cold mass.

voltage taps so intermediate voltages can be monitored for quench detection. The completed cold mass is shown in Fig. 2.

CURRENT LEADS

In the SCU0, one pair of current leads supplies 200- to 500-A current to the main superconducting coils, and two pairs of leads supply 50-A current to two correction coils wound at the ends of the main coils. The current lead assemblies use both normal-conducting brass leads and commercial HTS leads. The HTS leads are cooled by the first and the second stages of a cryocooler cold head that, together with the leads, comprises a current lead assembly as shown in Fig. 3.

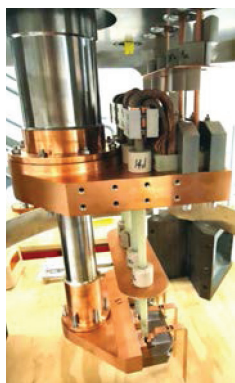


Figure 3: 50-A current lead assembly.

The original design of the current lead assemblies was substantially modified to lower the operation temperature of the HTS leads. This was achieved by improving the thermal contacts between the HTS leads and the copper blocks mounted on the first and second stage of the cryocooler cold head. Both 50-A and 500-A lead assemblies were pre-tested in a dedicated cryostat.

RADIATION SHIELDS

In the SCU0, two radiation shields are used to minimize radiative heat load on the cold mass. The inner shield is thermally connected to the second stages of the two bottom cryocoolers and will be at a temperature of about 20 K. The outer radiation shield is thermally linked



Figure 4: 60-K radiation shield with MLI blankets.

to the first stages of all four cryocoolers and will be at a temperature of about 60 K. This shield is also covered by multilayer insulation (MLI) blankets as shown in Fig. 4.

CRYOSTAT

The design of the SCU0 cryostat follows the concept developed at the Budker Institute, Novosibirsk, Russia, and implemented in their superconducting wigglers [3]. A 3D design model of the SCU0 cryomodule is shown in Fig. 5. The SCU0 cryostat vacuum vessel was manufactured by PHPK Technologies, Ohio. This vendor also manufactured the SCU0 radiation shields and the LHe tank. The superconducting undulator cryomodule is a complex system and the design included a detailed assembly procedure. Although the procedure developed

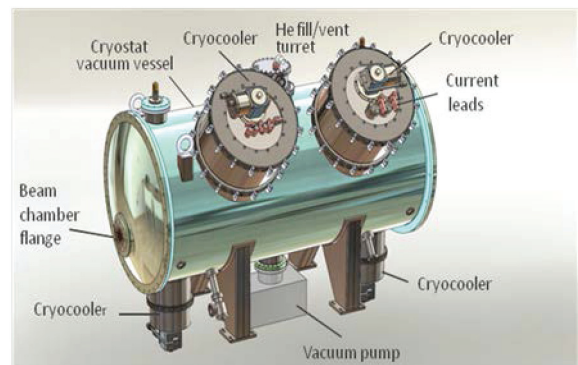


Figure 5: Drawing of the SCU0 cryomodule.

for the SCU0 assembly was carefully thought out, practical hands-on experience proved to be essential.



Figure 6: Assembly test of the SCU0 cryostat.

Therefore we tried to make fit tests of most of the SCU0 components before the final assembly. For instance, the fit test of the cold mass was done as shown in Fig. 6.

CONTROL SYSTEM

Two versions of the SCU0 control system are being developed – a LabVIEW-based system and an EPICS-based system. The LabVIEW control system, an extension of the system used for the earlier magnet tests, could be developed quickly for use as a standalone system for performing the SCU0 cold tests in the assembly and measurement facility. The final EPICS system will be used to control the device once it is installed into the APS storage ring. One of the windows of the LabVIEW control system is shown in Fig. 7.

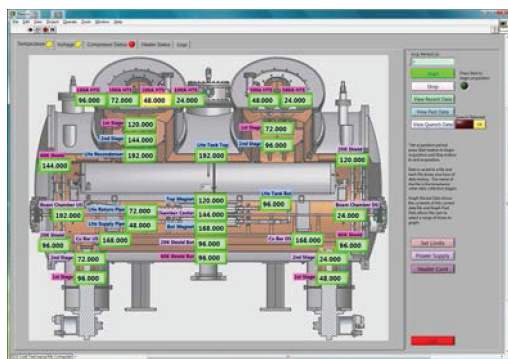


Figure 7: Temperature window of the LabVIEW-based control system.

MEASUREMENT SYSTEM

The design of the SCU0 measurement system is described in [4]. The mechanical part of the system includes a 4-m-long horizontal stage and two assemblies that will be mounted on the SCU0 cryostat flanges. The system was assembled as shown in Fig. 8. Hall probes as



Figure 8: Horizontal measurement system.

well as stretched rectangular and ‘figure-8’ coils will be used to measure the SCU0 magnetic performance.

PROJECT STATUS

The current status of the SCU0 can be summarized as follows:

- Magnet is built and has been tested in a vertical LHe cryostat.
- Cold mass is assembled and instrumented.
- Radiation shields are assembled.
- Current lead blocks are assembled and tested.
- Cryomodule assembly test is completed.
- Two versions of the control system are being developed.
- Horizontal measurement system is assembled and tested.

CONCLUSION

The APS superconducting undulator project team is working towards finishing assembly of the first superconducting undulator late in the spring of 2012. After completion of cold testing, planned for summer 2012, the device will be installed into the APS storage ring.

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