Possible application of HTS tapes for superconducting insertion devices

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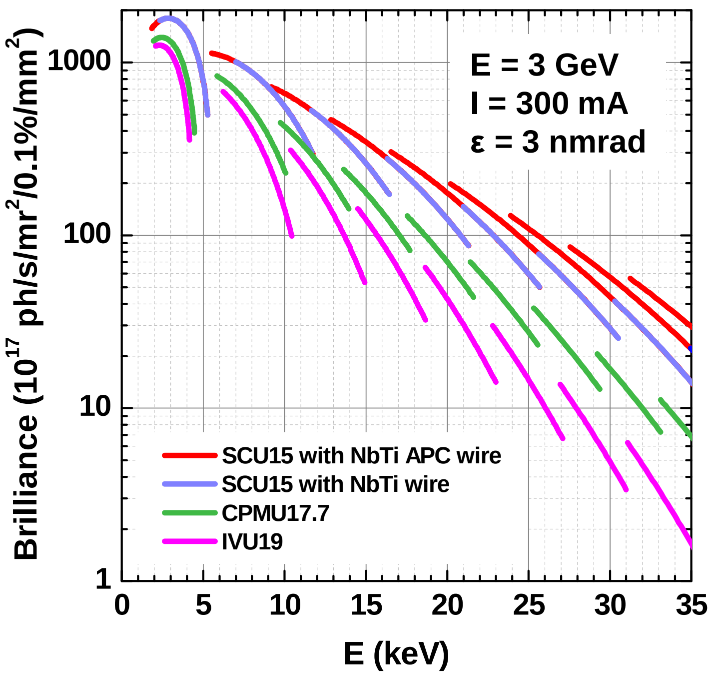
Outline

- **Motivation**
- **R&D activities on SCIDs @ ANKA**
- **HTS applications to SCIDs:**
  → **HTS tape planar undulator**
  → **HTS tape stacked undulator**
- **Conclusions**

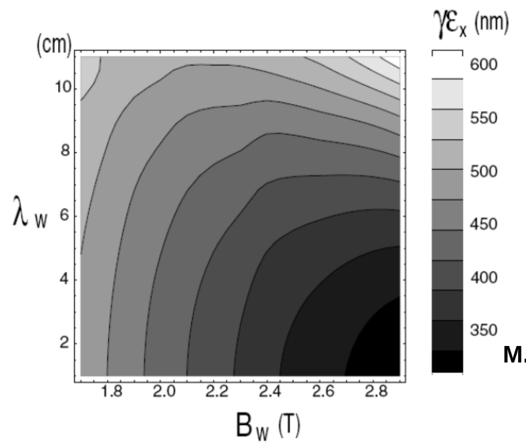
Motivation R&D SCIDs

Superconducting insertion devices (IDs) can reach, for the same gap and period length, higher fields with respect to permanent magnet IDs

- allowing to increase the spectral range and the brilliance when applied in low emittance storage rings, FELs, ERLs



	IVU [1]	CPMU [2]	SCU NbTi	SCU APCW [3,4]
λ_u [mm]	19	17.7	15	15
N	105	112	133	133
m. gap [mm]	5	5.2	6	6
B [T]	0.86	1.04	1.2	1.46
K	1.53	1.72	1.7	2.05



M. Korostolev Ph. D. Thesis, CLIC-Note-701

[1] F. Bødker et al., EPAC 2006
[2] C.W. Ostenfeld and M. Pedersen, IPAC 2010
[3] T. Holubek et al., Physics Procedia
[4] http://www.supramagnetics.com/

- allowing for more efficient reduction of beam emittance when employed as damping wigglers.

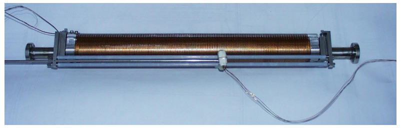
R&D on SCIDs in Karlsruhe and at ANKA

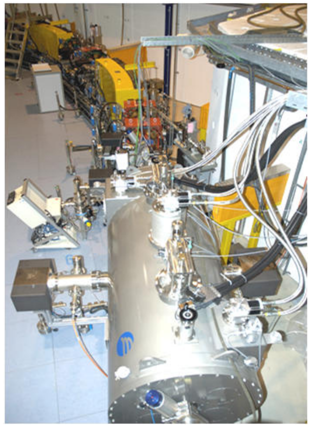
- Work on a superconductive micro-undulator started in Karlsruhe in the early 90's

Moser, H. O., Krevet, B. & Holzapfel, H. (1991), Mikroundulator, Patentschrift DE 4101094 C1, Kernforschungszentrum Karlsruhe GmbH, Germany.

- Test with beam at the MAINZ MICROTRON MAMI

T. Hezel et al., PAC1999



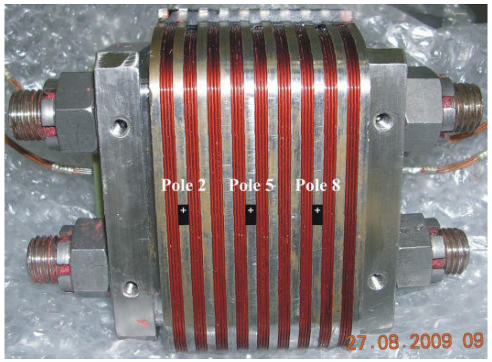


- Device developed in collaboration with ACCEL installed at ANKA in 2005

S. Casalbuoni, M. Hagelstein, B. Kostka, R. Rossmanith, M. Weisser, E. Steffens, A. Bernhard, D. Wollmann, and T. Baumbach
Phys. Rev. ST Accel. Beams 9, 010702 (2006)

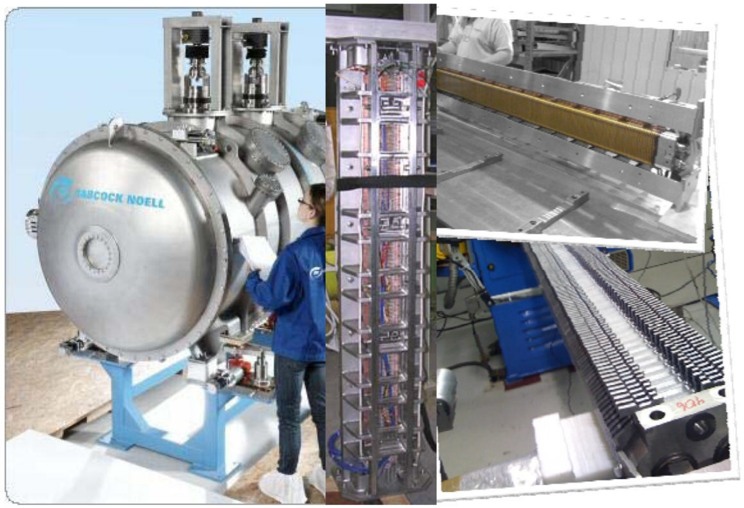
- Collaboration of ANKA with Babcock Noell GmbH (BNG) to develop two planar devices, one with switchable period length.

First experimental demonstration of period length switching for scIDs



A. Grau et al., IEEE Trans.
on Appl. Supercond. 1596-1599 Vol. 21-3 (2011)

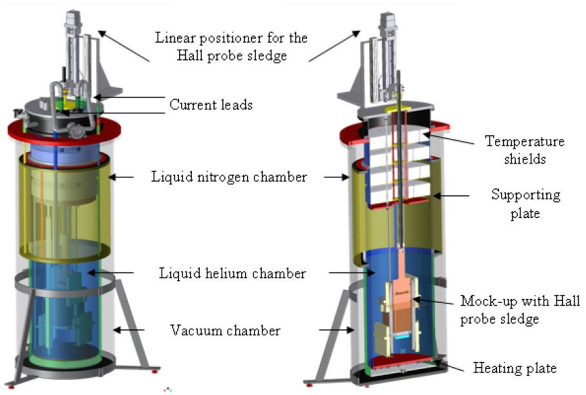
First step: DemoSCU15
Installation in ANKA
foreseen in 2012



R&D on SCIDs at ANKA

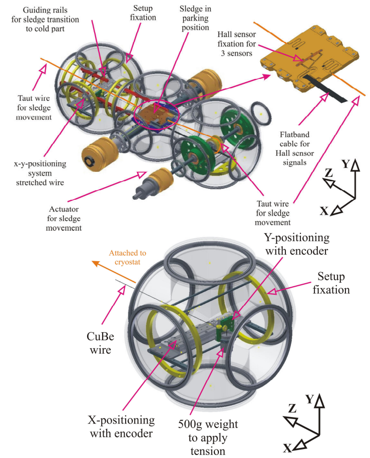
Tools and instruments for magnetic field characterization

CASPER I



E. Mashkina et al., EPAC2008

CASPER II

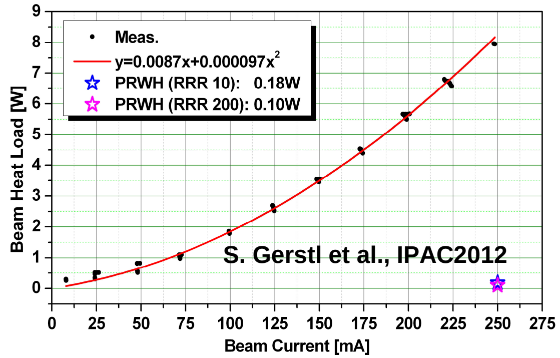


A. Grau et al., IEEE Trans. on Appl. Supercond. 2312-2315 Vol. 21-3 (2011)

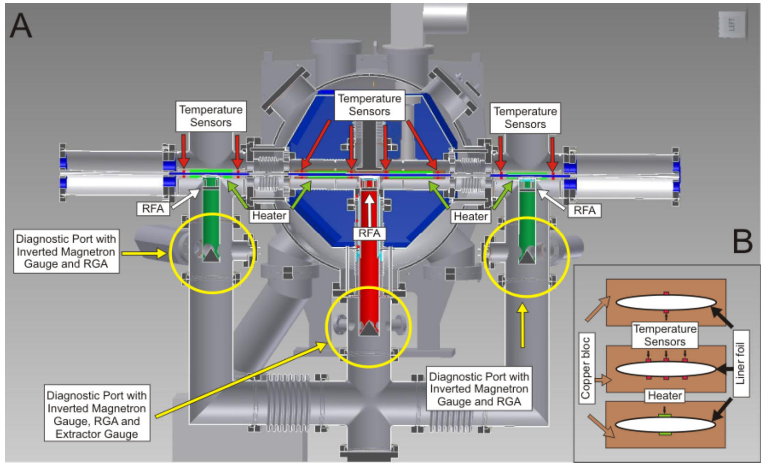
and for beam heat load measurements

COLDDIAG

Delivered to Diamond light source
Preliminary data



S. Gerstl et al., IPAC2012

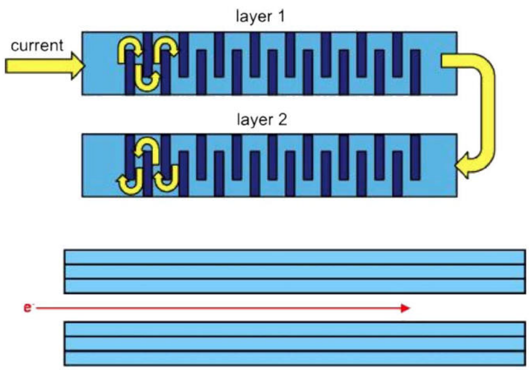


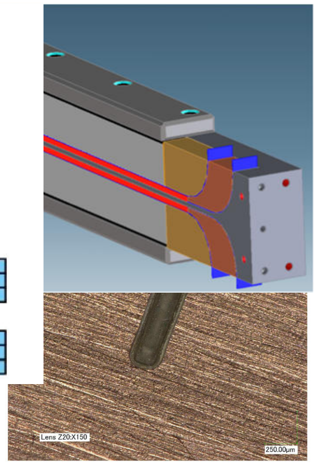
HTS tape application to SCIDs

Karlsruhe Institute of Technology

- The engineering current density of commercial HTS materials is rapidly increasing in performance making them more and more attractive, so that they could be competitive with NbTi.
- High mechanical accuracy required for SC undulators in light sources exclude application of Nb3Sn coils with actual technology, that requires heat treatment after winding
- HTS tapes can be operated at higher temperatures than NbTi allowing to sustain higher beam heat loads, and therefore simplifying the cryostat design for the final device.
- Two concepts of application of HTS tapes to produce a sinusoidal field have been so far proposed:

HTS tape stacked undulator

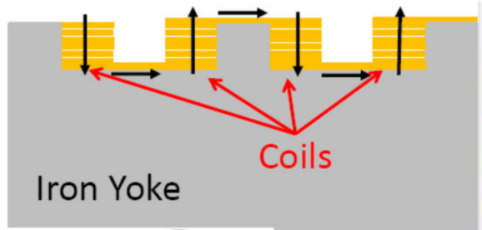


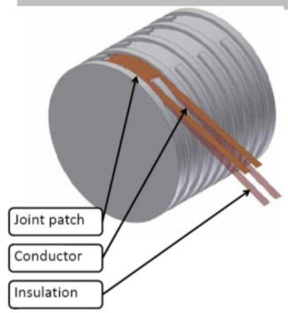


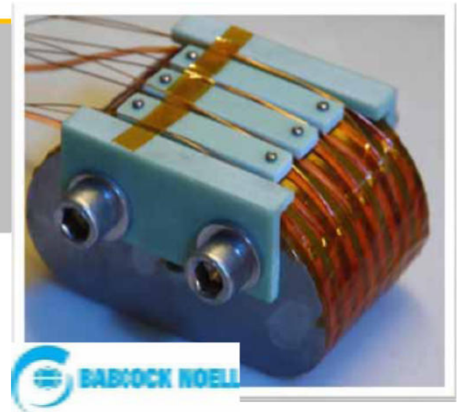
Etched using lithography techniques

S. Prestemon et al., IEEE Trans. on Appl. Supercond. 1880-1883 Vol. 21-3 (2011)

HTS tape planar undulator





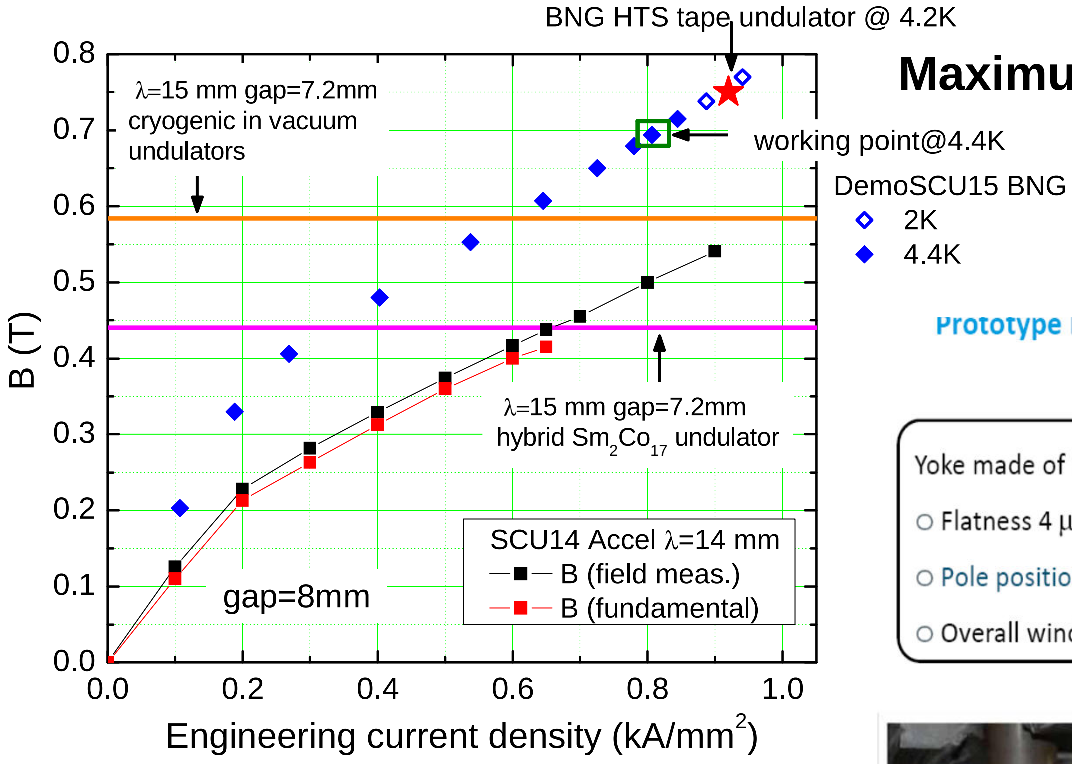


with Superpower 2G HTS wire

C. Boffo, IDMAX10

http://www.maxlab.lu.se/usermeeting/2010/sessions/

HTS tape planar undulator: Test at CASPER I



Maximum current 555 A ❾ I = 0.92 kA/mm^2

Prototype Fabrication

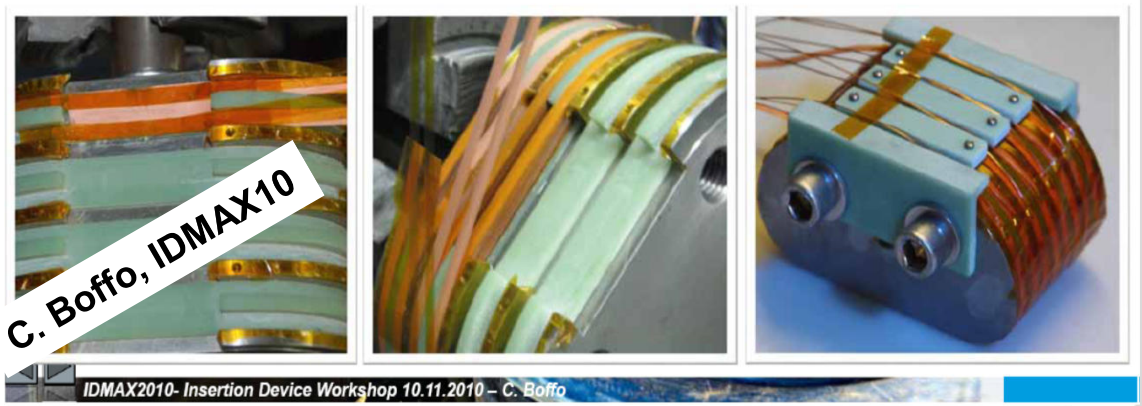
BABCOCK NOELL

Yoke made of a single block (68 mm long):

- Flatness 4 µm
- Pole positioning 1 µm
- Overall winding groove flatness 5 µm

Winding process:

- Co-winding 50 µm Kapton tape
- GRP layer as non magnetic material
- Side ground insulation 50 µm Kapton



HTS tape planar undulator: Working program

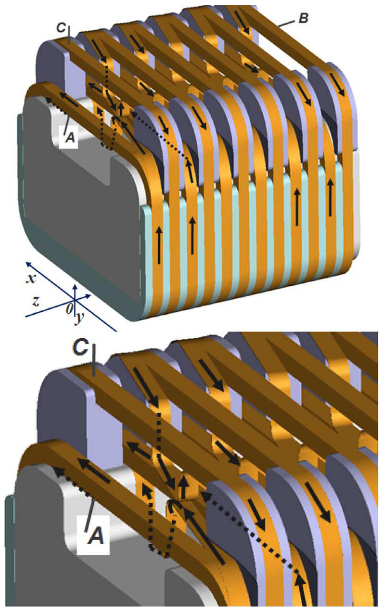
1. **Design short mockup**
2. **Test at CASPER I: quench + local field measurements**
3. **Test at CASPER II: quench + local and integral field measurements**
4. **Design longer mockup**
5. **Test at CASPER I: quench + local field measurements**
6. **Test at CASPER II: quench +local and integral field measurements**

Open issues:

- Joints resistance
- Quench detection and protection
- Test field accuracy

Possible improvements:

- Reduce insulation thickness
- Increase tape current density
- Alternative design without joints



S. H. Kim et al, IEEE Trans. Appl. Supercond. 1709-1712 Vol. 21-3 (2011)

HTS tape stacked undulator: Motivation

Karlsruhe Institute of Technology

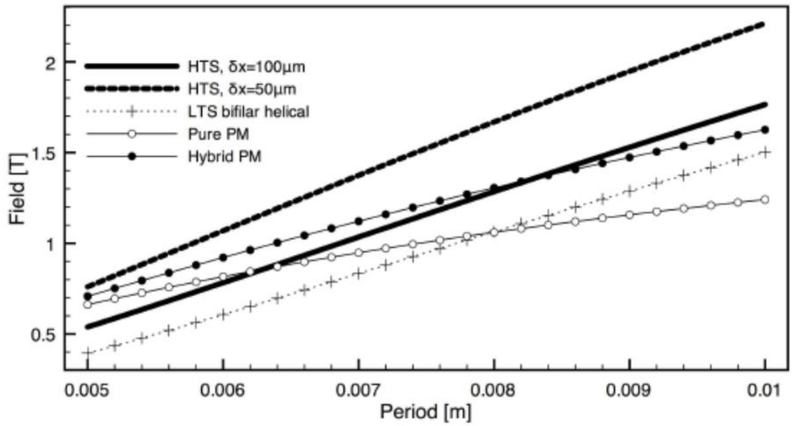


Figure 4: Performance comparison be[illegible] hybrid, superconducting bi-filar hel[illegible] [illegible]posed HTS tape concept technologie[illegible] [illegible] tapes was assumed for the calculat[illegible] [illegible]pe is a standard commercial product[illegible] [illegible] be readily obtained by eliminatin[illegible] [illegible]terial. Calculations for superconduc[illegible] [illegible]s neglect $J_c(B)$, and are only vali[illegible] [illegible] he bifilar helical SCU data assumes [illegible] m^2, but does not consider the possible [illegible] between coils. PM-based devices assume rema-n[illegible] field $Br = 1.35T$.

The concept is particularly promising for narrow-gap, short period <10 mm regimes.

S. Prestemon et al., PAC09

Open issues – challenges:

- Developing a highly accurate process for making the **cuts** in the YBCO tape (lithography, laser cutting)
- Providing thin, uniform **insulation** of the conductors from each other and from the support structure
- **Joint fabrication** - reproducibility, minimizing resistance,and maintaining thickness compatible with insulation
- Providing series connection from the top section to the bottom section without interrupting the beam path
- Minimizing variations in "height" along the beam path
- Develop support structure to maintain a precise beam aperture
- **Quench** detection and protection
- **Radiation damage**
- **Engineering current density as a function of the magnetic field, geometry, stress**
- **Mechanical design**

ANKA

HTS tape stacked undulator: Working program

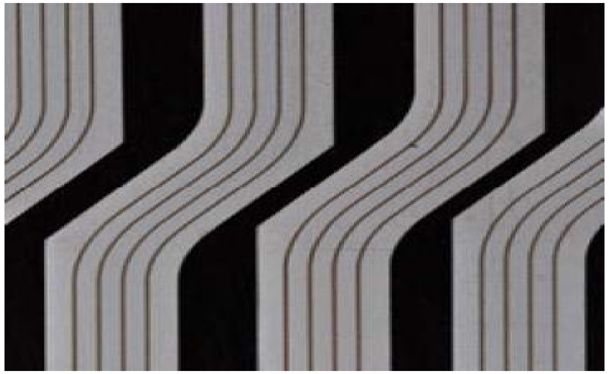
KIT internal collaboration: ANKA with ITeP (W. Goldacker, R. Nast)

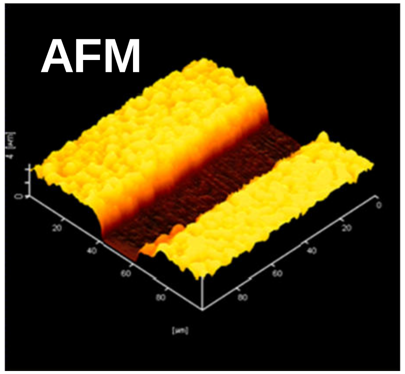
1. Choice design parameters (period length, width of cuts, length of cuts) by Radia simulations
2. Production of 1 tape machined with the design geometry by laser ITeP
3. Construction of Hall probe sledge and support structure for above tape.
4. Test at CASPER I: quench + field measurements
5. Stack two tapes
6. Quench test at CASPER I
7. Production of second tape machined with the design geometry by laser
8. Stack two machined tapes
9. Test at CASPER I: quench + field measurements
10. Production of 30 tapes machined with the design geometry by laser
11. Stack machined tapes
12. Test at CASPER I: quench + field measurements
13. Production of other 30 tapes machined with the design geometry by laser
14. Stack machined tapes
15. Design and production of support structure for both stacked structure with gap to be decided (=~3mm)
16. Design and production of sledge to hold Hall probes
17. Test at CASPER I: quench + field measurements

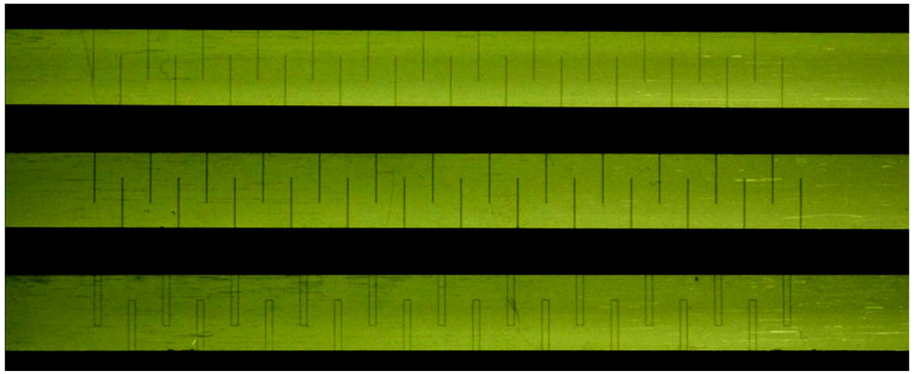
HTS tape stacked undulator: Laser structuring

KIT internal collaboration: ANKA with ITeP (W. Goldacker, R. Nast)

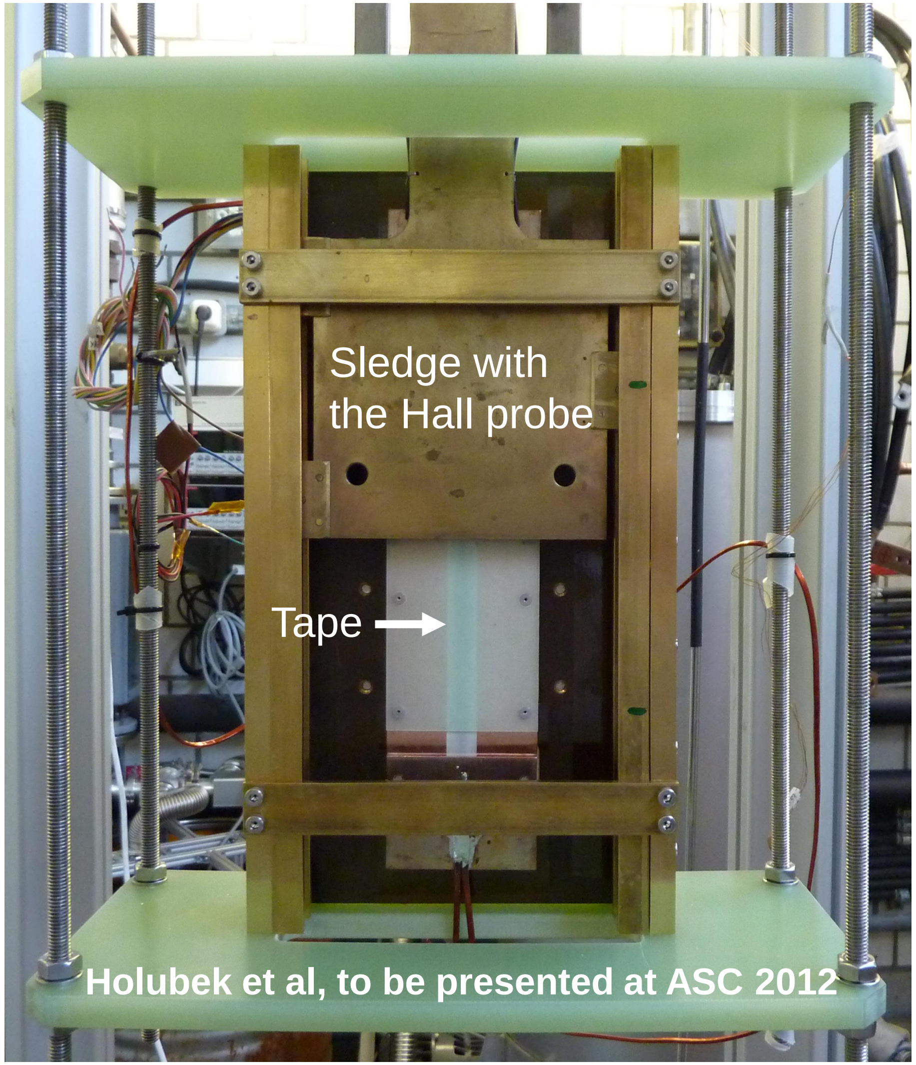
- Etching using Trumpf picosec YAG - IR laser
- Programmable beam control used already for Roebel cables
- High positioning precision
- Laser grooving is very reliable: No contamination of groove detected (SEM)
- Fast process: structuring is performed at ambient atmosphere

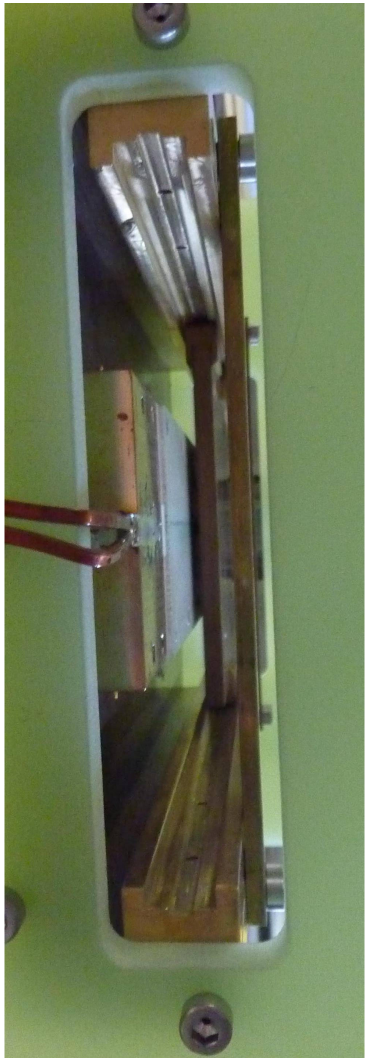






HTS tape stacked undulator: Setup at CASPER I





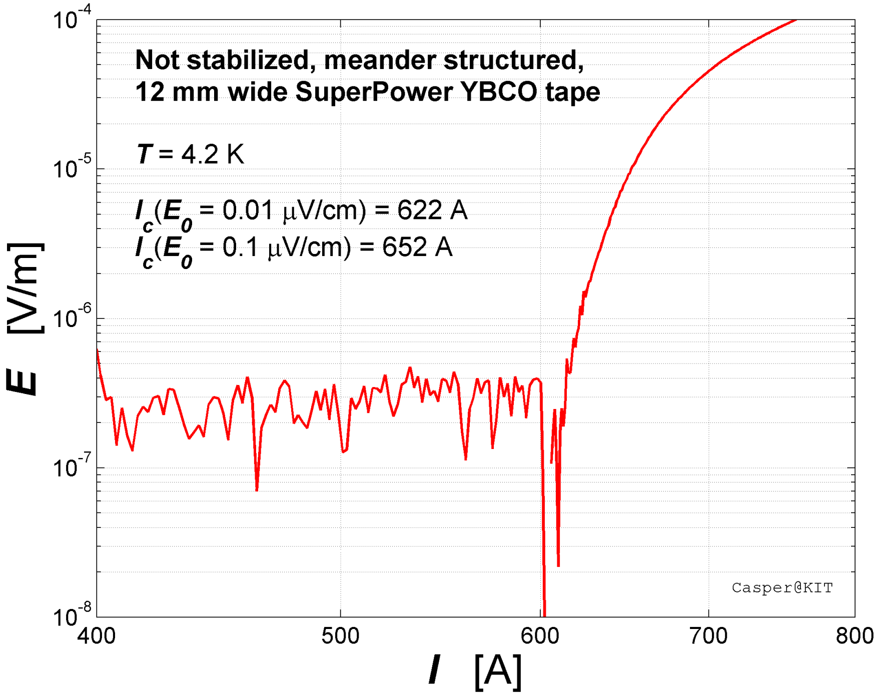
HTS tape stacked undulator: Test of single tape

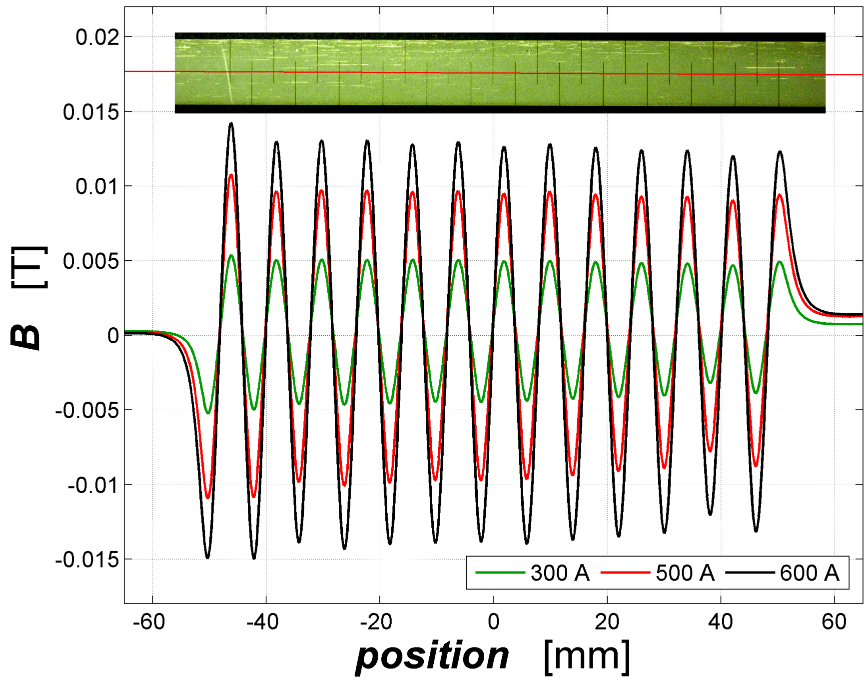
- Measured critical current corresponds to 1/3 of the critical current of unstructured tape (2 kA)
- This test proves that laser structuring has no negative impact on superconductive properties of the tape

T. Holubek et al, to be presented at ASC 2012

- First magnetic field line scans were obtained 2.05 mm above the meander structured, 12 mm wide HTS tape for different currents

(width of SC channel = 4 mm and period length = 8.05 mm)





Conclusions on HTS stacked undulator

- Critical current measurement confirmed that laser structuring has no negative impact on superconductive properties of the tape

- We obtained first magnetic field line scans above meander structured HTS tape