Small-Period Superconducting Undulator

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Argonne National Laboratory
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)
- $B_{\text{max}}$ 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
3 cases tried:

• 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$_3$Sn 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
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$_3$Sn conductor
• Higher critical current conductor than NbTi
• NHMFL is experienced in working with Nb$_3$Sn
• 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:
• $J_c$ 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 $I_c$
• 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