Superconducting undulators

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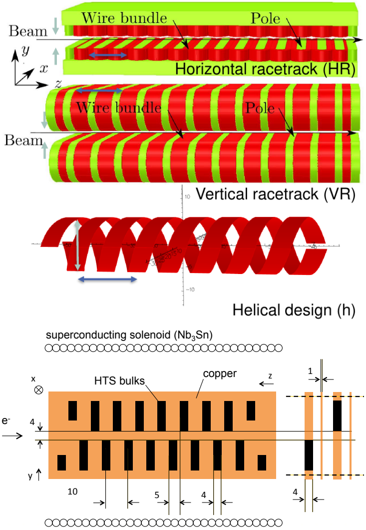
Status of Superconducting Undulator Technolgies

Low Temperature	Nb-Ti Nb_3Sn
High Temperature	REBCO tape coils REBCO bulk staggered arrays REBCO stacked tape staggered arrays



Strengths & Weaknesses

Strengths

- Magnetic performance

  PMU $<$ Nb-Ti $<$ Nb_3Sn $<$ REBCO

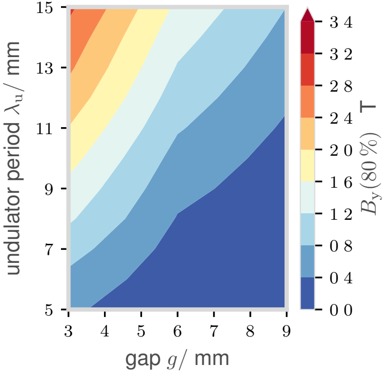
Weaknesses

Funded by the European Union

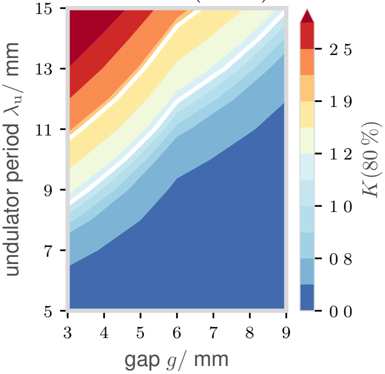
Magnetic Performance

Results of 2-D FEM Calculations for planar SCUs

Nb-Ti $B_\mathrm{y}(80\,\%)$



Nb-Ti $K(80\,\%)$



Conservative assumptions using properties of commercially available strands

Magnetic Performance

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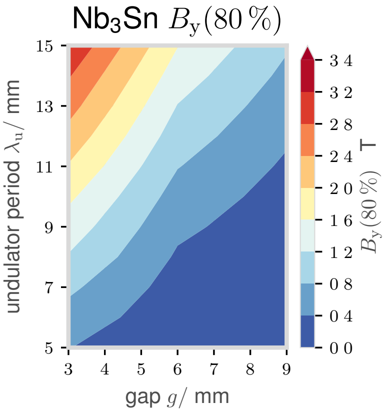

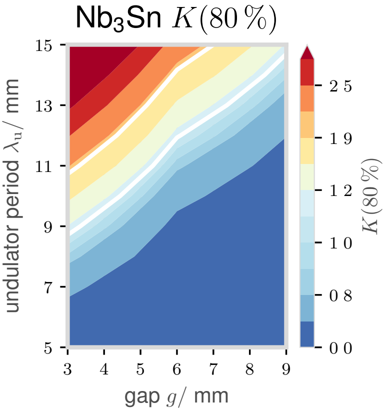

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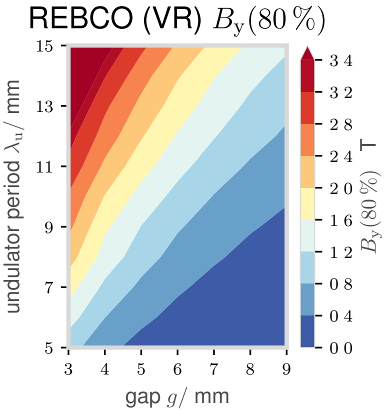
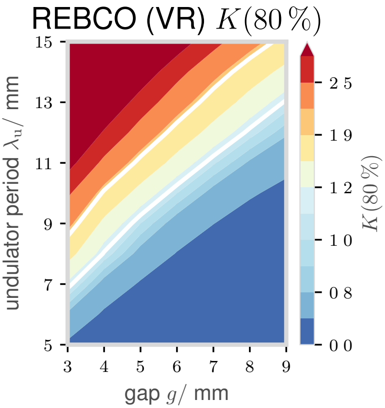


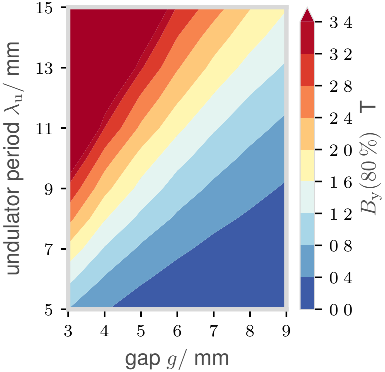


Assuming properties of most recently developed REBCO tapes
+ common vertical racetrack (VR) winding scheme

Magnetic Performance

Results of 2-D FEM Calculations for planar SCUs

REBCO (HR) $B_\mathrm{y}(80\,\%)$



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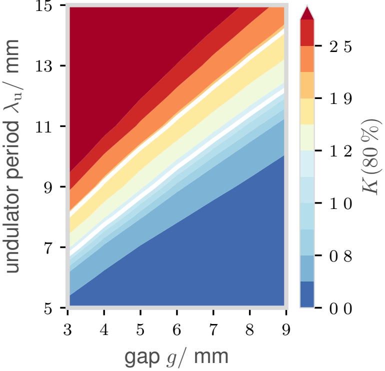

Additionally assuming a horizontal racetrack (HR) winding scheme

LTS

$$B(\lambda_u, g) = c_1 \cdot (c_2 + c_3\lambda_u - c_4\lambda_u^2 + c_5\lambda_u^3)\exp\left(-\pi\left(c_6\frac{g}{\lambda_u} - 0.5\right)\right).$$

HTS tape coils

$$B(\lambda_u, g) = c_1 \cdot (c_2 + c_3\lambda_u - c_4\lambda_u^2 + c_5\lambda_u^3)\exp\left(-\pi\left(c_7\frac{g}{\lambda_u} - c_6\right)\right).$$

HTS staggered array

$$B\left(\frac{g}{\lambda_u}\right) = B_0 \exp\left[-a\left(\frac{g}{\lambda_u}\right) + b\left(\frac{g}{\lambda_u}\right)^2\right].$$

Field Parametrizations

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HTS tape coils

See talk of Neil Thompson, this session

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  Complexity, Cost

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  Cryogenics, Nb-Ti proven for storage rings

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  $Nb_3Sn > $ HTS

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  LTS $\lesssim 30\,\mathrm{MGy}$, limited by insulation material

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  Nb_3Sn $>$ HTS
- Field quality control

  LTS complex, HTS undeveloped

Opportunities & Threads

Opportunities

- SCU technologies enable very compact design of FEL
  Nb-Ti: available now
  Nb_3Sn, HTS: high potential for future developments
- active R&D programs on SCU-FEL technologies
  in particular: LCLS-II
- still much progress on conductor performance
  $\Rightarrow$ XLS can take advantage

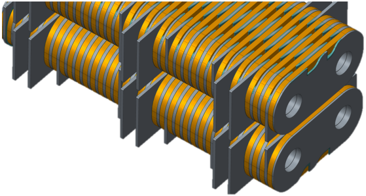
Threads

- risk that R&D on advanced SCU technologies might not lead to satisfactory results
  e.g. turn out to be too complex, too expensive, not feasible. . .

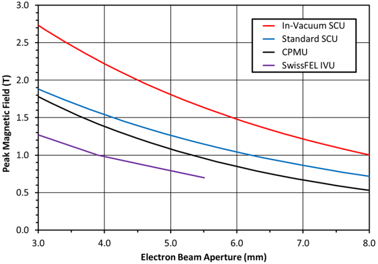
Ongoing R&D at XLS project partners

In-Vacuum SCU (STFC)

In-vacuum SCU at CLARA



SCUs for FELs



Parameter	Unit	Value
Period length	mm	15.5
Gap	mm	7.4
Number of periods		16
Peak field	T	1.25

- relaxed vacuum requirements
- in-vacuum SCU: magnetic gap reduced by 1 mm
- wakefield heating under our control

In-Vacuum SCU (STFC)

Test setup at CLARA

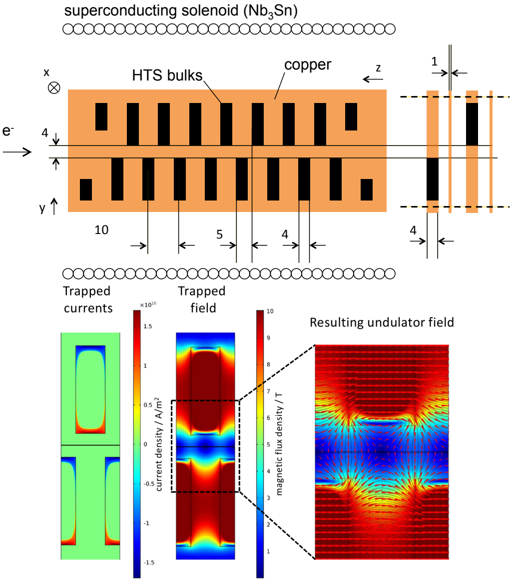
Experimental achievements

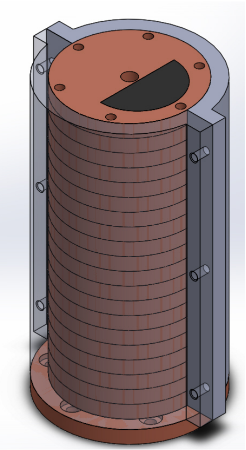
- Demonstrated that the in-vacuum SCU can operate with beam
- Thermal behaviour with beam measured

To be done

- Set up appropriate field integral compensation
- Measure photon beam spectrum to confirm magnetic field strength and quality

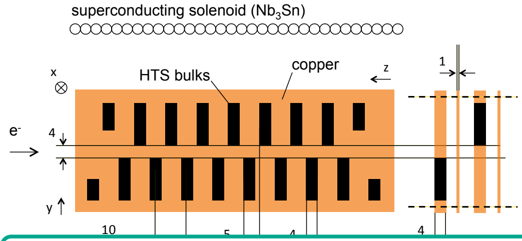
HTS staggered array (PSI)

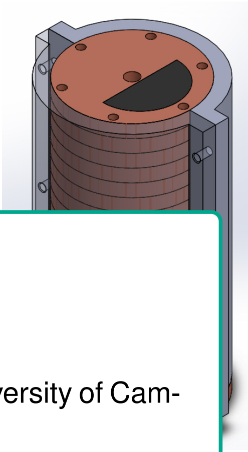




PSI GdBCO bulk sample

HTS staggered array (PSI)

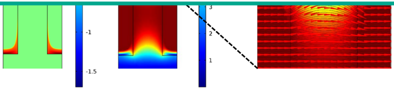




Two samples ready for test:

- 10-period GdBCO bulk sample
- 10-period GdBCO stacked tape sample

Test of first sample in co-operation with University of Cam-bridge in July



PSI GdBCO bulk sample

Activities at CERN and KIT

HTS tape coils (CERN)

- Model calculations concluded
- procurement of tapes started
- coil formers for sample windings under construction

Nb-Ti TGU development (KIT)

- Istallation of a 40-period TGU in its cryostat finalized
- magnetic characterization (hall probe scan) setup implemented
- experiments with beam foreseen for 2020

Thank you!

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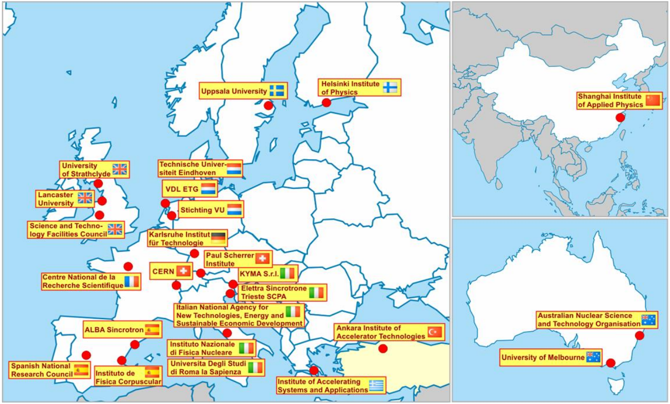

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