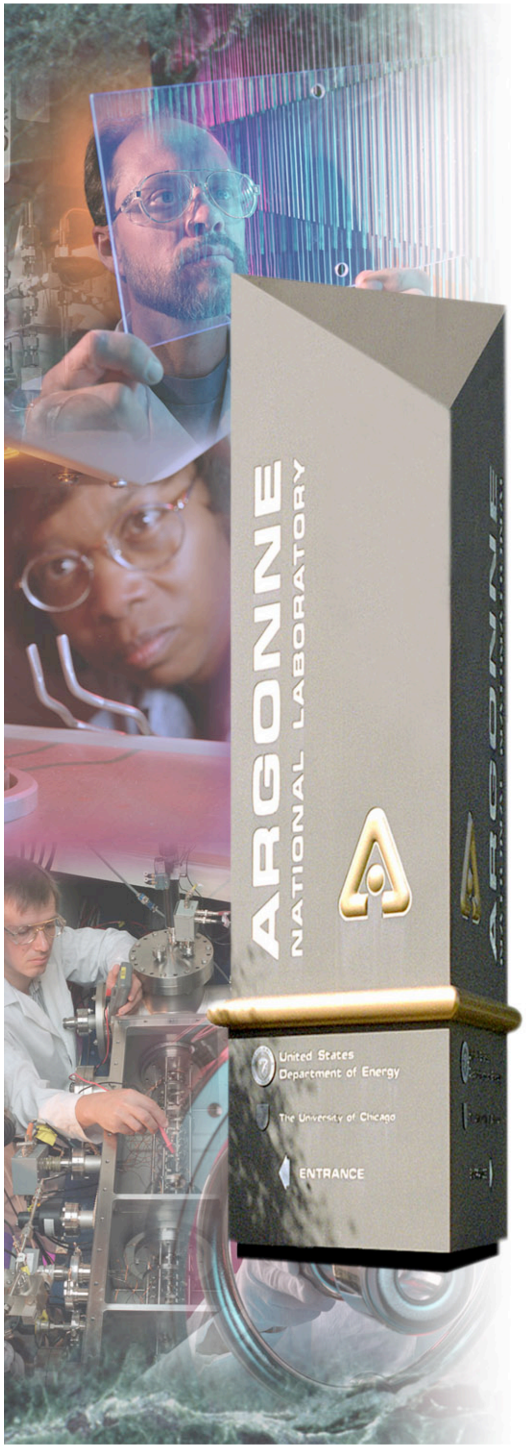


Small-Period Superconducting Undulator

Liz Moog

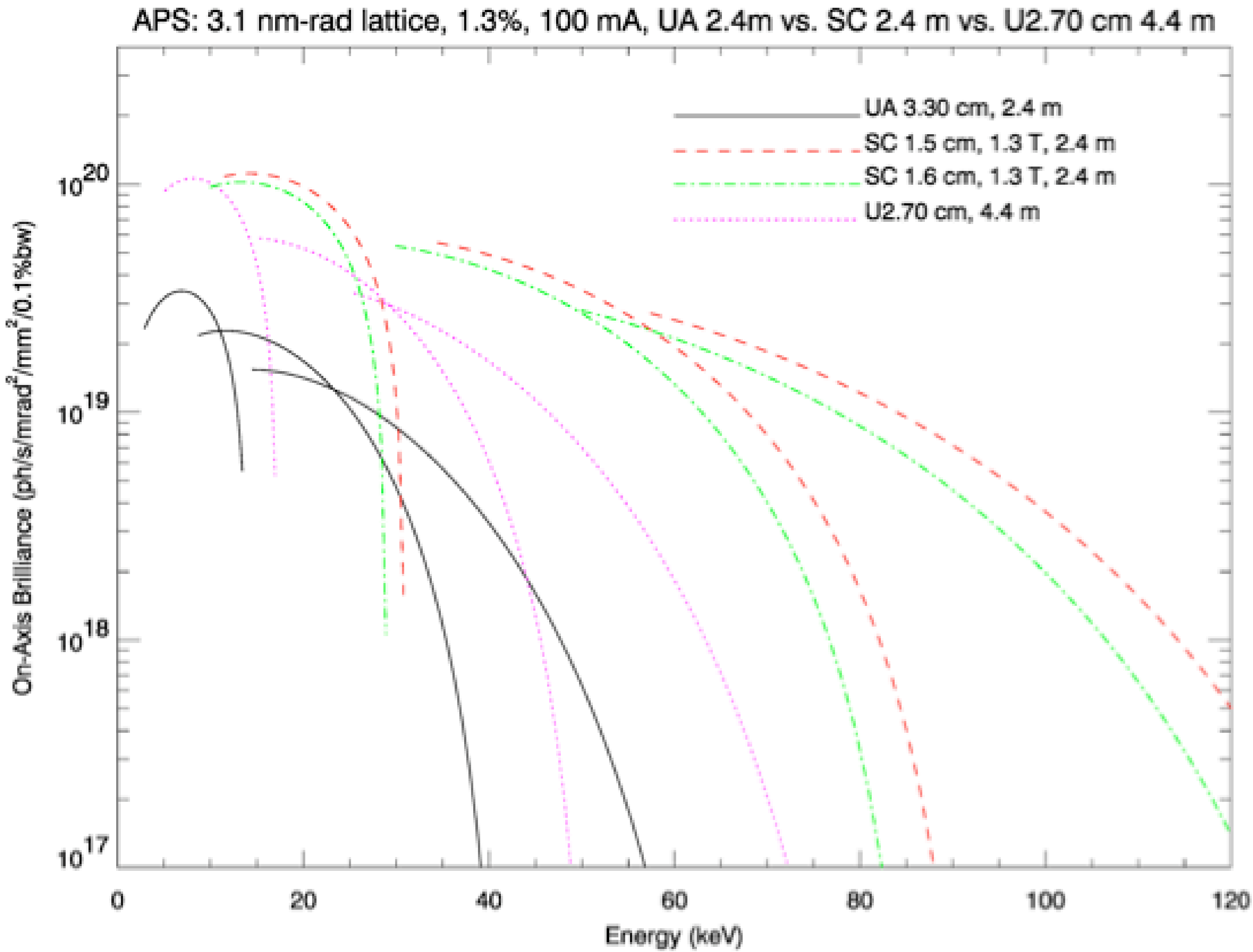
3-way meeting 9 Nov. 2004 at SPring-8

Argonne National Laboratory

Office of Science
U.S. Department of Energy

A U.S. Department of Energy
Office of Science Laboratory
Operated by The University of Chicago

Tuning Curves Show Benefit of Superconducting Undulator for 20-25 keV



Superconducting Undulator Program Goals

- Develop, fabricate and install an undulator tunable over the range of 20~28 KeV on first harmonic for inelastic x-ray scattering studies

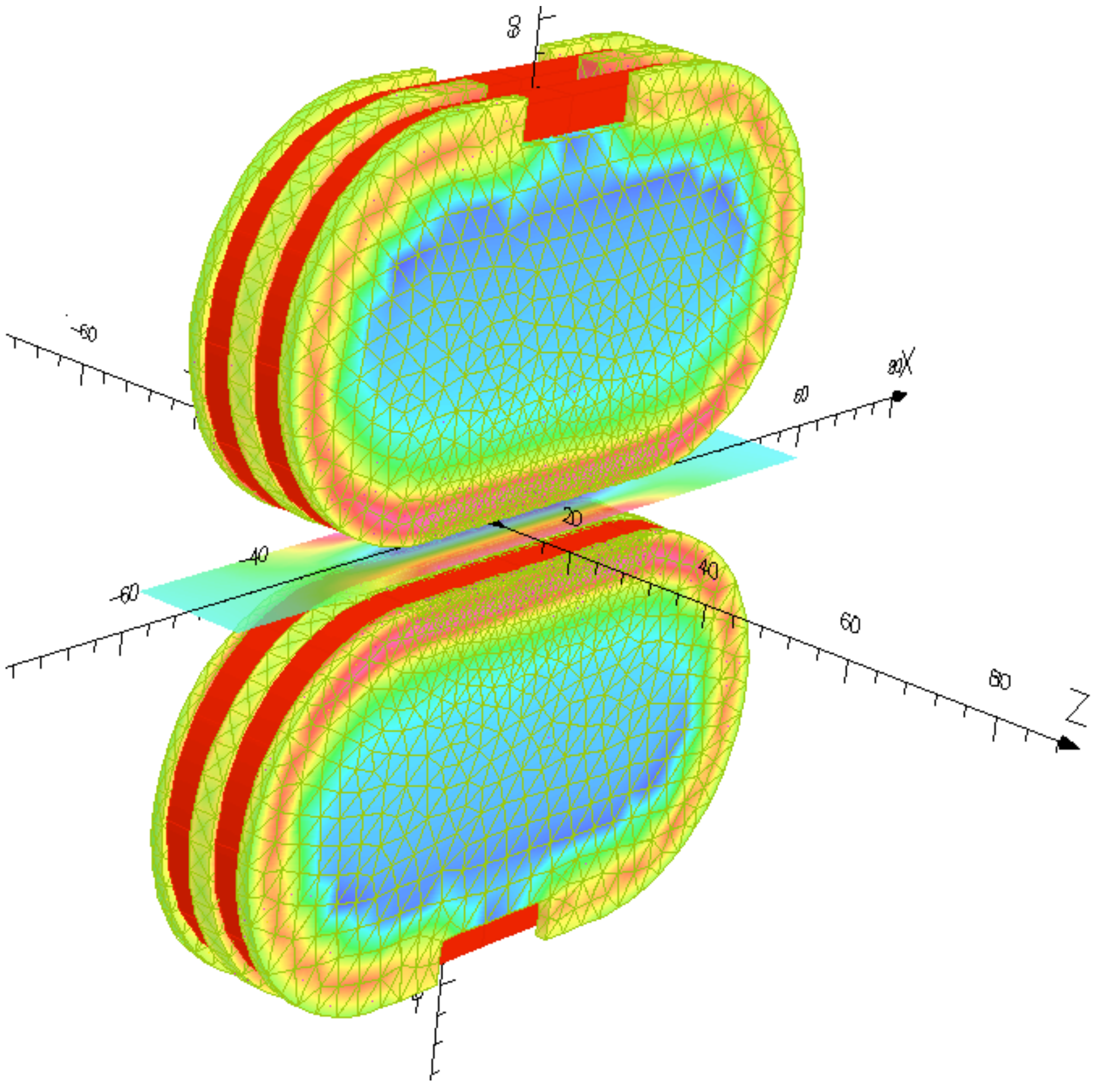
- Achieve high field quality to achieve high-intensity 3rd harmonic beams

- Investigate the possibility of shorter period undulators, ~ 12 mm for future programs in applied materials research, geological studies, and bulk material studies

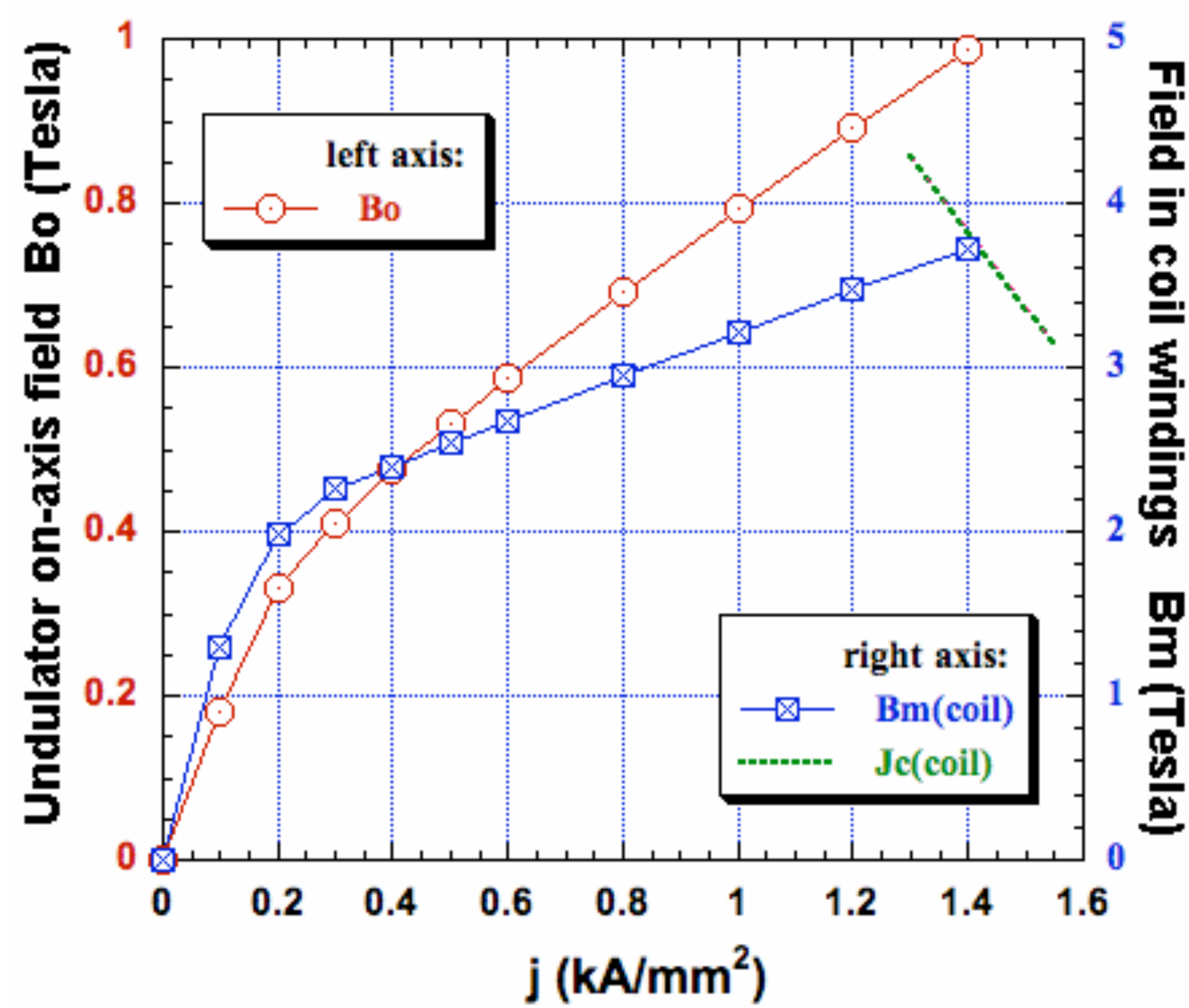
Requirements

- Period ≤15 mm
- Beam stay-clear 7 mm vertically and ±18 mm horizontally, "as rectangular as possible" (an oval shape, with a half-circle on the two sides is OK)
- B_{max} of 0.8 T, but higher is better
- Magnetic length 2.4 m
- Physical length (including end thermal transitions) 3.5 m

Model for one period of superconducting undulator

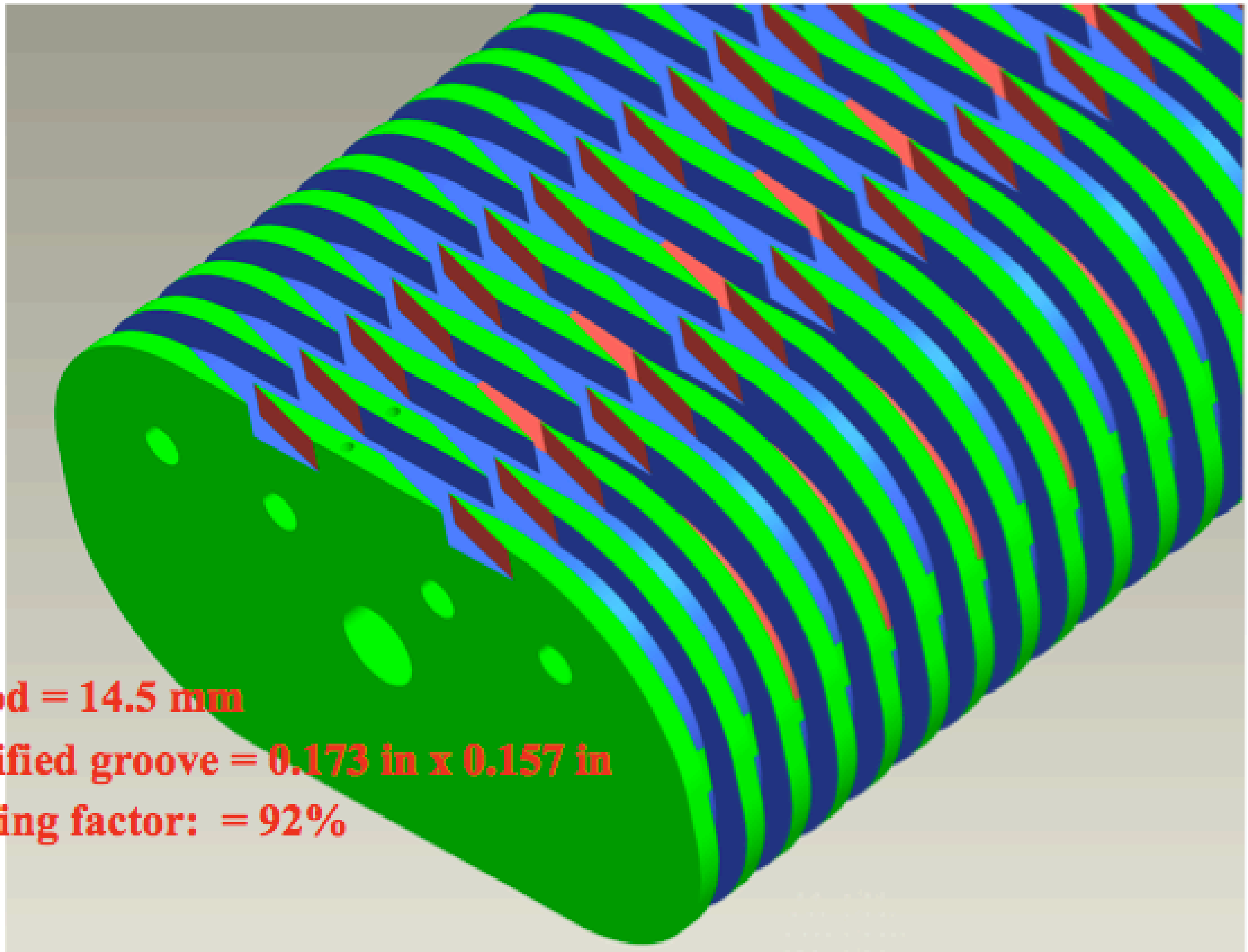


Magnetic model calculations



8 mm pole gap

Modified Steel Core

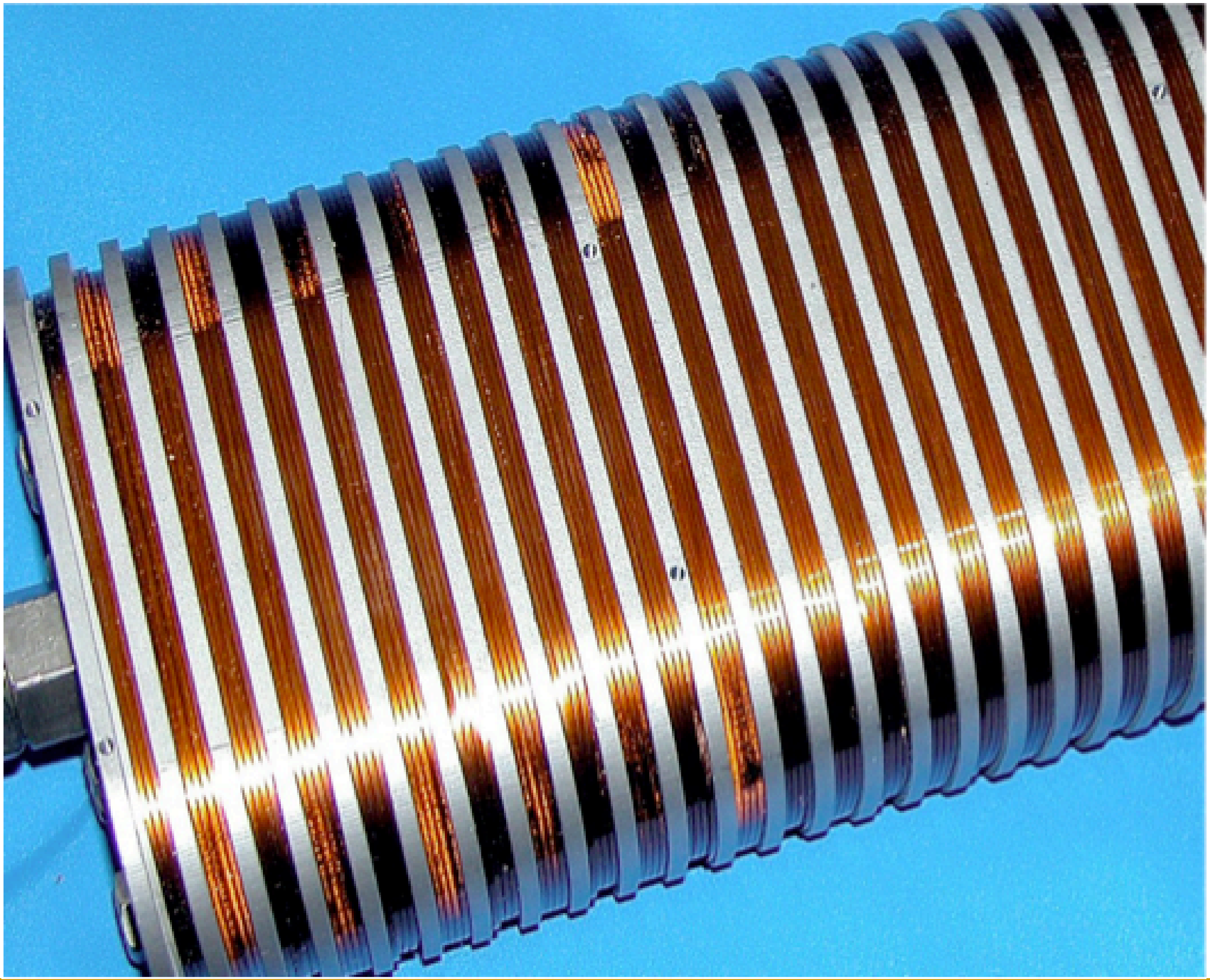


Period = 14.5 mm

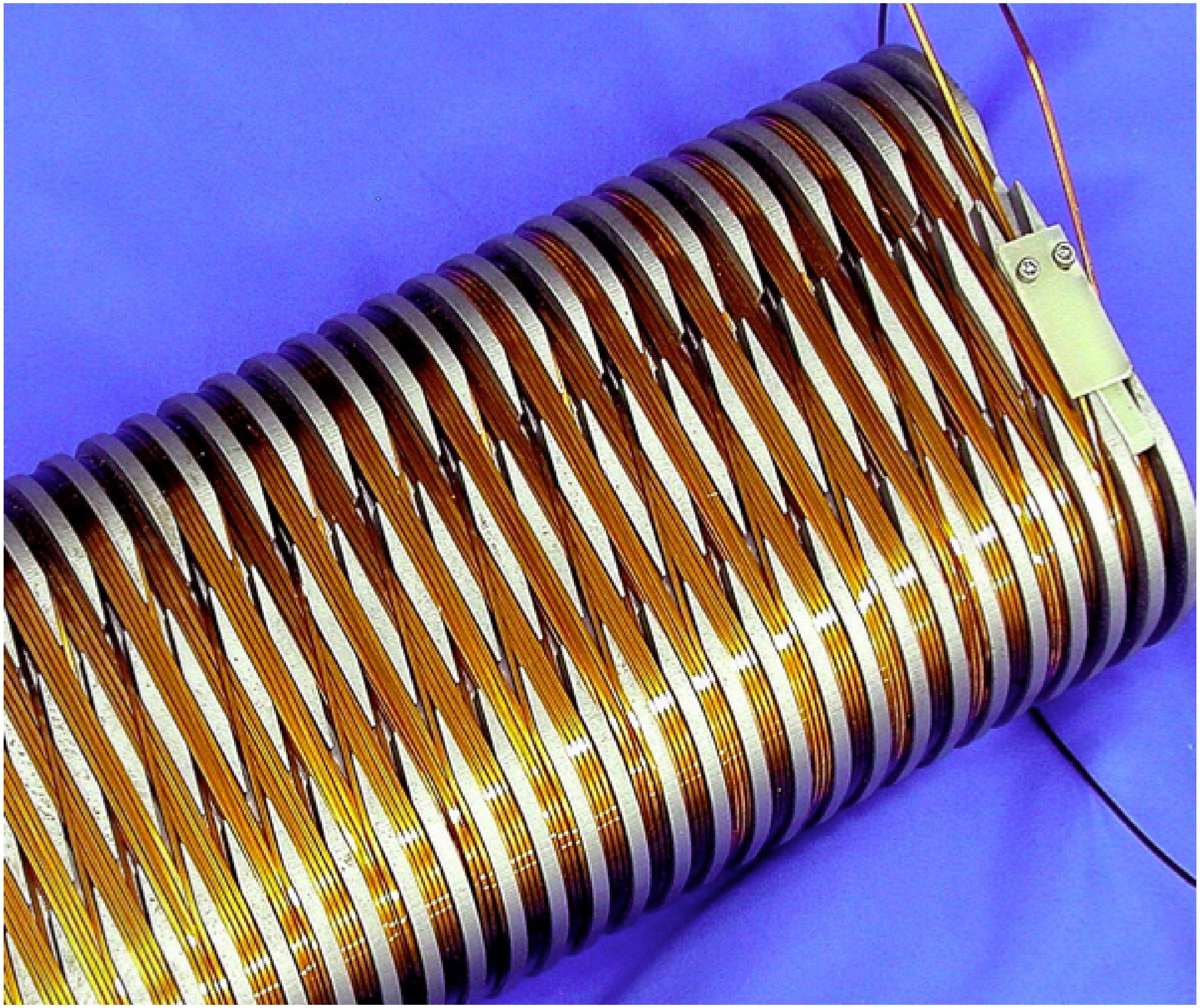
Modified groove = 0.173 in x 0.157 in

Packing factor: = 92%

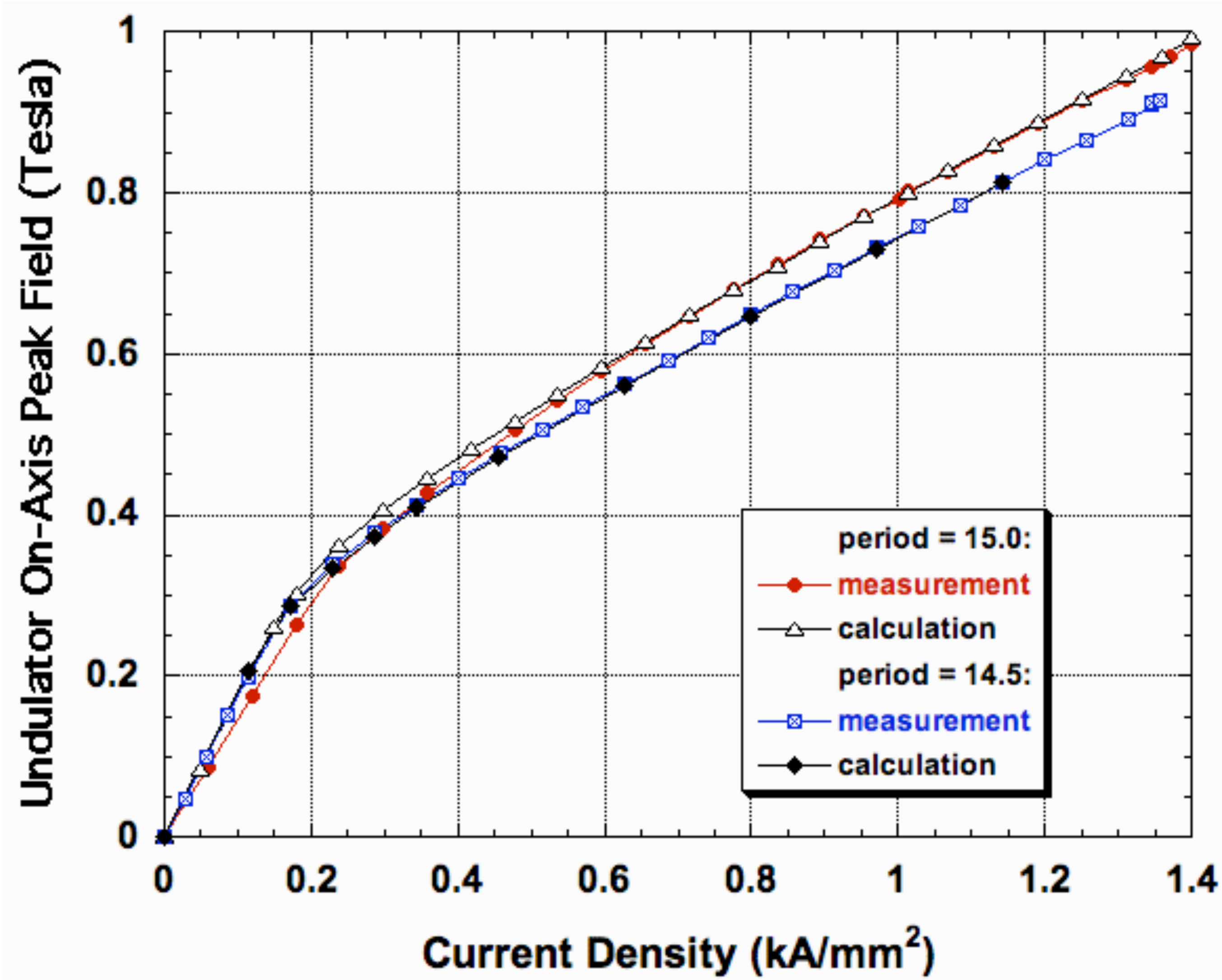
Beam side of coil



Cross-over Winding Side



High-Current-Density Tests

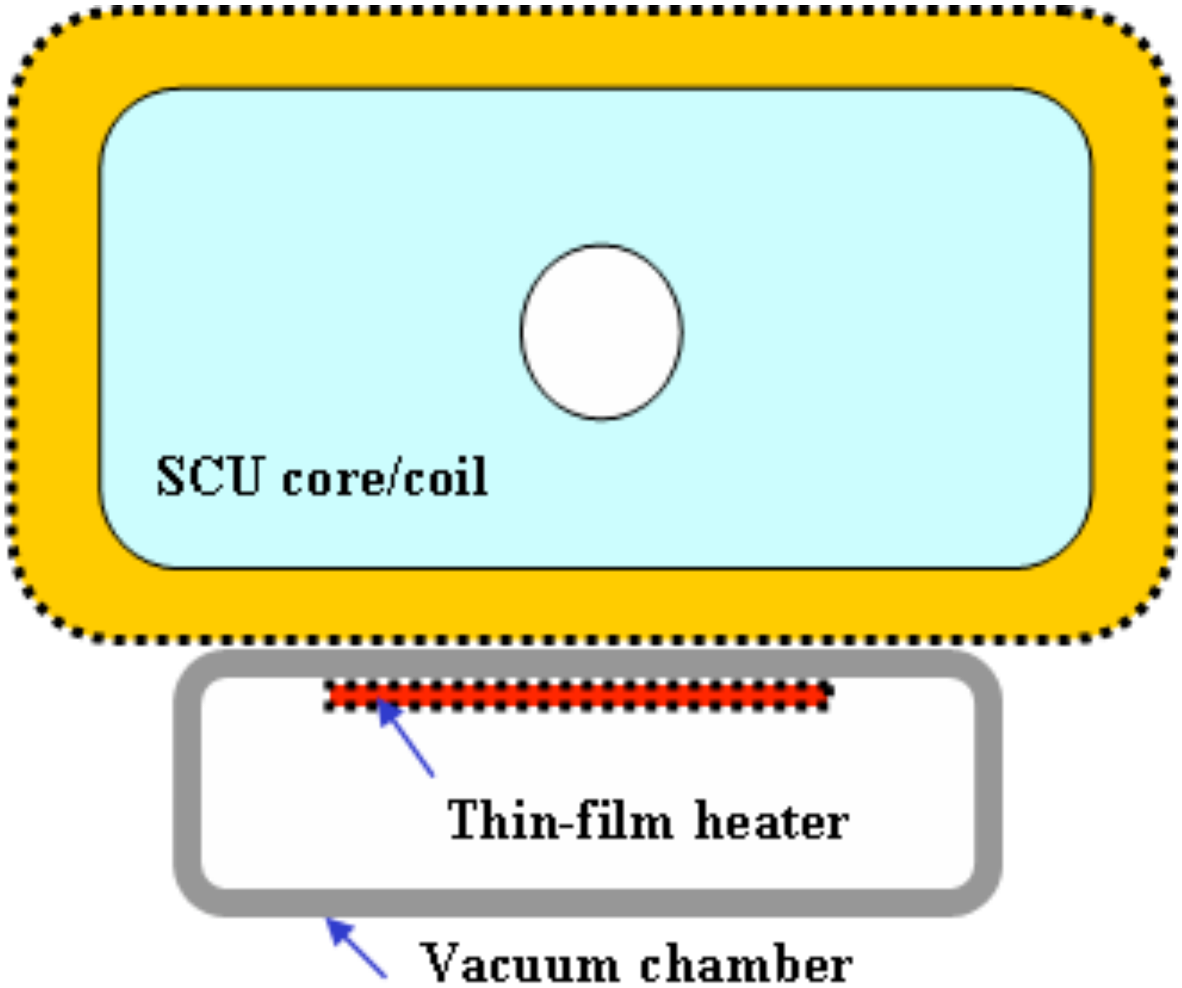


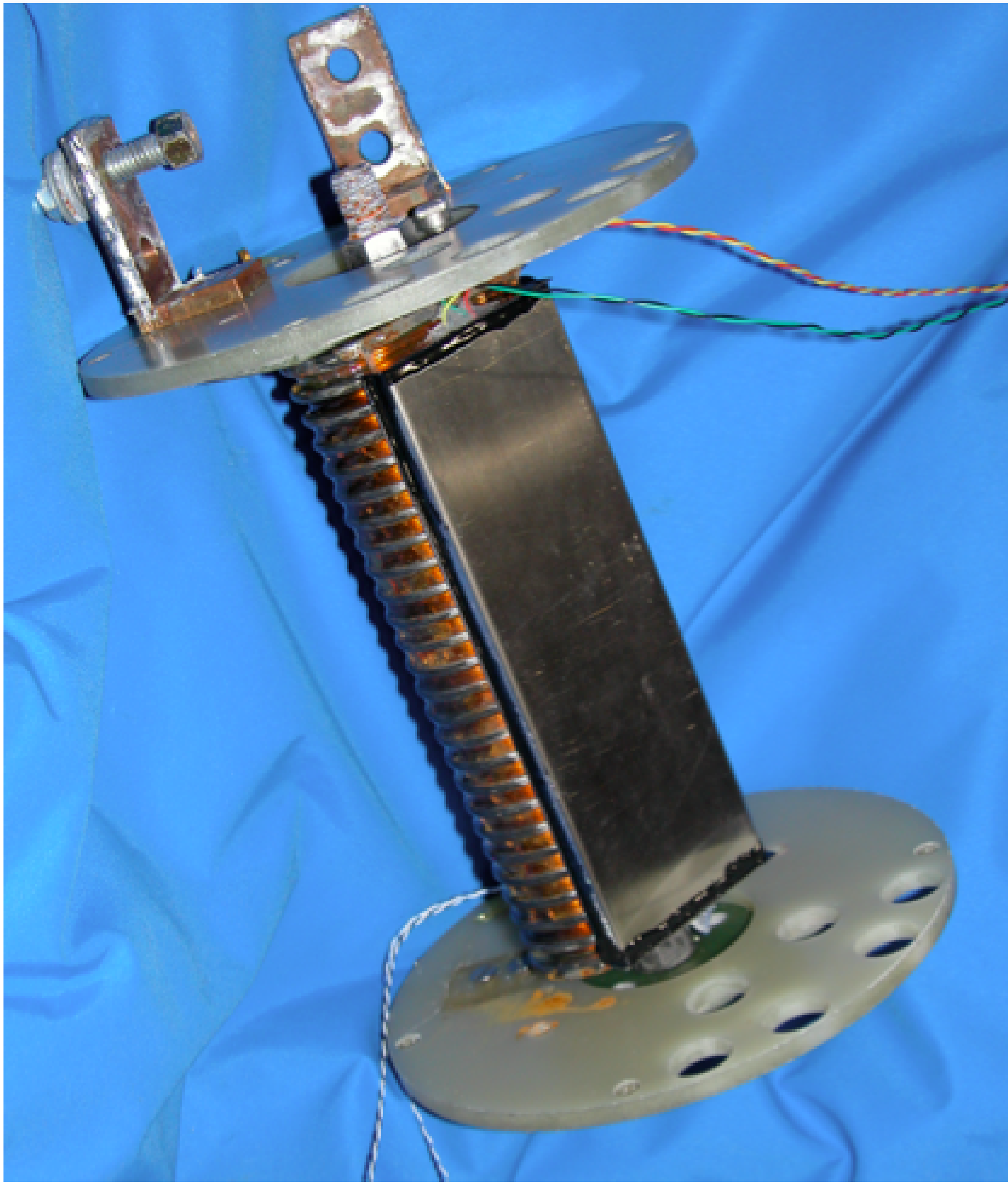
Potential sources of heat load

- Beam image current heating
- Low-energy synchrotron radiation heating
- Bremsstrahlung
- Electron cloud
- Wakefield effects due to transition from regular vacuum chamber to small-gap SCU
- High-energy beam loss due to finite beam lifetime and injection losses
- Thermal conduction

Total is expected to be a few Watts/meter

Stability Test Setup in Pool-Boiling LHe

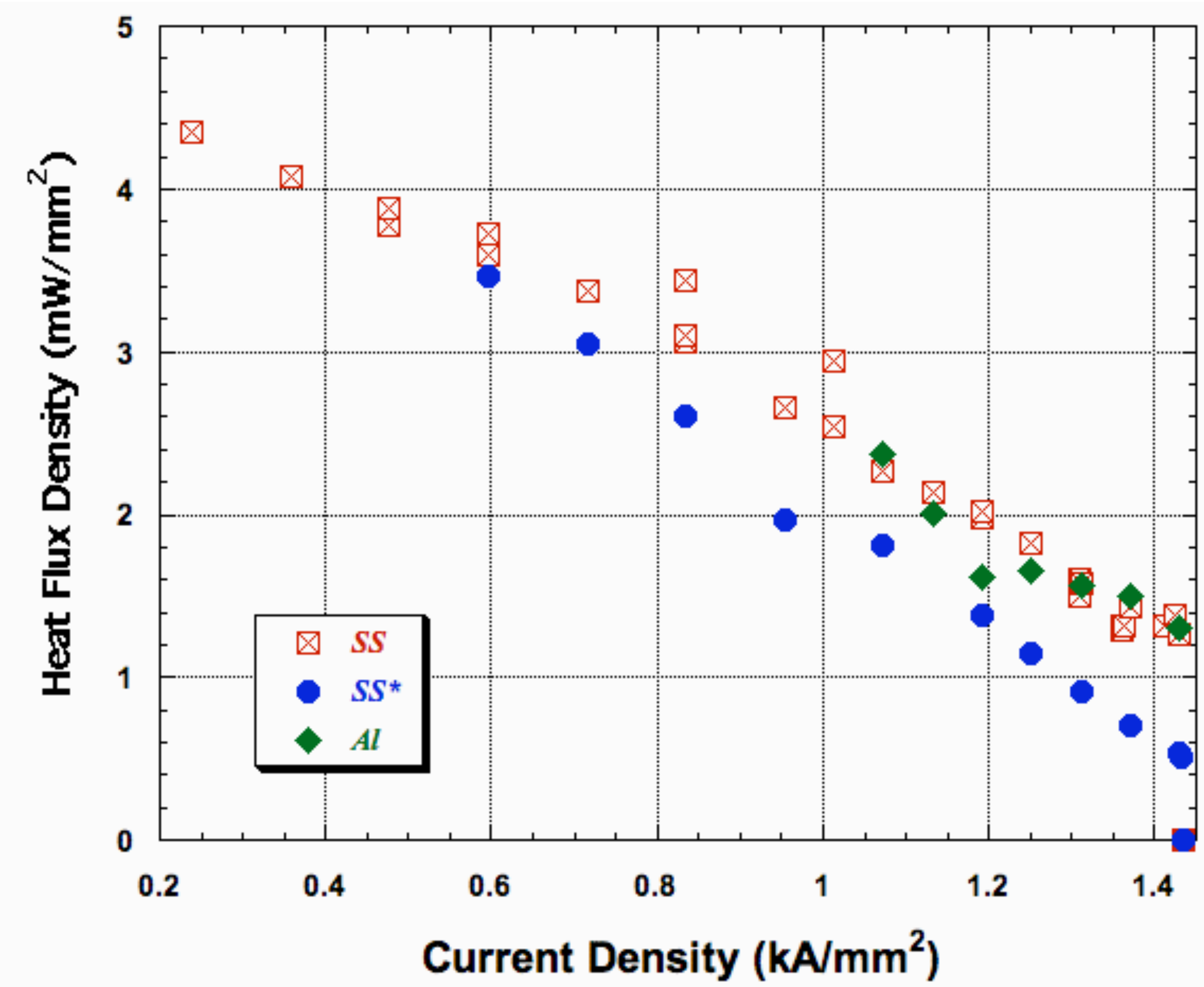




<u>3 cases tried:</u>

- Stainless vacuum chamber
- Al vacuum chamber
- Stainless chamber with grease between chamber and mandrel

Stability Tests



SS* is the case with grease between mandrel and chamber so LHe is excluded

Next step for R&D at APS is to try Nb_3Sn wire

•Higher critical current

•Must be wound in its non-superconducting state, then fired

•After processing, wire is brittle

Other Options: ACCEL

A study was commissioned. ACCEL considered adapting their designs to our needs (i.e., beam stay-clear 7 mm vertical and 36 mm horizontal, 15 mm period or less, 0.8 T on-axis effective field or higher)

- Design based on NbTi conductor
- Report completed mid-Sept 2004
- Conclusion: it’s possible but not much margin
- Issues considered:
  - Cryogen-free system (like the ANKA device) vs. pool boiling
  - Elliptical vs oval vacuum chamber - stresses and deformation
  - Magnetic field quality - their previous devices were good
  - Correction possibilities: at ends, by separate superconducting coils; working on a local active correction scheme
  - Vibration and mechanical stability

Other Options: NHMFL

The National High Magnetic Field Lab at Florida State University expressed an interest in helping.

- A study is being carried out by John Miller, Huub Weijers, Kurt Cantrell, and Andy Gavrilin
- Report is in preparation
- Design based on Nb_3Sn conductor
- Higher critical current conductor than NbTi
- NHMFL is experienced in working with Nb_3Sn
- Possibly, NHMFL may serve as general contractor for building a superconducting undulator according to their design.

Other Options: NHMFL cont.

Initial results of the NHMFL study:

- Jc non-Cu of 2000 A/mm^2 at 4.2K, 12T seems a reasonable assumption
- The additional critical current allows a larger gap
- A design with the beam tube at liquid N_2 temperature is proposed
- 11 mm pole gap:
    - 7 mm beam aperture
    - 0.75 mm chamber wall thickness
    - 1 mm vacuum gap
    - 0.25 mm margin
- Field calculations are guiding yoke design and winding shape
- Margin is 1.44K at 80% of Ic
- Lorentz force-induced stresses are low
- Low heat load

Other Options: NHMFL cont.,2

Cryogenic aspects:

- Conceptual layout done
- Liquid nitrogen from continuous fill or batch-filled
- Possibility of using a cryocooler in addition to LHe
- Estimated hold time of 1.8 days if cryocooler fails
- Beam tube stays cold at liquid nitrogen temp even if coils warm up
- Assembly structures proposed
    - Decisions to be made on assembly structure