Superconducting Insertion Devices

Three Laboratory Collaboration

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Robert Kustom for the SCID Group

SCID Participants

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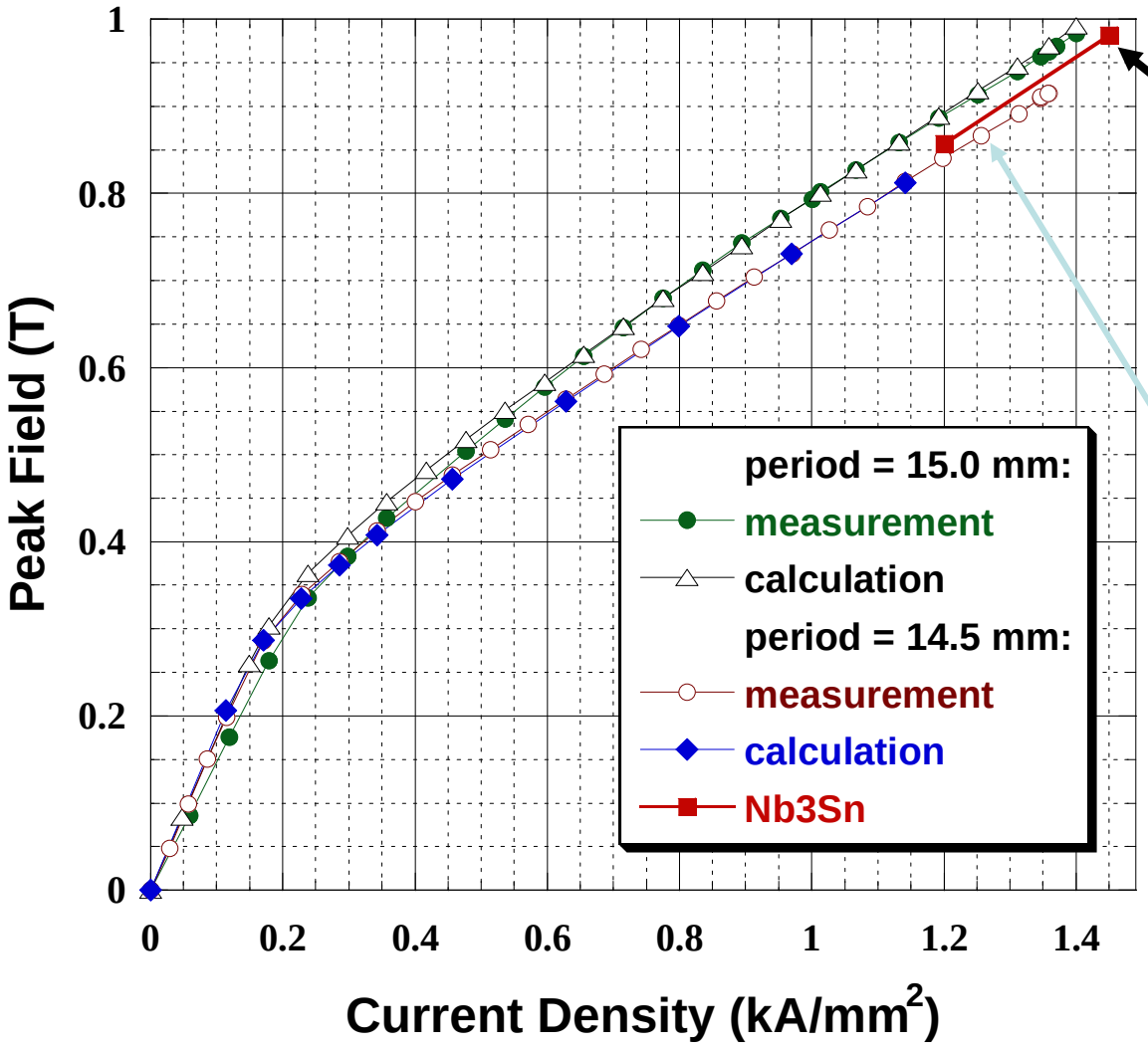
SCID Program

- Achieved considerable success with NbTi models, reaching 1.45 kA/mm^2 and K>1 with 14.5 to 15 mm periods.
- Nb_3Sn wire offers the possibility of higher Jc and Tc, allowing SCID to achieve even greater scientific capabilities.
- Have achieved >1.92 kA/mm^2 with Nb_3Sn wire with 10-20 period models.
- Believe Jcs greater than 1.92 kA/mm^2 are possible, and are encouraging the development of ceramic coatings that will significantly improve winding packing factors. Could add as much as 20-30% to effective Jc.
- Latest tests at NHMFL had wire breakage problems when joining multiple yoke and coil sections together. Cause may be stress on wire from excessive winding tension and/or tight bend at splicing fixture.
- Because the use of Nb_3Sn wire requires more R&D to insure a successful SCID, it is proposed to build the first device with NbTi wire, but to continue developing the use of Nb_3Sn wire as aggressively as the budget will allow.

Additional Elements of SCID R&D

- Fabrication and yoke studies.
- Magnetic measurements.
- Cryogenic studies.
- R&D on Nb_3Sn wire insulation.
- LDRD supported helical undulator studies.

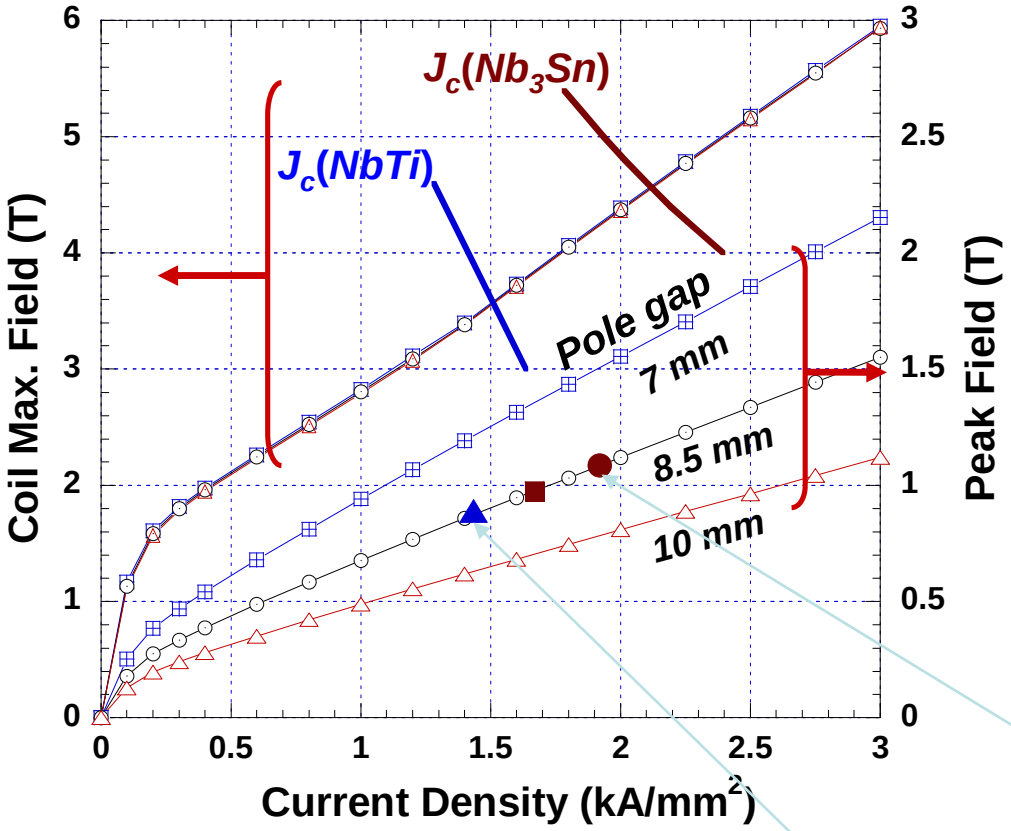
Peak Undulator Fields Achieved with 10-20 period models using NbTi and Nb_3Sn Wire



Nb_3Sn :
● = 14.5 mm,
g = 8, B_0 = 1.0 T
(*g* = 6, B_0 = 1.5 T)
@ 1.45 kA/mm²

NbTi :
● = 14.5, *g* = 8
B_0 = 0.9 T
@ 1.35 kA/mm²

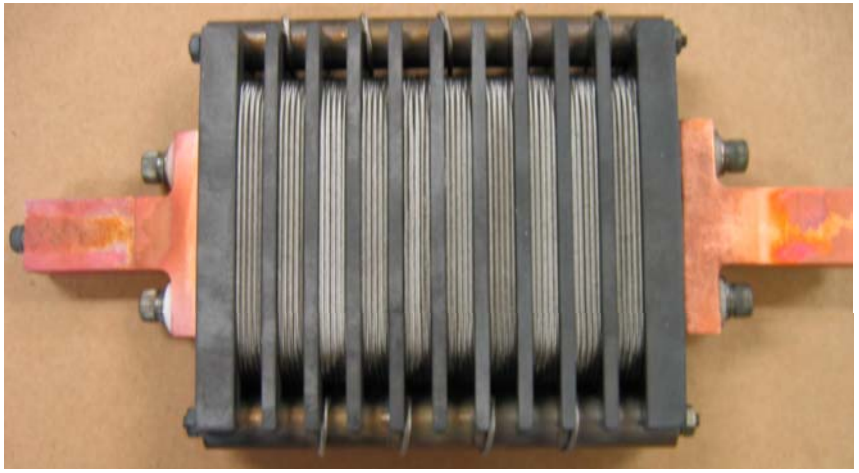
Maximum Achievable Undulator Fields with 14.5-mm Period Wound with NbTi and Nb_3Sn Wire at 4 K with Different Magnet Bores



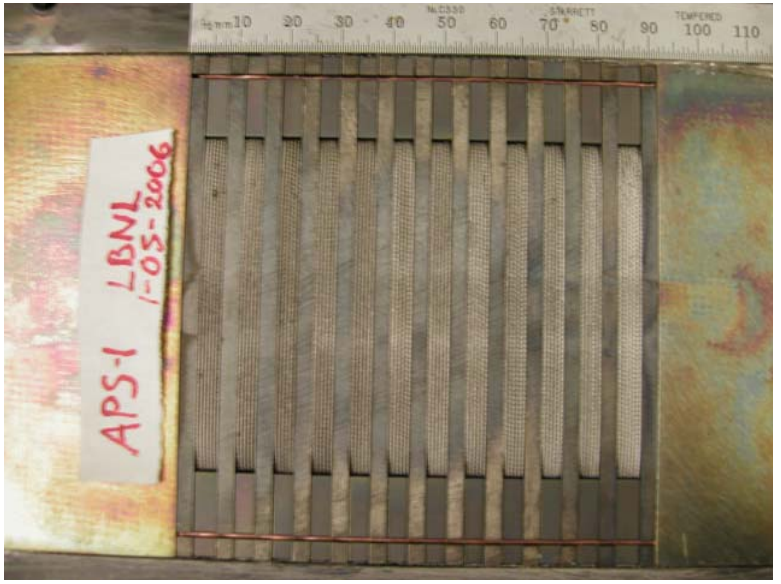
Parameters	NbTi	Nb_3Sn
J_c at B_{max}	1.5 kA/mm^2, 3.48 T	2.12 kA/mm^2, 4.46 T
J at B_0	1.43 kA/mm^2, 0.86 T	1.92 kA/mm^2, 1.08 T
J/J_c ratio	> 95 %	~90 %

Test windings with Nb_3Sn wire

Similar coils have been wound at ANL, NHMFL and at LBL and have successfully achieved 1750 amps/square mm
All labs achieved the necessary current density to meet our operating goals on 10 to 20 period models using conductor with smaller superconducting filament size.
Latest attempt to build a model with 4 yoke segments had problems with wire breakage, at least one at the joint, maybe the others as well..

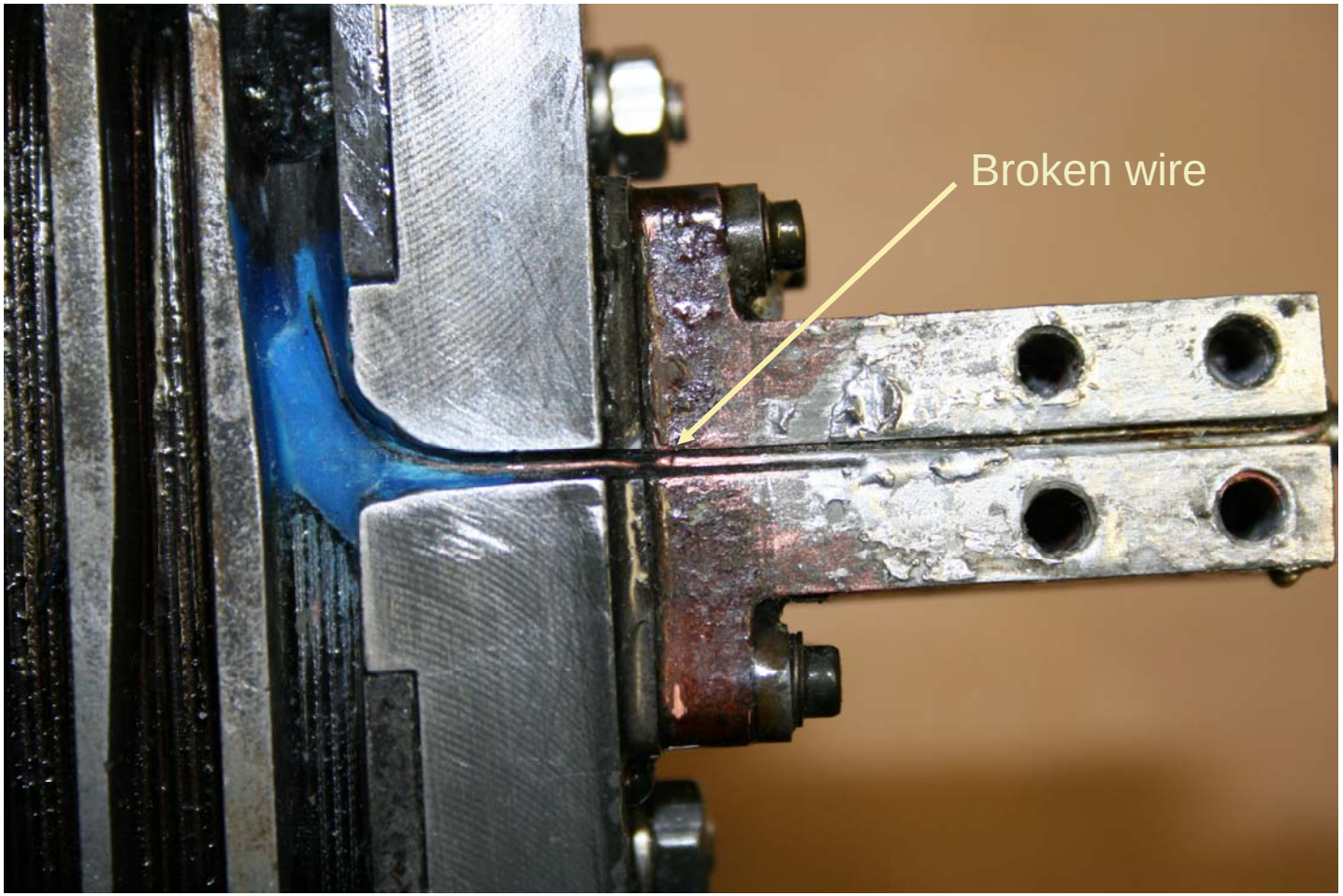


NHMFL, courtesy H. Weijers



LBNL, courtesy S. Prestemon

Location of Wire Breakage



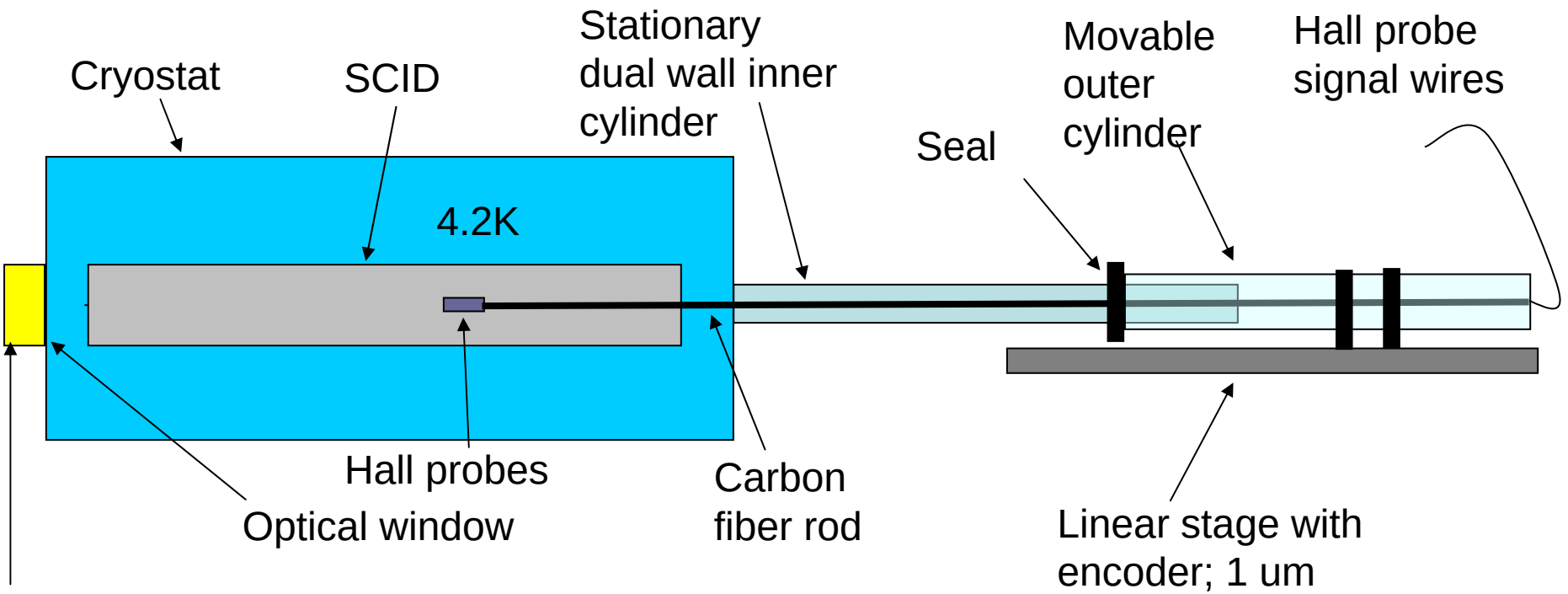
Some Possible Causes of Nb_3Sn Wire breakage

- Winding tension too high. The winding tension was increased between the winding of the earlier test sections and the final four-yoke segment
- Bend into joint fixture too sharp and tight causing a region of high strain

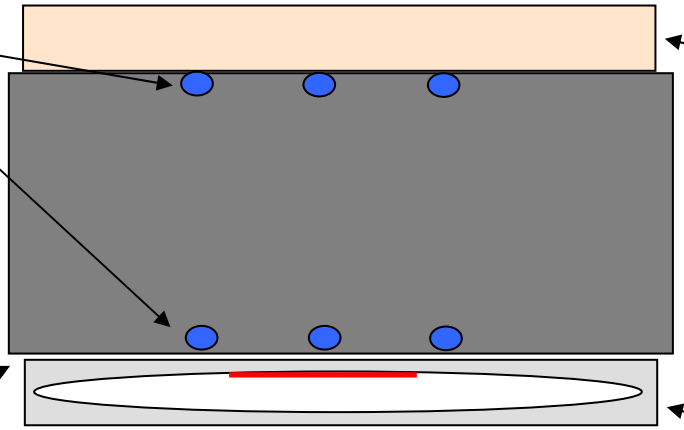
Fabrication and yoke studies

- Full sized 2.4-m-long, 1010-steel yokes have been purchased. Magnets wound on these yokes require no internal joints, but it remains to be seen if machining can achieve the necessary precision.
- The bars have also been heat treated to verify that they won't distort during the heat reaction cycle if using Nb_3Sn.
- A lamination approach to fabricating the 2.4-m yokes is also being pursued. The choice will be decided on the basis of cost and ability to meet specifications.
- A winding machine capable of handling the full 2.4-m core is on order and close to delivery from vendor.

SCID Hall probe magnetic measurement system concept



SCID thermal performance test concept



Cernox thermal sensors potted with Stycast 2750 epoxy

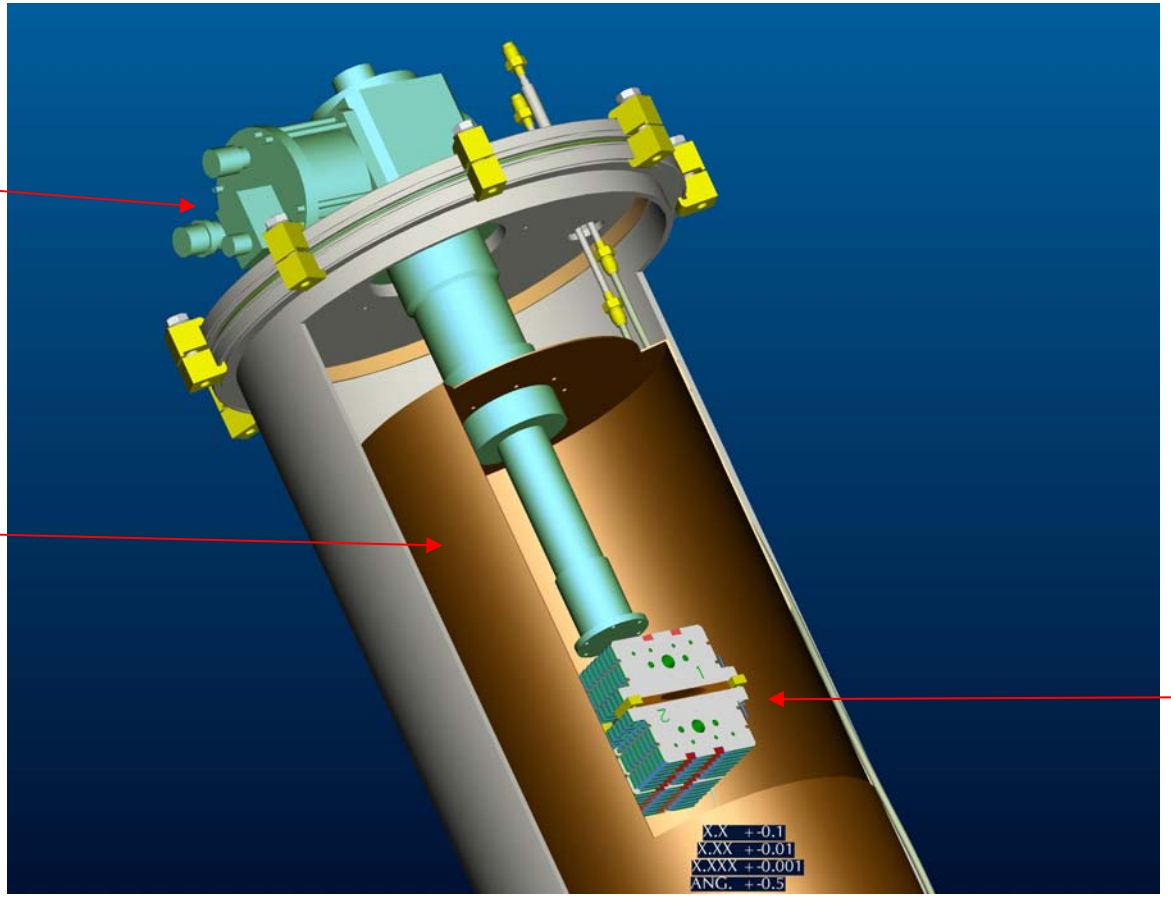
CU plate coupled to cryocooler

SCID half core

0.5 mm gap using various insulation materials

Beam Chamber with film heater 12.7 x 100 cm 10 W or cartridge heaters
Max Pd ~ 0.7 W/cm2

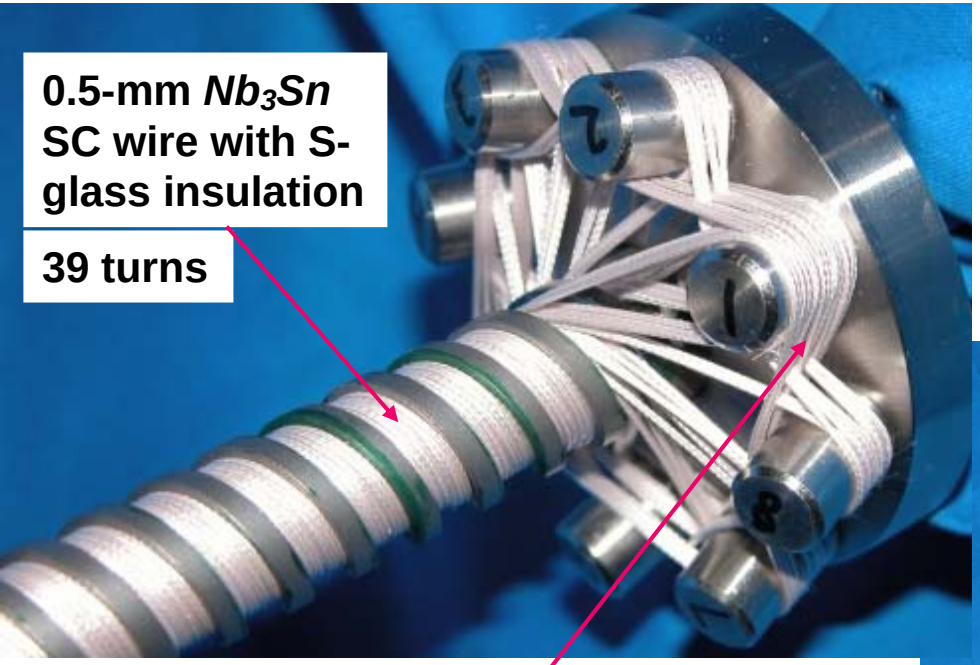
SCID thermal performance test system

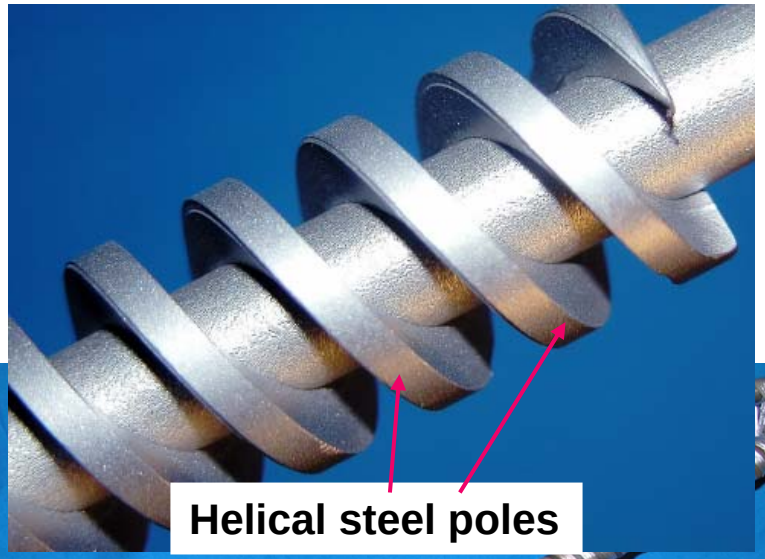


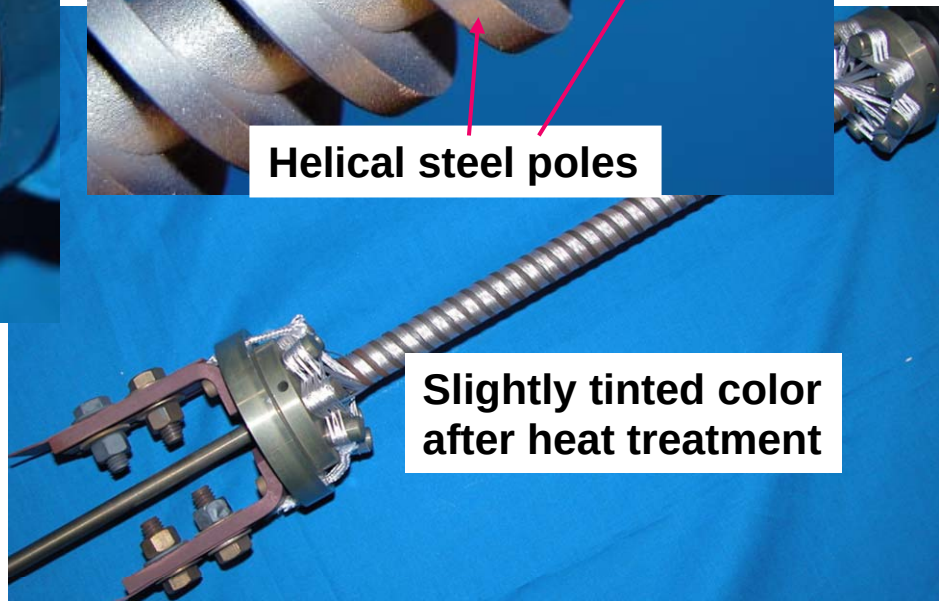
Ceramic insulation studies for Nb_3Sn Wire

- A US Company, nGimat, supplied LBL some ceramic coated wire that can reduce thickness of Nb_3Sn insulation, typically s-glass, from 65 microns down to 10-20 microns.
- The first samples had a number of bare spots, apparently because the company did the coatings with a small batch, laboratory test system. They received a SBIR grant to develop the batch process.
- We have received some of their first samples. The coatings are rugged and appear to be able to handle winding and heat treating.

Helical Nb_3Sn SCU Fabrication, l = 14 mm

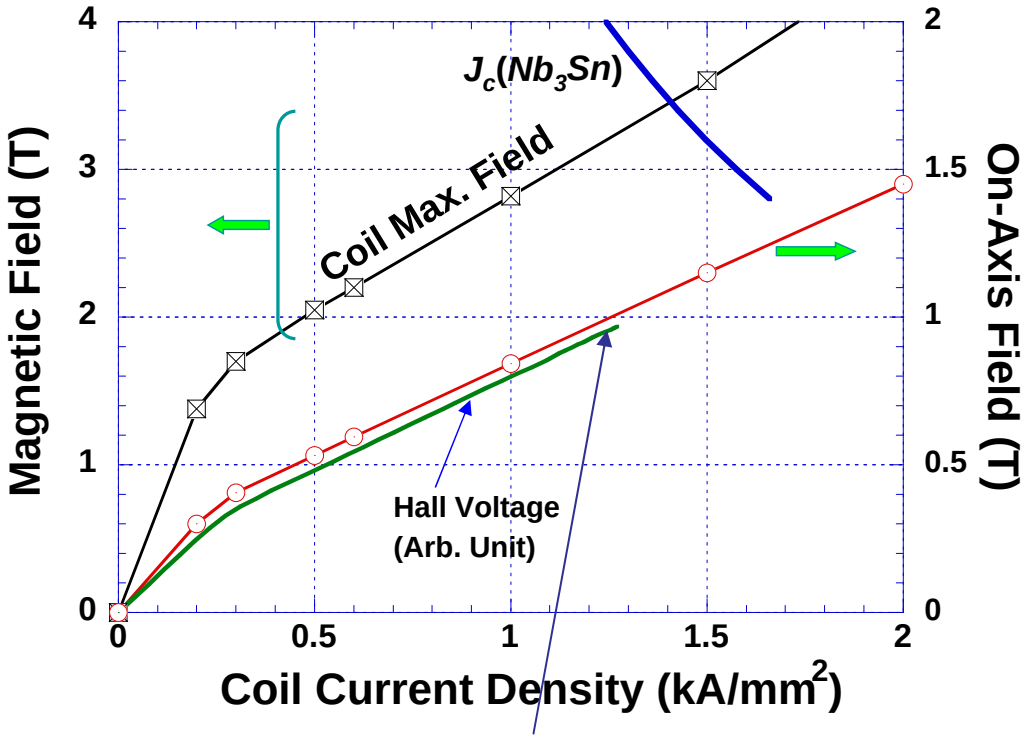






Undulator ends: designed for continuous winding of the double helix without any conductor joints and to minimize the stray field

Helical Nb_3Sn SCU, l = 14 mm, *r0* = 3.97 mm, vacuum bore radius = 3.47 mm



Approx. B*0* =0.95 T, j =1.28 (820 A, 90% of *jc*) after four quenches

Summary

- Believe that NbTi undulator can be built and will meet the first users requirements.
- Continuing studies with Nb_3Sn wire because it should be possible to achieve higher undulator fields for the same gap and period, or would allow reducing the period to 14 mm or less while maintaining field strength. Believe the wire breakage problem will be overcome by more careful control of winding tension and redesign of the joint fixture.
- Other elements of development program are proceeding well and no real show stoppers are apparent.
- One key question is whether the beam liner can be adequately insulated from the undulator's yoke and coils to allow the beam liner to be operated at an elevated temperature, 20-80 K.