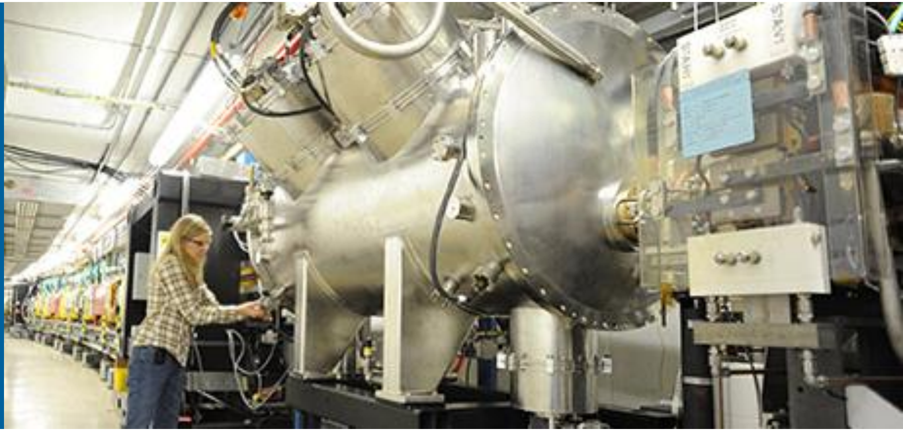
R&D AND OPERATIONAL EXPERIENCE OF SCUs IN AMERICA



YURY IVANYUSHENKOV
Advanced Photon Source
Argonne National Laboratory

on behalf of the US SCU Community

Superconducting Undulators for Advanced Light Sources Virtual Workshop, April 19-21, 2021

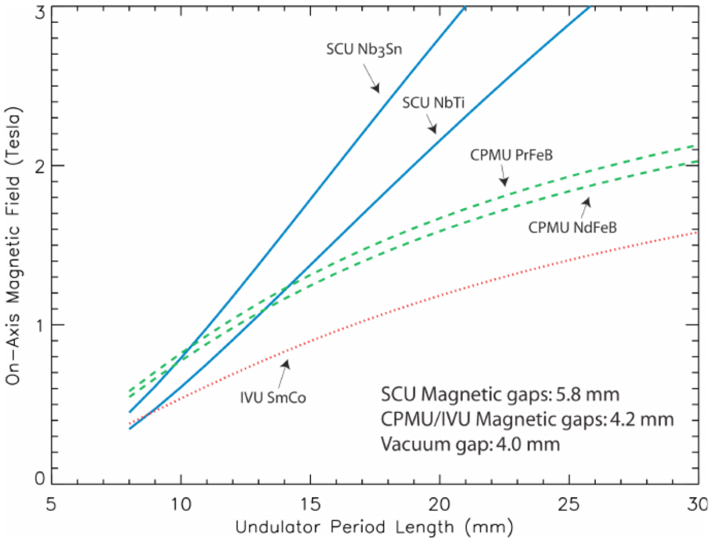
SCOPE

- Motivation for superconducting undulators (SCUs)
- SCUs for storage ring light sources:
  - SCUs for APS
  - Operation of SCUs
  - SCUs for APS Upgrade
  - SCUs for NSLS-IIU
- SCUs for FELs
  - Magnet prototype
  - Undulator demonstrator for LCLSII
  - Advanced SCUs at FNAL
- Employing various conductors in SCUs:
  - Development of Nb_3Sn Undulators at LBNL
  - Nb_3Sn undulator for APS
  - R&D on HTS SCU
- Summary

ADVANTAGE OF SUPERCONDUCTING UNDULATORS

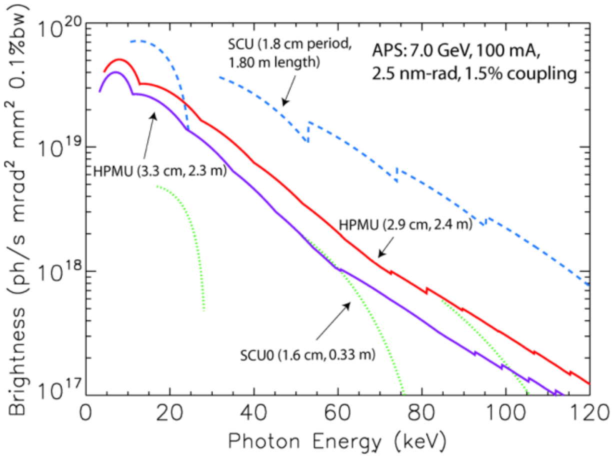
MAGNETIC FIELD OF VARIOUS INSERTION DEVICE TECHNOLOGIES

- A superconducting undulator (SCU) is an electromagnetic undulator that utilizes superconducting coils for generating magnetic field.
- Superconducting technology-based undulators outperform all other technologies in terms of peak magnetic field and, hence, energy tunability of the radiation
- Superconducting technology opens a new avenue for insertion devices



Calculated on-axis magnetic fields of two cryogenic permanent magnet undulators (CPMUs), two superconducting undulators (SCUs) and on in-vacuum undulator (IVU) for a vacuum gap of 4.0 mm for period length from 8 mm to 30 mm.

Calculated tuning curves for SCUs and for hybrid undulators.

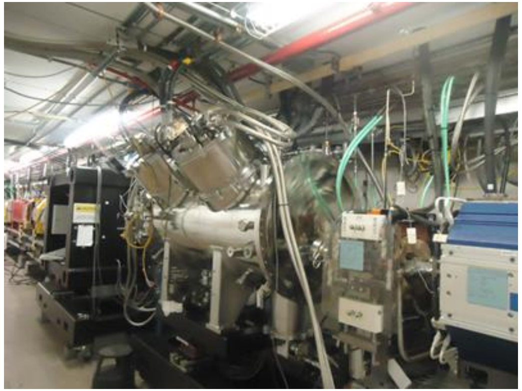


E. Moog, R. Dejus, and S. Sasaki, "Comparison of Achievable Magnetic Fields with Superconducting and Cryogenic Permanent Magnet Undulators – A Comprehensive Study of Computed and Measured Values", ANL/APS/LS-348, 2017.

SUPERCONDUCTING UNDULATORS FOR APS

DEVELOPMENT OF SUPERCONDUCTING UNDULATORS AT THE APS

- SCU0 [1]:
  - 16-mm period length
  - 0.33-m long magnet
  - In operation: Jan2013-Sep2016
- SCU1(SCU18-1) [2]:
  - 18-mm period length
  - 1.1-m long magnet
  - In operation: since May2015
- SCU18-2:
  - 18-mm period length
  - 1.1-m long magnet
  - In operation: since Sep2016



SCU18-2 in Sector 6 of the APS ring.

- LCLS R&D SCU:
  - 21-mm period length
  - 1.5-m long magnet
  - Project completed in 2016
- Helical SCU [3]:
  - 31.5-mm period length
  - 1.2-m long magnet
  - In operation: since Jan2018
- Nb_3Sn undulator:
  - 18-mm period length
  - 1.1-m long magnet
  - In progress
- R&D projects [4]:
  - HTS SCU – completed
  - SCAPE – in progress

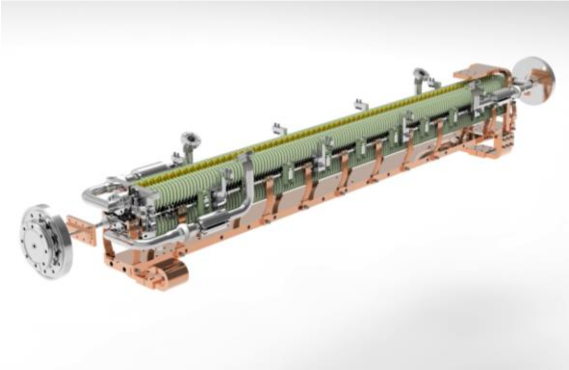
[1] Y. Ivanyushenkov et al., “Development and operating experience of a short-period superconducting undulator at the Advanced Photon Source,” Phys. Rev. ST Accel. Beams 18, 040703 (2015).
[2] Y. Ivanyushenkov et al., “Development and operating experience of a 1.1-m-long superconducting undulator at the Advanced Photon Source,” Phys. Rev. Accel. Beams 20, 100701 (2017).
[3] M. Kasa et al., "Development and operating experience of a 1.2-m long helical superconducting undulator at the Advanced Photon Source," Phys. Rev. Accel. Beams 23, 050701 (2020).
[4] Yury Ivanyushenkov and Efim Gluskin. "Development of Superconducting Undulators at the Advanced Photon Source." ICFA Beam Dynamics Newsletter, No. 78, December 2019: 8-26.

PLANAR SCU LAYOUT

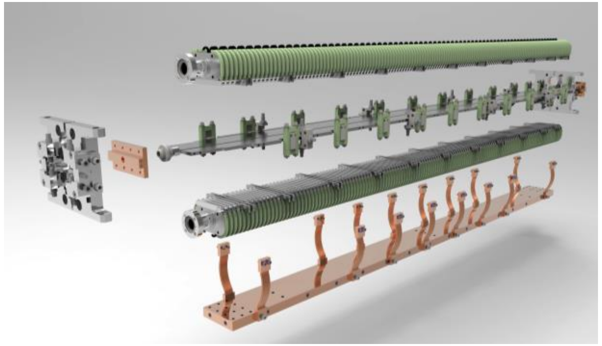
Assembled cryostat.

SCU cold mass.

Magnet – beam vacuum chamber assembly.



Magnet cores and beam vacuum chamber.

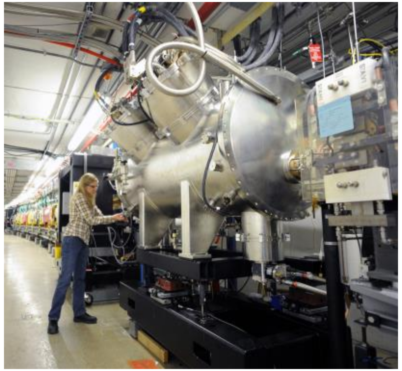


- SCU0-type cryostat was developed in collaboration with Budker Institute, Russia
- SCU cryostat consists of vacuum vessel, thermal shield and a cold mass
- Two-core SCU magnet structure
- Cooling is provided by cryocoolers
- Closed-loop LHe circuit
- LHe is contained in a tank connected with the magnet
- NbTi coils are cooled indirectly with LHe passing through channels in the magnet cores
- Beam chamber is thermally isolated from the magnet, and cooled independently

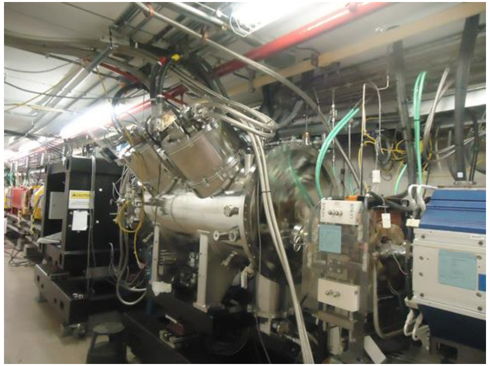
SCU18-1 (SCU1) AND SCU18-2

- Two similar undulators, SCU18-1 and SCU18-2, were completed and installed on APS storage ring
- The SCU18-1 has been in operation since May 2015 and SCU18-2 started operation in September 2016

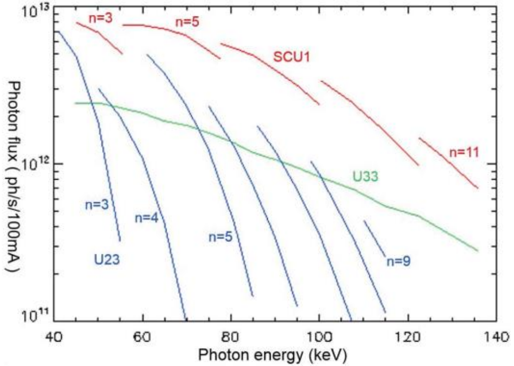
Parameter	SCU18-1 and SCU18-2
Cryostat length (m)	2.06
Magnetic length (m)	1.1
Undulator period (mm)	18
Magnetic gap (mm)	9.5
Beam vacuum chamber vertical aperture (mm)	7.2
Undulator peak field (T)	0.97
Undulator parameter K	1.63



SCU18-1 in Sector 1 of the APS ring.



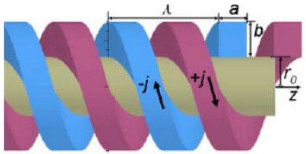
SCU18-2 in Sector 6 of the APS ring.



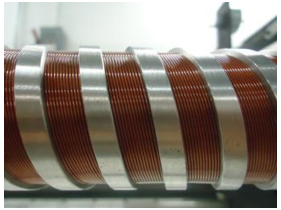
Measured SCU18-1 tuning curves in comparison with those of hybrid undulator U33 (Undulator A) and undulator U23.

HELICAL SCU FOR APS

- SCU technology offers the possibility of building circular polarizing helical undulators
- A helical SCU (HSCU) was installed on APS ring in December 2017. In operation since January 2018
- X-ray photon correlation spectroscopy program at the APS benefits from the increased brilliance provided by an HSCU

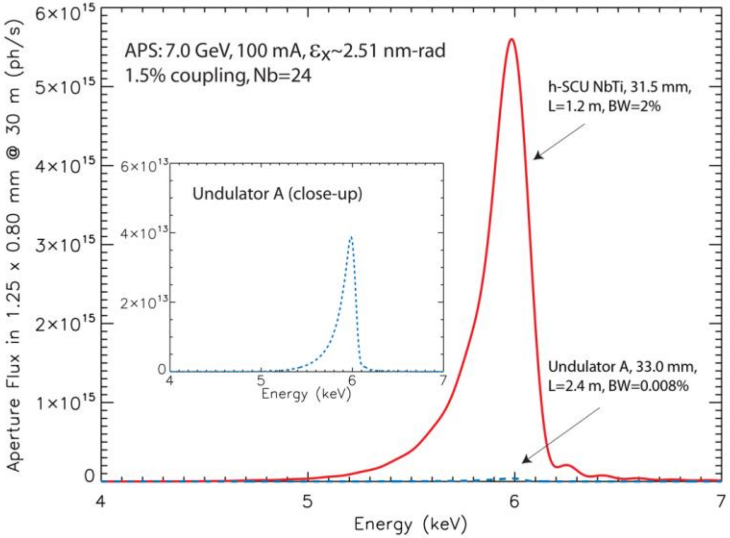


Magnetic model of HSCU.



HSCU prototype coil winding.

HSCU magnet core.



Calculated photon spectrum of helical SCU.

Parameter	HSCU
Cryostat length (m)	1.85
Magnetic length (m)	1.2
Undulator period (mm)	31.5
Magnetic bore diameter (mm)	31.0
Beam vacuum chamber vertical aperture (mm)	8
Beam vacuum chamber horizontal aperture (mm)	26
Undulator peak field Bx=By (T)	0.4
Undulator parameter Kx=Ky	1.2

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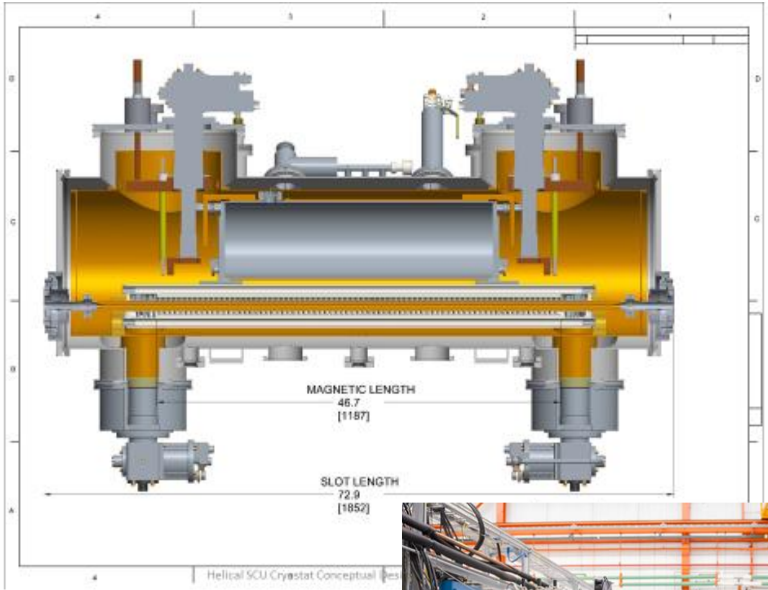
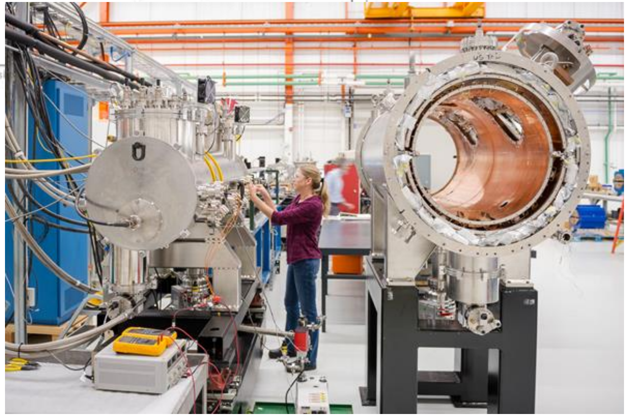
HSCU CRYOSTAT

- The 2nd generation cryostat is developed at the APS
- One thermal shield
- Four RDK415D cryocoolers
- Two temperature stages
- Reduced diameter of the vacuum vessel
- Vertical turrets
- Standard flanges for the end covers
- Simplified design of He filling port



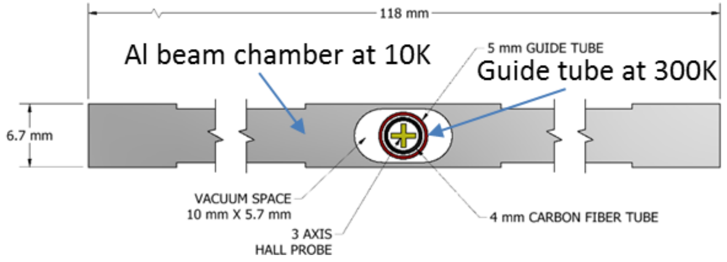
J. Fuerst et al., “A second-generation superconducting undulator cryostat for the APS,” Proceedings of CEC-ICMC 2017, Madison, 2017.



HSCU cryostat (left) and SCU0/SCU1 cryostat (right)

MEASURING SCU FIELD

- Warm sensor concept (by Budker Institute, Russia):
  - Metallic guide tube is stretched inside the beam chamber cold bore
  - Guide tube is heated by the current passing through it
  - Guide tube bore is open to atmosphere
- Sensor (Hall probe or wire coil) operates at the room temperature
  - Hall probe:
  - 3-axis commercial Hall sensor measures By, Bx, Bz components
  - Attached to fiber tube and driven by precise 3.5-m linear stage
  - Bz- field is used to measure vertical position of the sensor
- Stretched wire coils:
  - Rectangular, delta and 'figure- 8' coils stretched between two linear and rotation stages
  - Measure static and dynamic field integrals and multipole components



Warm-sensor concept

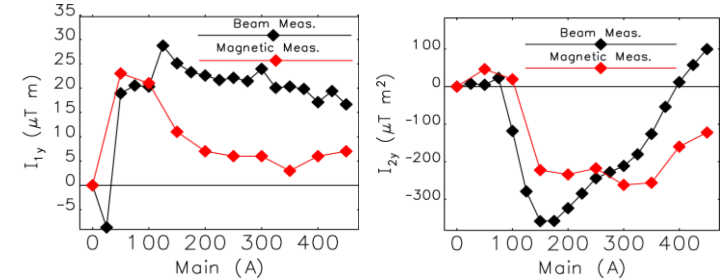
SCU horizontal measurement system

C. Doose and M. Kasa, "Magnetic measurements of the first superconducting undulator at the Advanced Photon Source," Proceedings of PAC2013, THPBA06, Pasadena, CA USA, 2013.

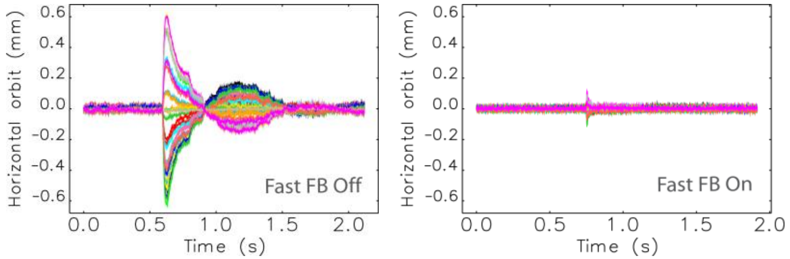
OPERATION OF SCUs

SCU EFFECT ON THE ELECTRON BEAM

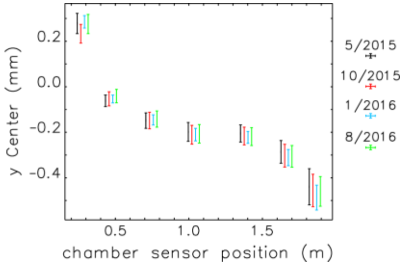
- SCU field integrals satisfy the physics specifications
- SCU quench produces only small beam motion and does not cause loss of the beam
- Position of the SCU vacuum chamber is stable and does not require realignment
- SCU cryocooler vibrations do not affect beam stability
- SCU operation does not affect the beam lifetime



Vertical-field integrals of initial correction as measured using the stored beam, before final beam-based adjustments. The first integral is on the left and the second integral is on the right [1].



Effect of induced quench on the beam orbits at all the insertion devices. Left panel: Slow orbit correction only. Right panel: Fast orbit correction (FB) turned on [1].



Measured vertical position of the vacuum chamber inside the cryostat over a one-year period using the beam-based method [1,2].

[1] Y. Ivanyushenkov et al., PRAB, 20, 100701 (2017)
[2] K. Harkay et al., Proc. of NA-PAC'13, WEPSM07, 2013

APS SCU RELIABILITY

- SCU0, SCU18-1 and SCU18-2 have been essentially transparent to the APS SR beam
- Most quenches occur during unplanned beam dumps; only 3 self-quenches in 2017
- SCU18-1/18-2 quenches decreased dramatically after beam abort system added Jan 2016

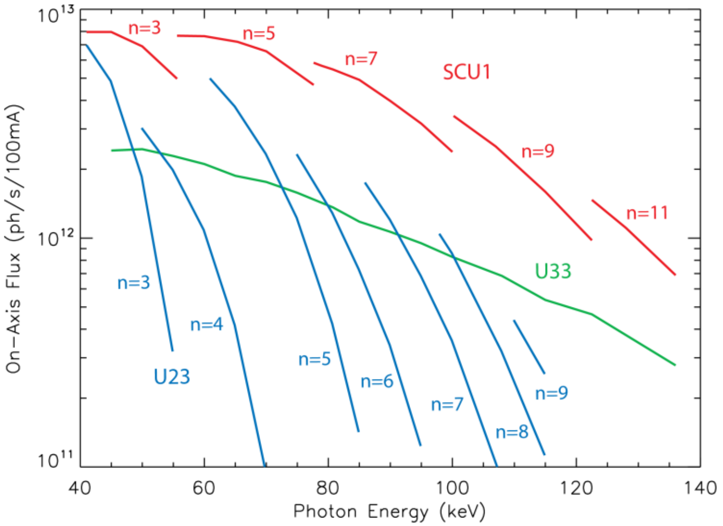
		SCU0 and SCU18-2				SCU18-1				HSCU			
Year	**APS delivered**	**Operation**	**Down**	**Quench**	**Avail. %**	**Operation**	**Down**	**Quench**	**Avail. %**	**Operation**	**Down**	**Quench**	**Avail. %**
2013	4871 h	4189 h	20 h	*34* + 3	99.5	-	-	-	-	-	-	-	-
2014	4926 h	4391 h	174 h [1]	*32* + 2	96.2	-	-	-	-	-	-	-	-
2015	4940 h	4834 h	0 h	*26* + 1	100	3059 h [2]	0.1 h	*5* + 0	99.997	-	-	-	-
2016	4941 h	4647 h [3]	0 h	*9* + 0	100	4585 h	0.3 h	*11* + 1	99.990	-	-	-	-
2017	4840 h	4756 h	0 h	*8* + 1	100	4818 h	0.75 h	*13* + 2	99.984	-	-	-	-
2018 [4]	3327 h	3236 h	5 h	*11* + 1	99.8	3199 h	0.59 h	*9* + 2	99.981	533 h	0 h	*0* + 0	100
Total	27845 h	26053 h	199 h	*120* + 8	**99.24**	15661 h	1.74 h	*29* + 3	**99.99**	533 h	0 h	*0* + 0	**100**

- e-beam has never been lost due to self-quenches
- *Red = beam dump-induced quench*
- Blue = non-beam dump, possible self-induced quench

[1] November: Partial loss of one cryocooler capacity
[2] Installed in May; operated May – Dec. 2015
[3] SCU18-2 replaced SCU0 in Sep.; SCU0 3310 h, SCU18-2 1337 h
[4] January 2018 through September 2018

RADIATION PERFORMANCE OF APS SUPERCONDUCTING UNDULATORS

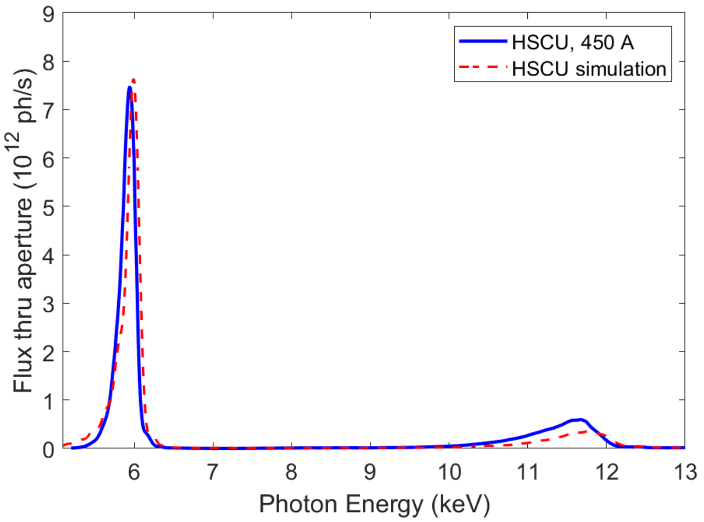
SCU1



Measured odd-harmonic SCU1 tuning curves (450 A maximum) of monochromatic flux through a 0.5 × 0.5 mm2 aperture at 27.5 m compared with those of 11-mm minimum gap permanent magnet devices U33 (continuous tuning curve envelope) and U23 (even and odd harmonics) [1].

[1] Y. Ivanyushenkov et al., Phys. Rev. Accel. Beams 20, 100701 (2017).

HSCU



Simulated and measured spectrum of HSCU with the device operating with a 450 A current. The aperture is 0.2 mm vertical by 0.6 mm horizontal at 27 m from the source, giving an angular aperture of 7.5 μrad vertical by 22 μrad horizontal [2].

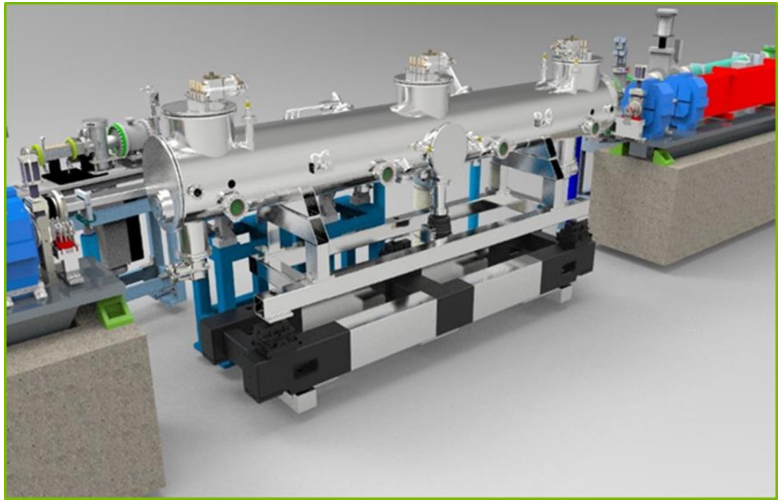
[2] M. Kasa et al., Phys. Rev. Accel. Beams 23, 050701 (2020).

SUPERCONDUCTING UNDULATORS FOR APS UPGRADE

SCUs FOR APS UPGRADE

- Four planar SCUs:
  - Two in-line SCUs (each with two in-line undulator sources in a long cryostat)
  - Two canted SCUs (each with two canted undulator sources in a long cryostat)
- Variably polarizing SCU:
  - SCAPE

Location	Configuration	Upstream device	Downstream device
01-ID	Dual Inline in Long Cryostat	SCU 1.65	SCU 1.65
11-ID	Canted in Long Cryostat	SCU 1.65	SCU 1.65
20-ID	Dual Inline in Long Cryostat	SCU 1.65	SCU 1.65
28-ID	Canted in Long Cryostat	SCU 1.85	SCU 1.85



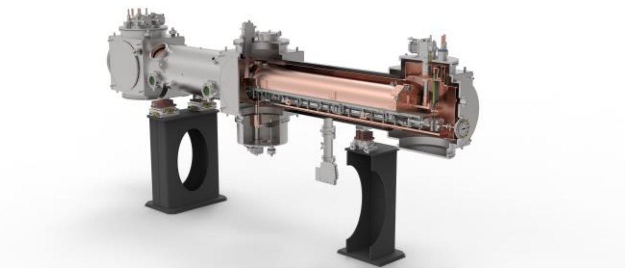
Design model of APS-U ID straight section with an SCU

APSU SCUs

- Magnet design is based on a proven design of existing SCU magnets:
  - up to 1.9-m long core with a channel for LHe
  - proven winding scheme
- Cryostat design is based on a proven design of the 2-m cryostat for Helical SCU:
  - 4.8-m long 20”-diameter vacuum vessel;
  - single thermal shield;
  - off-shelf vacuum components;
  - three thermal stages (4K – 20K – 40K);
  - 6 cryocoolers (two types) with a possibility of adding one if required
- Article #1 is in fabrication

Completed 1.9-m long core

Cryostat design model



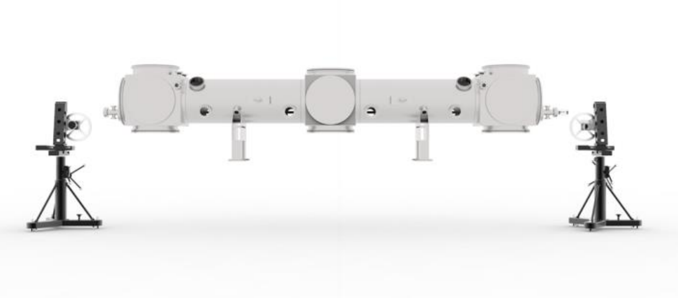
Cryostat vacuum vessel

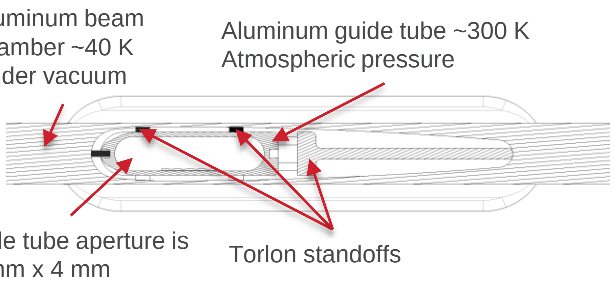
LHe tank

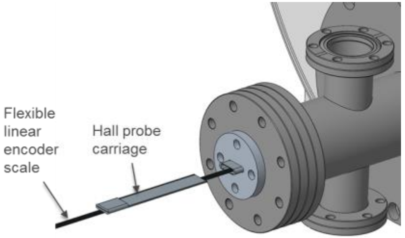
NEW SCU MEASUREMENT SYSTEM

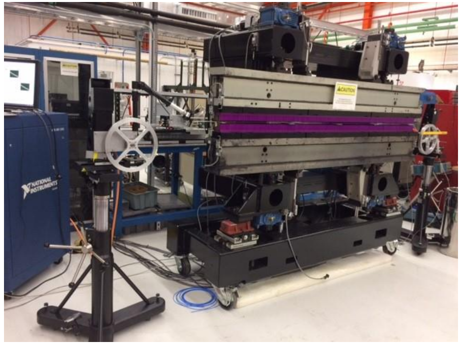
- New design is based on experience of using a 2-m long measurement system for the APS SCUs:
  - a proven concept of a warm guiding tube
  - Hall probe carriage is moved with a flexible linear encoder scale
  - does not require a long holder attached to a long travel linear stage
- System is fabricated, assembled and tested. It’s being used to measure a well characterized HPMU.

M. Kasa and Y. Ivanyushenkov, “Magnetic measurement system being developed for SCU program at the APS”, presented at IMMW21, Grenoble, France, June 2019.
M. Kasa et al., U.S. patent No.10,908,231, 2021







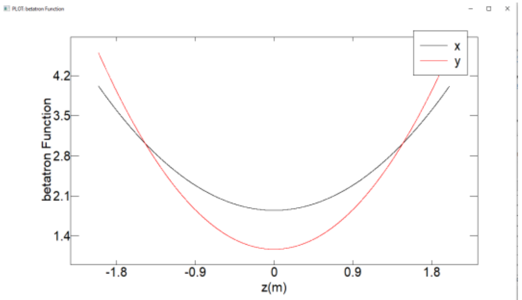


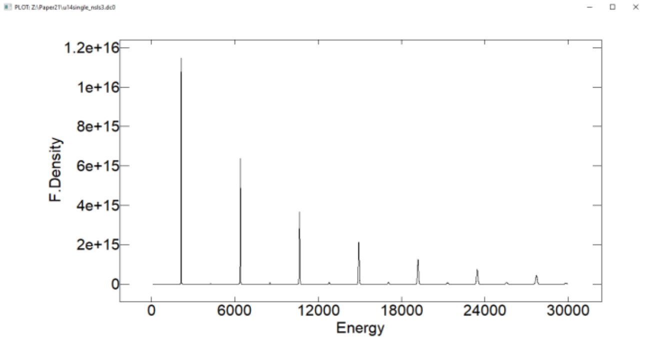
NSLS-II UPGRADE DOUBLE MINIMUM BETA LATTICE WITH SCU14s

NSLS-IIU Lattice (20 pm.rad/8pm.rad, 0.1% energy spread)

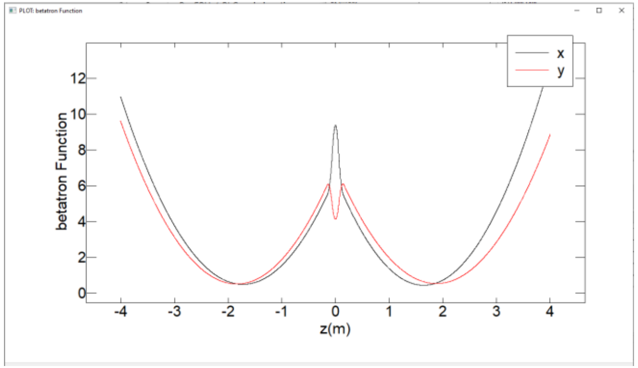
Flux Density (photons/sec/mm^2/0.1% BW) at 30m

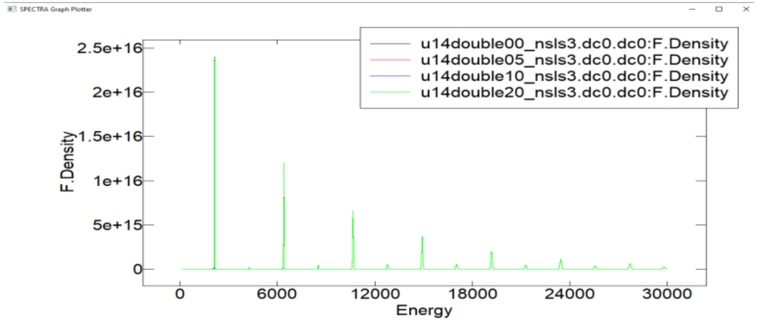
4m SCU14 with K=2.25, Betax=1.85m, Betay=1.17m





2x2m SCU14 with K=2.25





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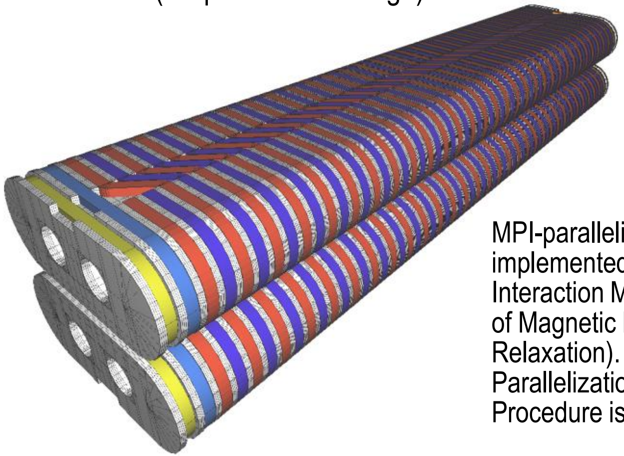
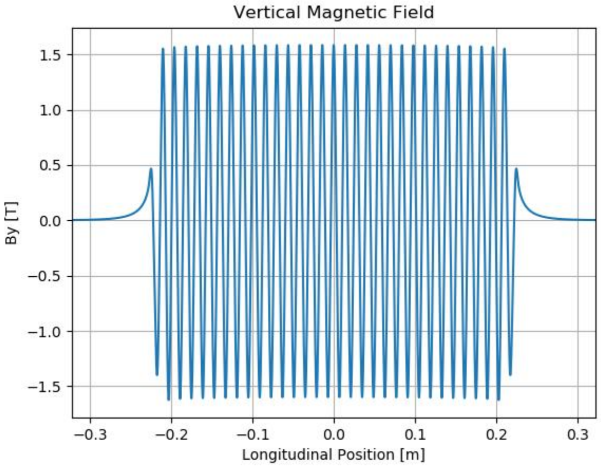
NEW OPEN-SOURCE PARALLEL VERSION OF RADIA CODE WITH PYTHON INTERFACE

Test SCU Model
(simplified APS design)



MPI-parallelization is currently implemented for setting up of Interaction Matrix and calculation of Magnetic Field (after Relaxation).
Parallelization of the Relaxation Procedure is still in progress.

On-Axis Magnetic Field
at 14 mm Period, 1.3 kA/mm^2 Current Density, 5 mm Vert. Gap



New RADIA versions are available from:
https://github.com/ochubar/Radia
(including the ones with Python and Mathematica interface; just "pull" the open source repository)

Development of new interfaces to Radia, based on Jupyter Notebooks and Sirepo GUI is in progress.

Work supported by US DOE SBIR Phase 2/2A grants - collaboration between NSLS-II and RadiaSoft LLC

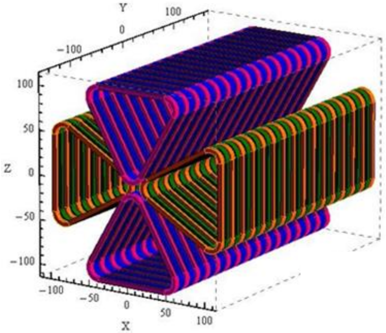
Problems can be solved within ~minutes on multi-core server or cluster (depending on complexity, segmentation, symmetries).

Work on new RADIA versions is done by O. Tchoubar, A. Banerjee (SBU) and RadiaSoft
Many thanks to Joel Chavanne and ESRF Management for releasing RADIA to Open Source!

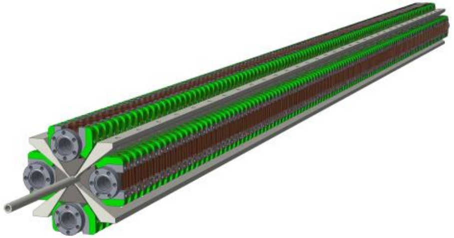
SCAPE

VARIABLY POLARIZING SCU— SCAPE

- Users of APS POLAR beamline would like to have an undulator that can generate both circular and planar polarized photons
- To answer this challenging request, APS SCU team developed the concept of a Super Conducting Arbitrary Polarizing Emitter, or SCAPE
- This electromagnetic superconducting undulator employs four planar magnetic cores assembled around a cylindrical beam vacuum chamber
- The APS Upgrade multi-bend achromat lattice enables round beam chambers (6 mm ID) for insertion devices
- The SCAPE concept is tested in a 0.5-m long prototype

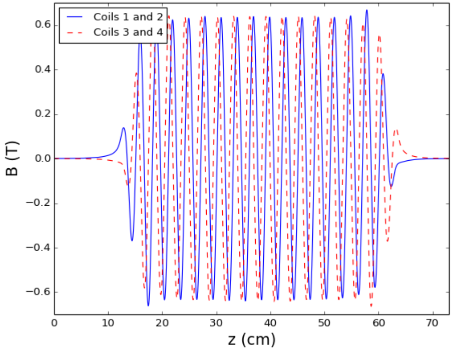


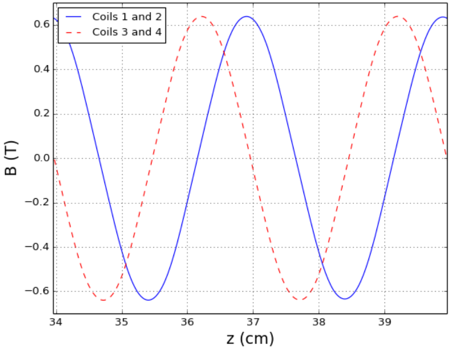
Concept of SCAPE: a universal SCU with four planar superconducting coil structures. A beam chamber is not shown.



SCAPE 3d design model

Measured field profiles

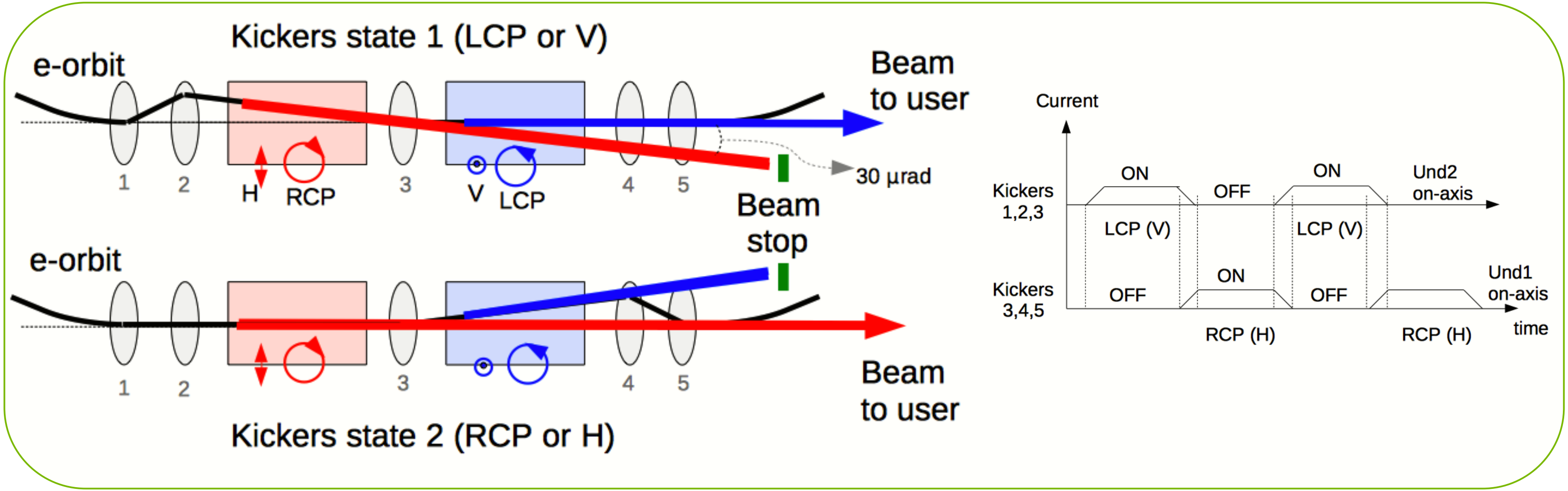




SCAPE mechanical structure

SCAPE POLARIZATION SWITCHING BY USING BEAM ORBIT BUMPS

- Local, alternating electron orbit bumps
- ~ 30 micro-rad bumps sufficient to achieve desired rejection (polarization “purity”)



Courtesy of Daniel Haskel, APS

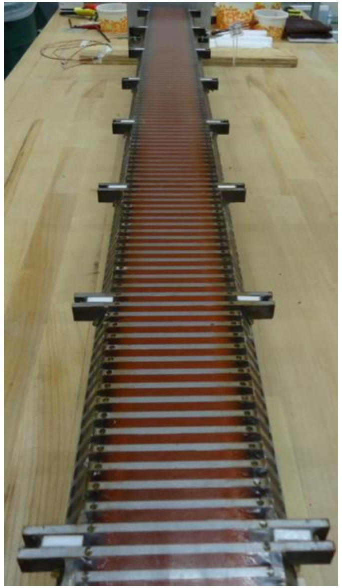
This scheme is a baseline for the APS-U

SCUs FOR FELs

LCLS R&D UNDULATOR

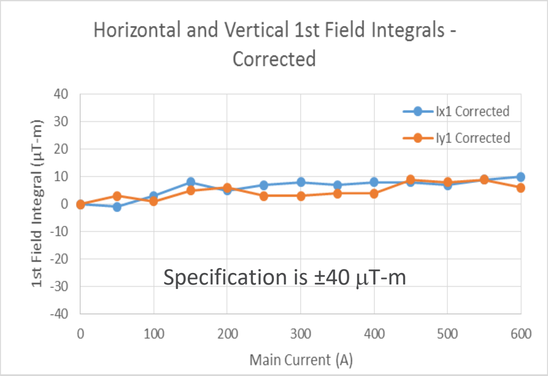
- The NbTi undulator was built at the APS as a part of the LCLS SCU R&D project aimed at demonstrating that SCU technology can achieve challenging specifications of FEL undulators [1].
- The undulator did achieve all the specifications including the most challenging requirement of 5º rms phase errors.

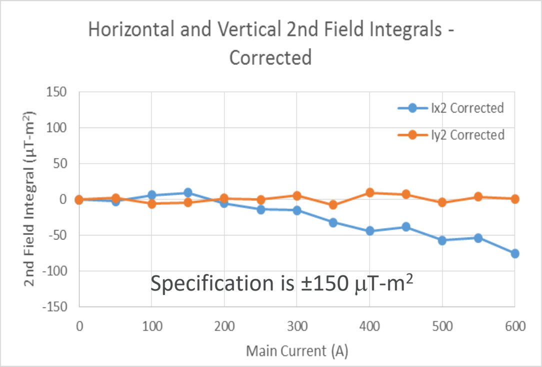
Parameter	LCLS R&D SCU
Cryostat length (m)	2.06
Magnetic length (m)	1.5
Undulator period (mm)	21
Magnetic gap (mm)	8.0
Beam vacuum chamber vertical aperture (mm)	5.7
Undulator peak field (T)	1.67
Undulator parameter K	3.26



Beam side of magnet core.

Measured first and second field integrals of LCLS R&D SCU.



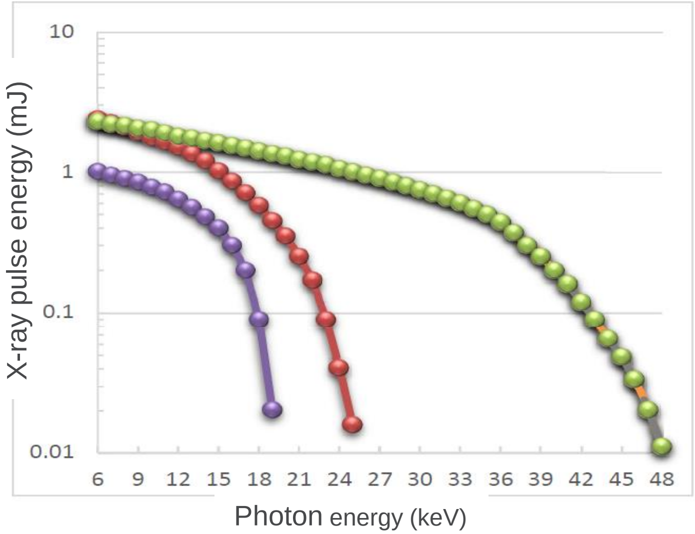


[1] P. Emma et al., in *Proc. of FEL2014*, Switzerland, 2014, paper THA03, pp.649-653.

BENEFITS OF SCUs OVER HPMUs

- Stronger magnetic fields, higher FEL performance.
- No mechanical motions for wavelength controls.
- Less susceptible to radiation damage, temperature drifts and wakefield effects.
- Cryo-pumped e-beam pipes provide excellent vacuum.
- SCUs increase the high X-ray energy reach for XFELs. Example: LCLS Cu linac with SCU can reach 48 keV.
- Combined with the high-repetition-rate SRF linac, SCU XFELs will increase the average coherent X-ray flux.

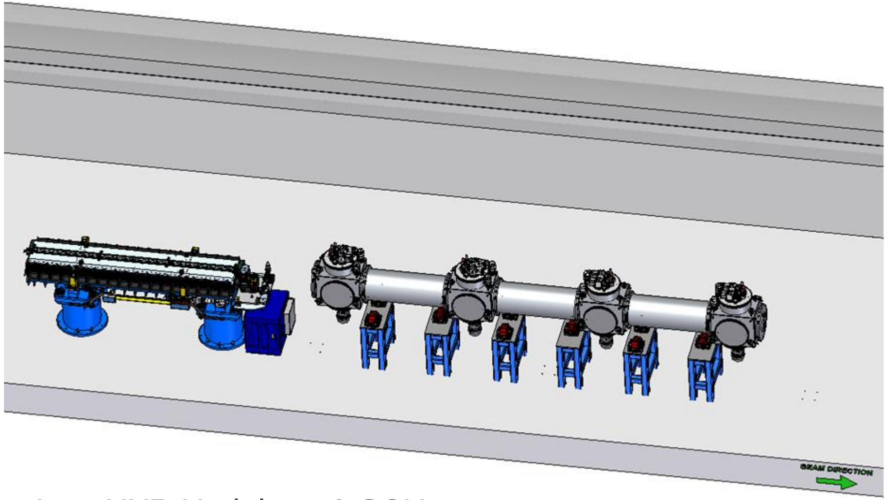
Parameter	Value	Factor driving requirement
Period length (mm)	21	Design Choice
Gap (mm)	8	Design Choice
B_0 @ full current	> 1.67 T	Matching with HXR FEL wavelength
$\Delta B/B_0$ variation along undulator	$\pm 5.5 \times 10^{-4}$	FEL requirement
$\lvert\int B_{x,y}dz\rvert$	< 50 μT-m	FEL requirement
$\lvert\iint B_{x,y}dz^2\rvert$	< 100 μT-m²	FEL requirement
Phase Shake (rms)	< 5°	FEL requirement



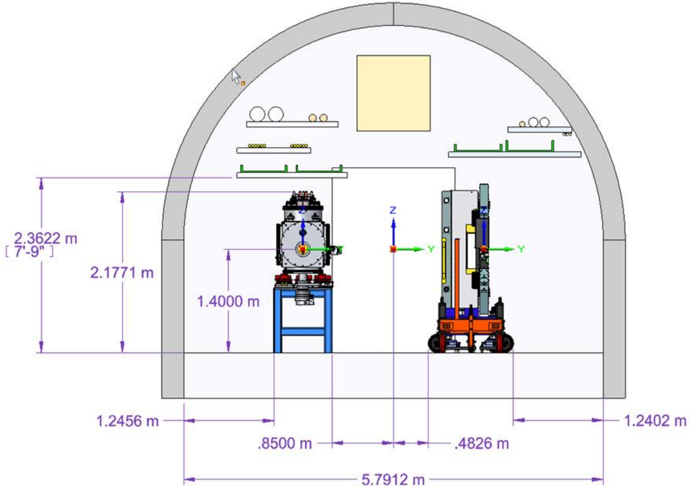
LCLS-II-HE can produce 2 mJ pulse energy with low emittance e- beams and SCUs.

SCU PERFORMANCE AS AN LCLS AFTER-BURNER

SLAC and Argonne National Laboratory propose to test SCU FEL performance at LCLS. The SCUs will be installed on the Hard X-ray Undulator beamline and operated as an after-burner to test alignment and to measure FEL gain.



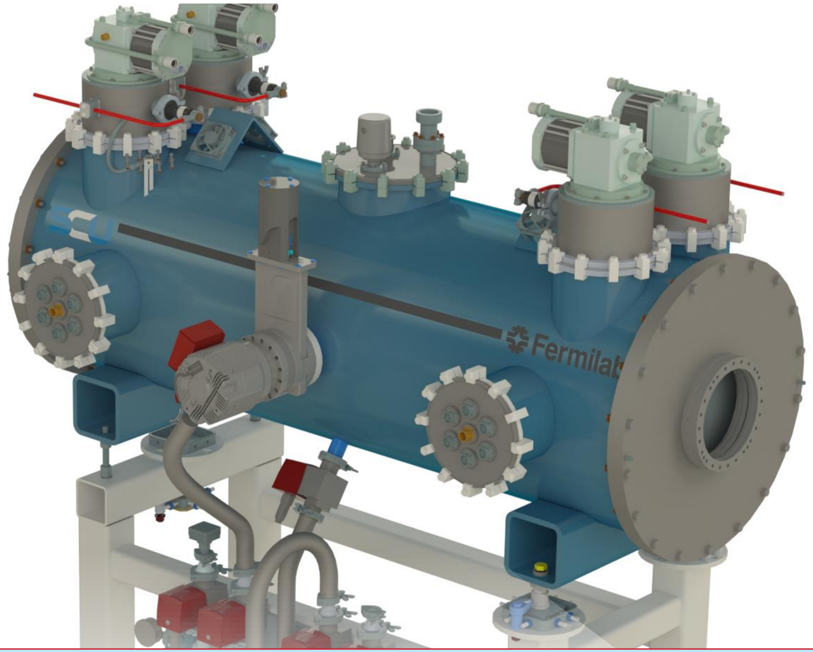
Last HXR Undulator & SCUs



Undulator Hall cross-section

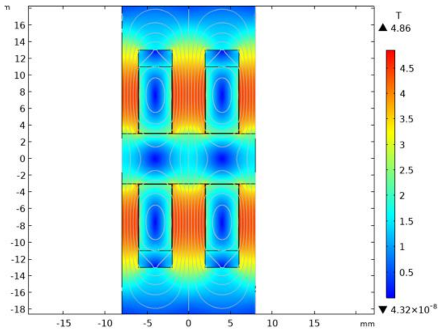
The FEL performance test proposal has been submitted to DOE Office of Science

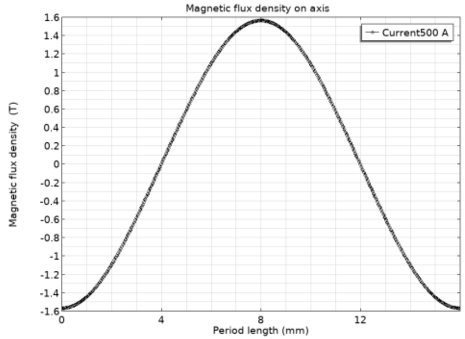
ADVANCED SCUs AT FERMILAB



Parameter	Value	Unit
Period	< 16	mm
Beam stay clear	5	mm
FEL wavelength	~3	nm
K-value	>1.2	-
Ramp to operating field	<600	s
Cooling	Cryocoolers	-
Operating temperature	4.2	K
Magnet length	1.5	m
Flange to flange length	<2.0	m
Beam height	1.1	m
Vacuum vessel diameter	0.6	m
Insulation vacuum	$1*10^{-5}$	mbar
Cooldown time	<7	days

EuPRAXIA@SPARCLAB Specifications





Advance NbTi conduction cooled SCU design for FELs and explore HTS designs (LDRD funding)

Refurbishing the conduction cooled test stand in APS-TD-IB1

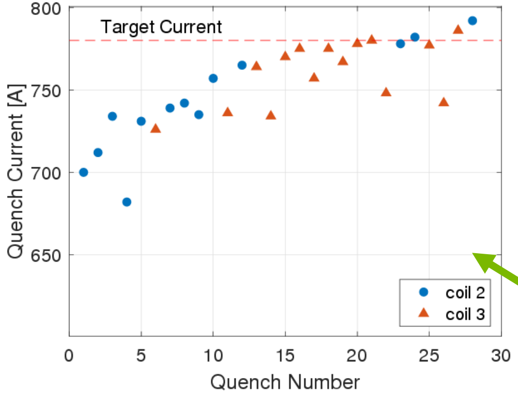
Establishing collaborations with EuPRAXIA and PSI

EMPLOYING VARIOUS SUPERCONDUCTORS IN SCUs

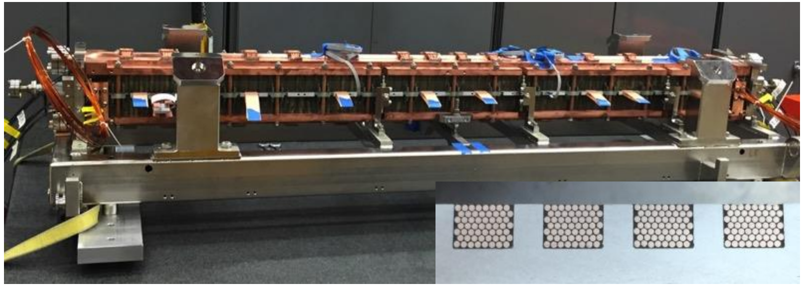
DEVELOPMENT OF NB3SN UNDULATORS AT LBNL

- 6-period prototype in 2006 reached 98% of short sample after three quenches
  - Demonstrated stability at high current density (7.6 kA/mm^2 non-Cu Jc) with 0.48 mm MJR strand
  - Demonstrated magnet protection at high Cu current densities (8.0 kA/mm^2 in Cu)
- 1.5-m long prototype reached target field (80% of short sample limit) in 2017
  - Demonstrated conductor stability with modern 132/169 RRP conductor (0.6 mm diameter)
  - Developed fast quench protection system and demonstrated that full length Nb_3Sn undulator can be protected
  - Reasonably good field quality (RMS phase errors ~11º at 500 A) which can be improved with better control of undulator gap
- Main issues encountered
  - Long training of individual coils
  - One coil led to low performance and required replacement to achieve target field

Training curve For Full 1.5 m SCU



1.5 m Long Nb_3Sn Superconducting Undulator Prototype



6 Period Prototype

D. Arbelaez et al, ICFA Beam Dynamics Newletter, NO. 78.

D.R. Dietderich et al, IEEE Trans on Applied Superconductivity VOL. 17, NO. 2

ANL-FNAL COLLABORATION ON NB_3SN UNDULATOR FOR APS

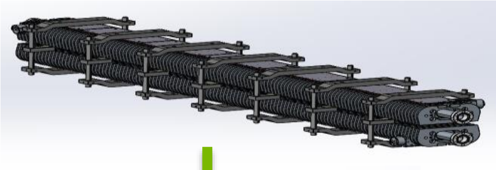
- A 3-year project
- Goal: Develop, build and install on the APS ring a Nb_3Sn undulator (in a modified SCU0 cryostat) a year before the APS-U ‘dark time’ starts
- Collaboration with FNAL and LBNL
- Plan:
  – R&D phase – build and test short magnet models (complete)
  – 0.5-m long prototype (complete)
  – Full scale magnet and cryostat
  – Undulator assembly, test, installation on the APS ring

More details are in the presentation by Ibrahim Kesgin

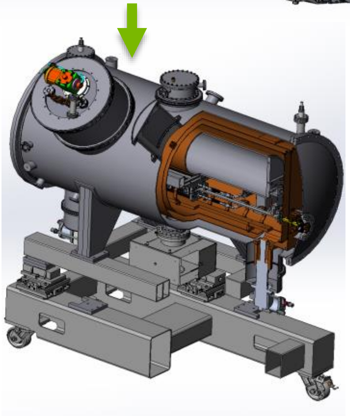
I. Kesgin[1], M. Kasa[1], S. MacDonald[1], Y. Ivanyushenkov[1], E. Barzi[2], D. Turrioni[2], D. Arbelaez[3], Q. Hasse[1], A. Zlobin[2], S. Prestemon[3] and E. Gluskin[1], "Fabrication and Testing of 18-mm-Period, 0.5 m Long Nb3Sn Superconducting Undulator," in *IEEE Transact. on Applied Supercond.*, vol. 31,no 5.
[1] Argonne National Laboratory [2] Fermilab [3] Lawrence Berkeley National Laboratory

84 mm

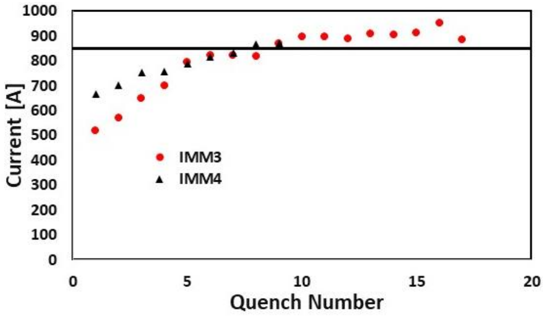
0.5 m



1.1 m

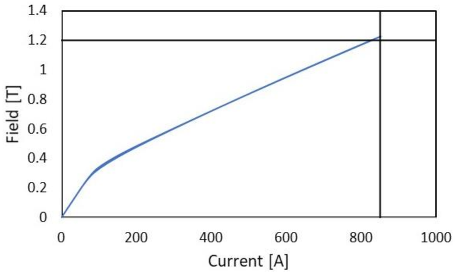


Quench training profile of individual cores



Nb_3Sn SCU did not require any training to reach the design current in 2nd cooldown and demonstrated excellent training memory.

Excitation curve of 0.5-m long Nb_3Sn SCU



The performance exceeded the design current and undulator field of ~850 A and 1.2 T, respectively. The magnetic field simulations agreed well with the measured field values. Nb_3Sn SCU offers at least 20% undulator field increase compared to a NbTi SCU with the same magnetic gap (9.5 mm) and period length (18 mm).

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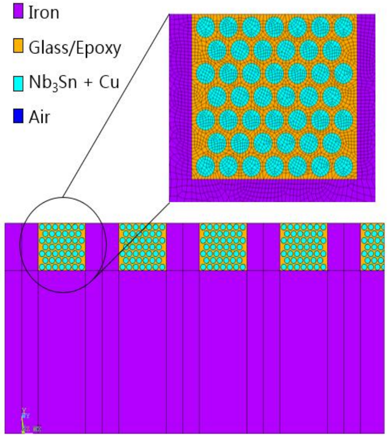
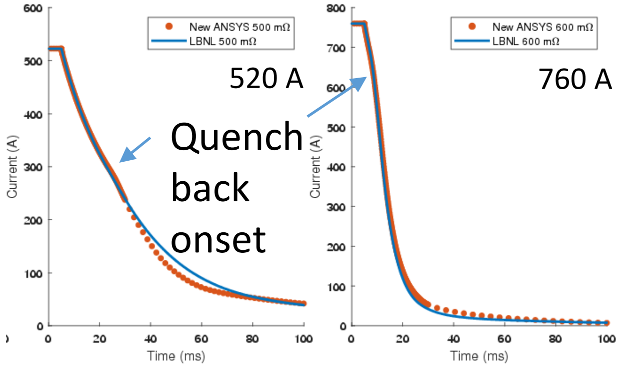
ANL-LBNL COLLABORATION ON NB3SN UNDULATORS: DEVELOPMENT OF QUENCH PROTECTION SYSTEM

- Nb3Sn SCUs can operate at extremely high current density (> 6,000 A/mm^2 in Cu during quench)
- This requires fast quench detection and extraction system
- Initial system was developed for LCLS-II SCU collaboration and further refined in Nb3Sn undulator collaboration with ANL
  - Improved modeling methods allow for accurate simulation of quench back effects
  - Fast extraction using IGBT switches
  - More efficient energy extraction with the implementation of varistors

Finite Element Model

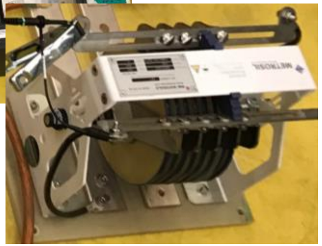


Current Decay Simulations



Quench Extraction Hardware

Varistor



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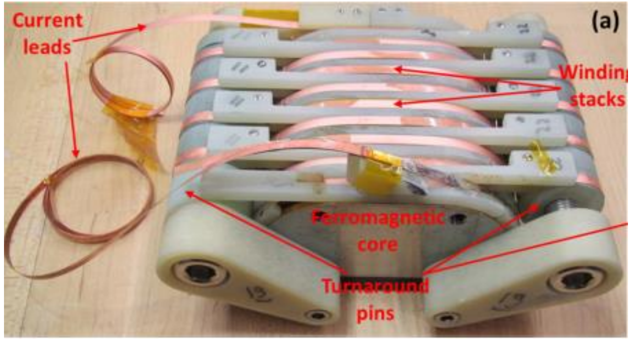
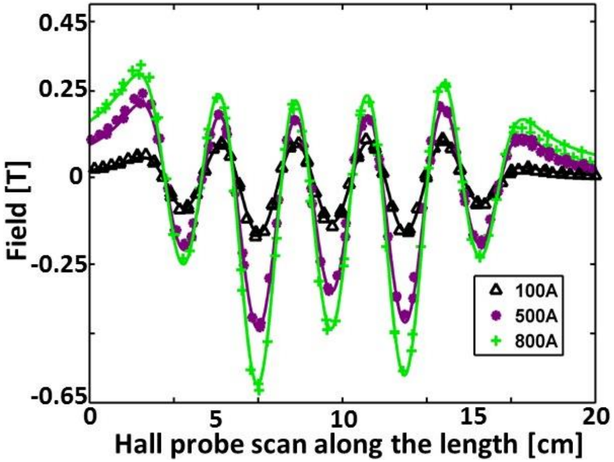
R&D ON HTS SCU AT THE APS

A Laboratory Directed R&D on HTS SCU demonstrated that 2G HTS conductors are suitable for fabrication of undulator magnets:

- A technique of winding an undulator magnet with HTS tape without electrical joins is developed [1].
- Partial interlayer insulation reduces charging delay [2].
- Prototype undulator shows superior performance at 4.2 K compared to NbTi counterparts (2.1 kA/mm^2 versus 1.4 kA/mm^2 for NbTi). This is power supply limit, not superconductor.
- Simulations confirm the measured field profiles. Estimated field value of HTS undulator is about 30% greater than analogous NbTi undulator magnets.
- Availability of long length wire with uniform I_cs and weak mechanical properties are the remaining issues that are currently being addressed by the multiple HTS manufactures.



Continuously wound HTS undulator prototype.



Measured field of HTS undulator prototype.

[1] I. Kesgin et al., US patent # US 10,249,420 B2
[2] I. Kesgin et al., 2017 Supercond. Sci. Technol. 30 04LT01

SUMMARY

- SUPERCONDUCTING TECHNOLOGY OPENS A NEW AVENUE FOR UNDULATORS AT SYNCHROTRON LIGHT SOURCES AS WELL AS FELs OFFERING HIGHER MAGNETIC FIELD THAN OTHER UNDULATOR TECHNOLOGIES
- SUPERCONDUCTING UNDULATORS ARE SUCCESSFULLY EMPLOYED AT THE ADVANCED PHOTON SOURCE. MORE SCUs ARE ON THE WAY FOR THE APS UPGRADE . NSLS-IIU IS CONSIDERING SHORT PERIOD SCUs.
- LCLS FEL SCU DEMONSTRATOR WILL BE DEVELOPED AND TESTED IN THE NEXT FEW YEARS. FERMILAB IS WORKING ON CONDUCTION COOLED SCUs FOR FELs.
- VARIOUS TYPES OF UNDULATORS CAN BE BUILT IN SUPERCONDUCTING TECHNOLOGY. VARIOUS SUPERCONDUCTORS CAN BE EMPLOYED.
- DEVELOPMENT OF NB3SN UNDULATOR FOR THE APS IS IN PROGRESS
- THE US SCU COLLABORATION IS GROWING

ACKNOWLEDGEMENT

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  ** NOW WITH SLAC

  * WORK SUPPORTED BY THE U.S. DEPARTMENT OF ENERGY, OFFICE OF SCIENCE, UNDER CONTRACT NO. DE-AC02-06CH11357.

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- LBNL: D. ARBELAEZ, L. BROUWER, K. EDWARDS, M. TURQUETI AND S. PRESTEMON
- SLAC: H. BASSAN, G. BOUCHARD, D. CESAR, B. DUNHAM, P. EMMA, D. FRITZ, J. FUERST, Z. HUANG, P. KREJCIK, B. MCKEE, C. NANTISTA, D. NGUYEN, H-D. NUHN, A. RATTI, T. RAUBENHEIMER, T. TAN, P. WELANDER, Z. ZHANG

POSTDOC POSITIONS AT ARGONNE

Two postdoc positions are currently open in Accelerator Systems Division of ANL to work on development of the next generation of superconducting undulators.

Position descriptions can be found on ANL website:
https://www.anl.gov/hr/postdoctoral-applicants

Requisitions #408892 and #408949

Postdoctoral researchers are welcome to join Argonne SCU Team !