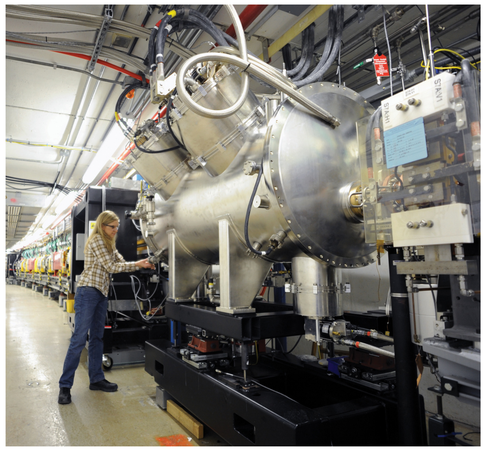
Evolution of the Design of the Magnet Structure for the APS Planar Superconducting Undulators

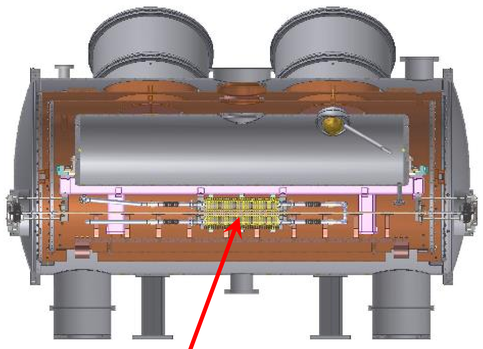
Emil Trakhtenberg, Matt Casa, Yury Ivanyushenkov
Advanced Photon Source, Argonne National Laboratory, Argonne IL 60439
* **E-mail:** emil@aps.anl.gov

INTRODUCTION

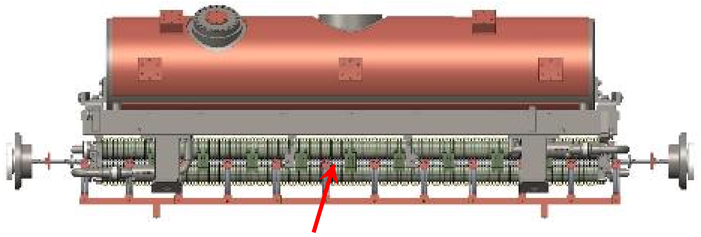
A number of superconducting planar undulators (SCU) with different pole gaps and periods were designed, manufactured, and successfully operated at the Advanced Photon Source (APS) storage ring. A key component of the project is the precision machining of the magnet structure and the precision of the coil winding. The design of the magnet core had a number of modifications during the evolution of the design in order to achieve the best magnetic performance. The current design of the magnet structure is based on the assembled jaws with individual poles, while previous designs utilized solid cores with machined coil grooves. Also, the winding procedure changed from the first test cores to the current final design.



First Superconducting Undulator SCU0 in the Storage Ring

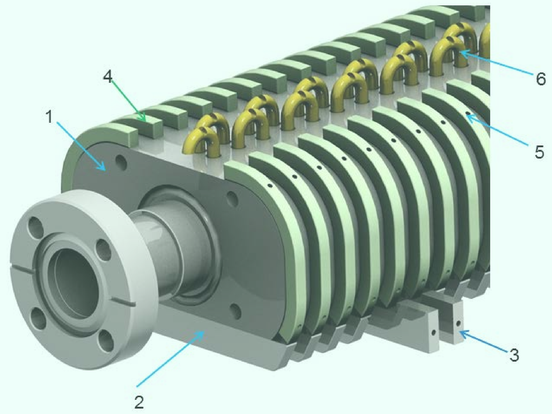


SCU0 Cross-Section (33.6-cm-long magnet structure attached to the liquid helium tank)



Cryostat Cold Mass (with 1.5-meter-long magnet structure attached to the liquid helium tank)

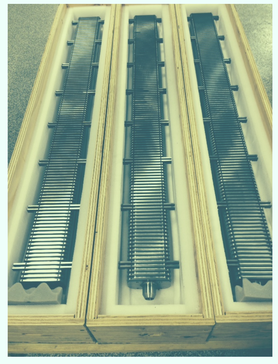
Final Design of the Magnet Structure Jaw for the Planar Superconducting Undulator



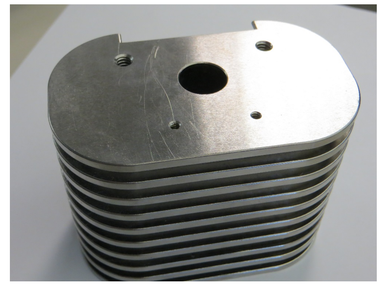
1. Core with machined grooves only on the face side
2. Main poles
3. Poles with the end tabs used for jaw assembly
4. G10 side spacers
5. Spring pins holding G10 spacers in place
6. Special pins for "U-turn" during winding

Here is the final technological process of production of the magnet cores for the planar SCU:

1. Preliminary machining of the core made of low carbon steel 1018 with annealing after it;
2. Final grinding of the core to achieve the best flatness (better than 50μm over the whole length) and the best surface finish;
3. Machine grooves for the poles avoiding accumulation errors;
4. Machining, annealing, grinding and final lapping of the poles made of 1006 steel to achieve the best surface finish and dimensional uniformity within 10 μm;
5. Pole installation inside core grooves using "go" "no go" gages and #1 screws;
6. Grinding of the pole face side with the reference to the core face plane to get maximal uniformity of the groove depth for winding;
Inspection of the all critical dimensions (groove depth and width, pole face flatness along the whole core). Inspection is made two times – at the vendor place first and then in house before winding .

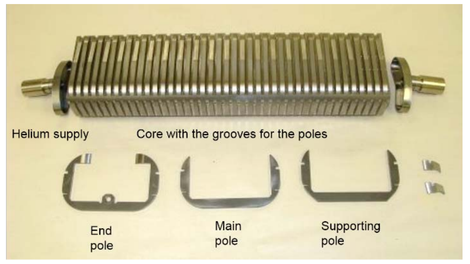


1.5-meter-long magnet structures precisely machined according this technology



First Design of the Magnet Structure Jaw for the Planar Superconducting Undulator

Several planar SCU magnet structures with lengths of 0.4 meter, 1.1 meters (two) and 1.5 meters have been machined and wound with superconducting wire. Initially for prototyping we considered a core made of one rectangular piece with round corners of low carbon steel 1006-1008. This core had continuous grooves for the superconducting wire around the whole piece. It required rotation of the core around its longitudinal z-axis to produce such grooves during the machining process. This is acceptable for a short core length, but will create machining challenges for cores of lengths greater than one meter. One more detail which requires much attention is the surface finish of the bottom of the coil winding groove and the groove side walls. The surface finish is required to be very smooth in order to avoid damaging the superconducting wire insulation during the coil winding process. Hand polishing of these surfaces could be very labor intensive and therefore costly.



Design Modification of the Magnet Structure Jaw for the Planar Superconducting Undulator

. The racetrack was machined precisely with flatness on the face plane (the beam side) better than 50 microns over the whole length and the surface of the core can be polished easily. This polished surface ends up being the base of the winding groove.
The next operation is to machine precise grooves on the face plane with strict tolerances on the groove width, depth and location. To avoid an accumulated error in the pole location each groove is machined from the same initial reference plane. Magnetic poles, precisely grinded and lapped which results in an excellent surface finish are installed in the prepared grooves. Such a design allows the poles to be ground all together after installation and with reference to the flat core plane to achieve uniformity of the depth of grooves for the superconducting wire coil packs. The poles are attached to the core with #1-64 screws.

Complete 33.6-cm-long cores