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ILC Helical Undulator Development Update

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On behalf of Helical team

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(Moved on)

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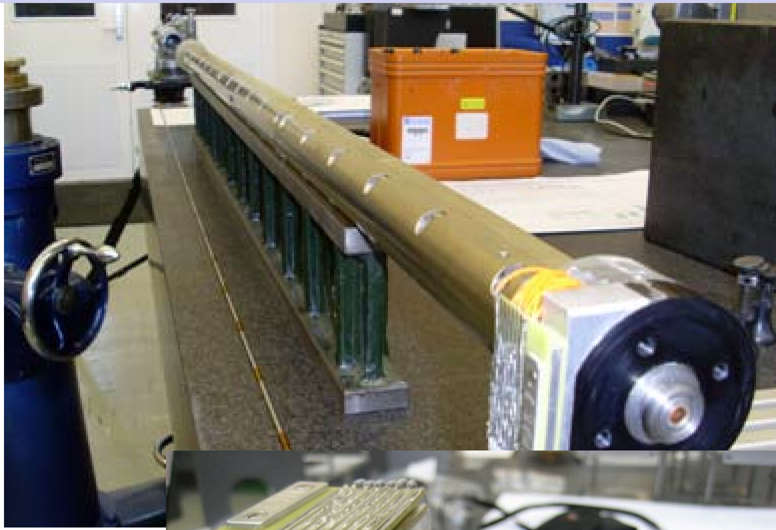
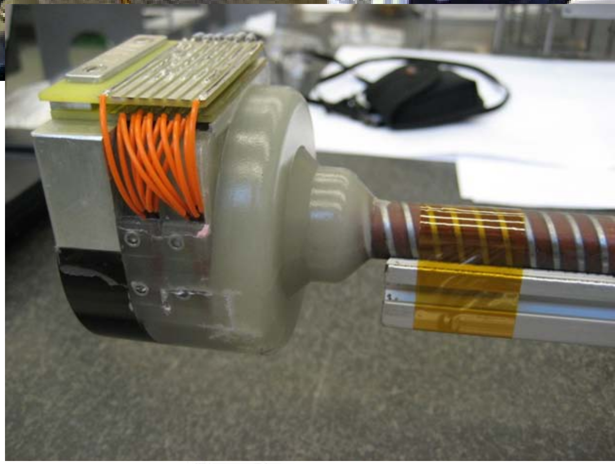
Contents

- Brief overview of the construction of the undulator
- Main parameters
- Testing in 4m cryomodule
- Work (EuCARD) on the use of Nb_3Sn
- Nb_3Sn magnet insulation issues
- Summary

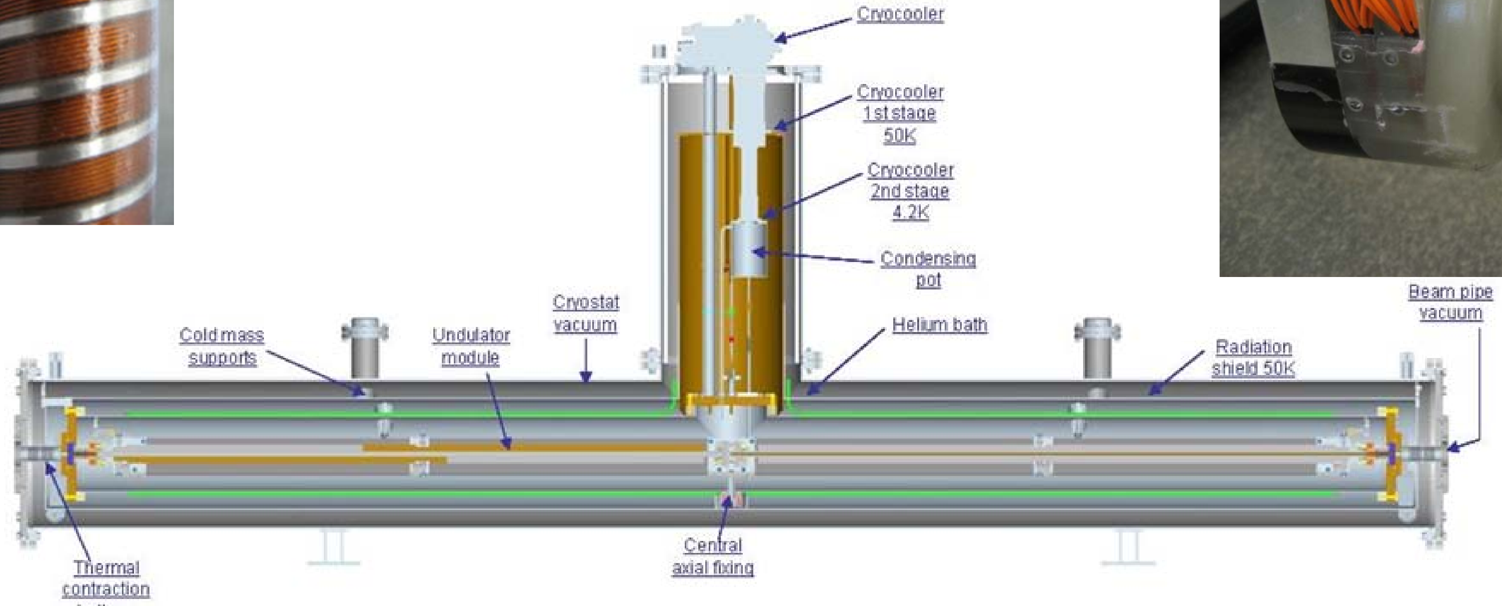
4 metre Cryomodule

- Two 1.7 metre helical undulator magnets have been successfully made using NbTi.
- Magnets positioned back to back in cryostat.
- Cryostat has been assembled and tested – was designed to be zero-loss





View of windings



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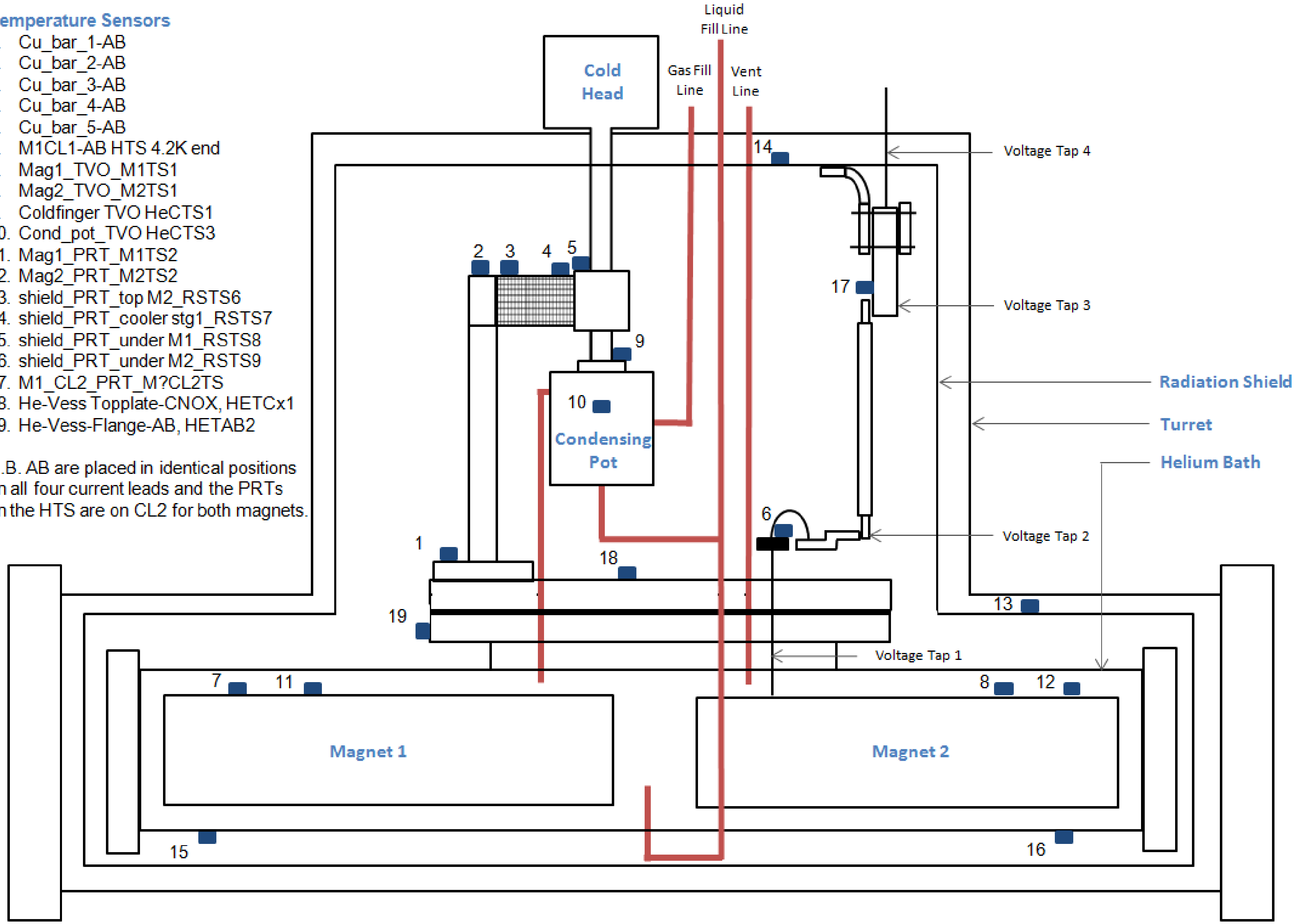
Cryostat configuration

Temperature Sensors

1. Cu_bar_1-AB
2. Cu_bar_2-AB
3. Cu_bar_3-AB
4. Cu_bar_4-AB
5. Cu_bar_5-AB
6. M1CL1-AB HTS 4.2K end
7. Mag1_TVO_M1TS1
8. Mag2_TVO_M2TS1
9. Coldfinger TVO HeCTS1
10. Cond_pot_TVO HeCTS3
11. Mag1_PRT_M1TS2
12. Mag2_PRT_M2TS2
13. shield_PRT_top M2_RSTS6
14. shield_PRT_cooler stg1_RSTS7
15. shield_PRT_under M1_RSTS8
16. shield_PRT_under M2_RSTS9
17. M1_CL2_PRT_M?CL2TS
18. He-Vess Topplate-CNOX, HETCx1
19. He-Vess-Flange-AB, HETAB2

N.B. AB are placed in identical positions on all four current leads and the PRTs on the HTS are on CL2 for both magnets.



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Results

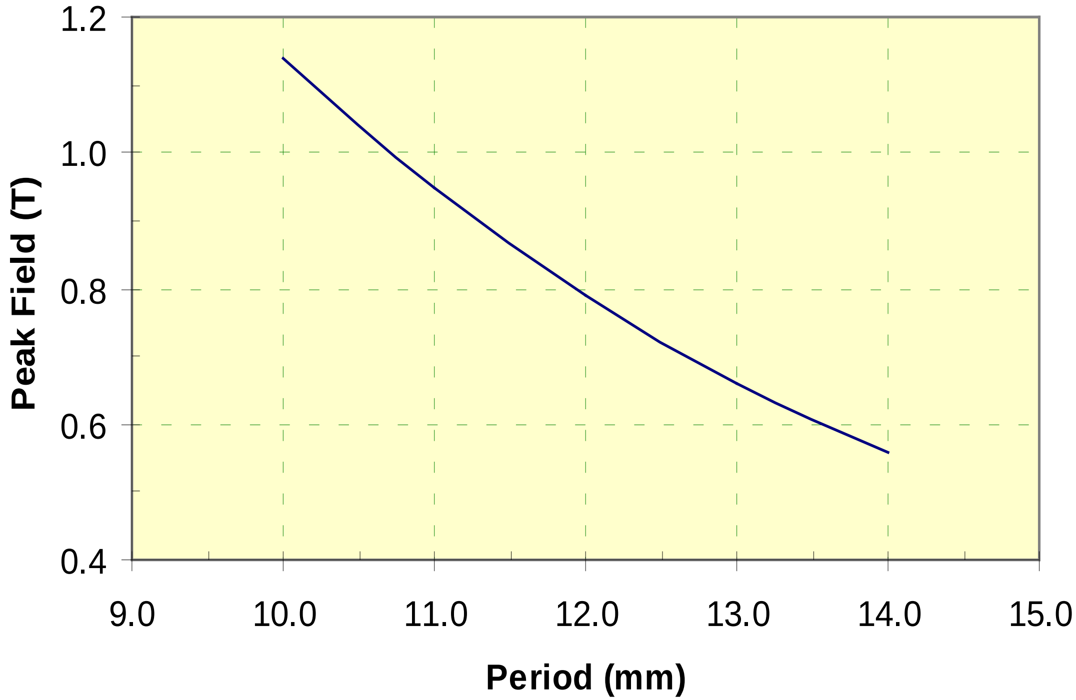
Powering tests

- Magnet has achieved 215A (0.88T) and was stable
- Achieved 252 A but there was a problem with a burn-out of the current lead just below the top plate
- This is being repaired and the thermal issues are being addressed

Design drivers

Initial specification

- Electron Drive Beam Energy 150 GeV
- Photon Energy (*1st harmonic*) 10.06 MeV
- Photon Beam Power 131 kW
- Total undulator length 100-200m
- Undulator Period 11.6mm
- Field on Axis 0.84 T
- Beam Stay clear 4.5mm dia



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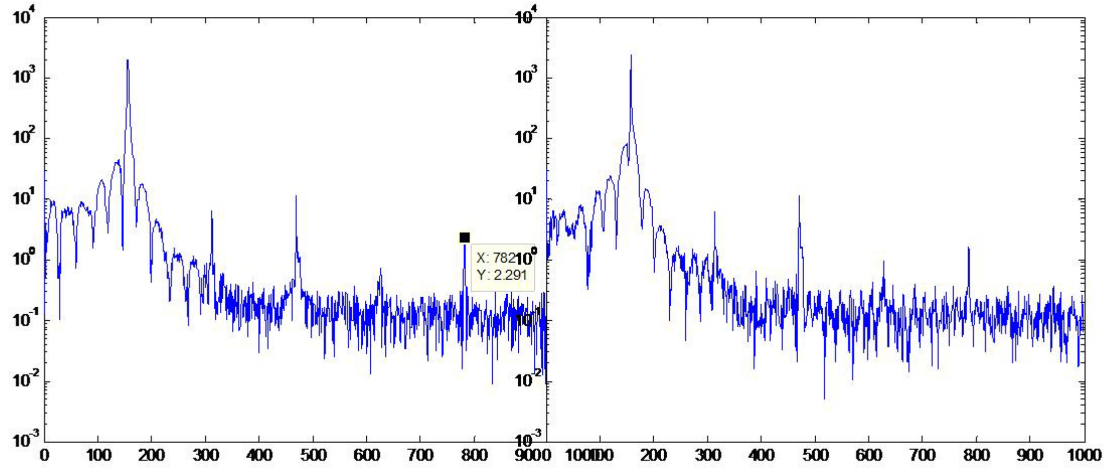
Design specification

Undulator Period		11.5 mm
Field on Axis		0.86 T
Peak field homogeneity		<1%
Winding bore		>6mm
Undulator Length		147 m
Nominal current		215A
Critical current		~270A
Magnetic bore		6.35mm
K		0.92
Manufacturing tolerances		
	winding concentricity	+/-20um
	winding periodicity	+/-50um
	Axial straightness	+/-50um
NbTi wire Cu:Sc ratio		0.9
Winding block		9 layers
		7 wire ribbon

Helical beam purity

Field profile Fourier analysed and plotted on a semi- logarithmic scale – sinewave is very pure – these are the same magnet with data taken on two different runs.

Peak corresponds to 11.5mm period



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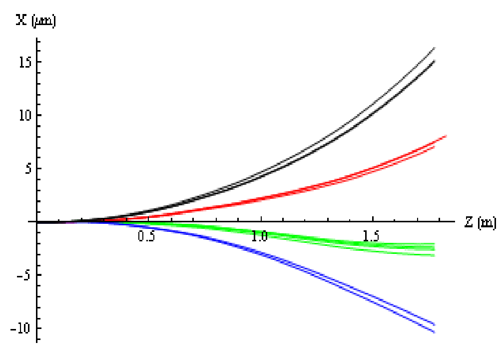
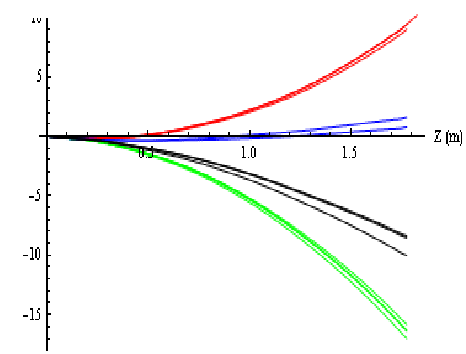
Particle trajectories using measured beam profile as calculated by SPECTRA as expected

R(um)



R(um)



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Wakefield heating

Power deposited from resistive wall heating

We need to know this for thermal reasons as we don't want the beam to quench the magnet

Parameter	Unit	1	2	3
Repetition rate	Hz	5	5	5
Bunch spacing	ns	150	300	500
Bunch length	µm	150	300	500
Particles/bunch	10^{10}	1	2	2
Peak Bunch Frequency	MHz	6.66	3.33	2
Bunches/pulse		5640	2820	2820
Fill factor	$X\ 10^{-3}$	14.1	4.23	7.05
Power/metre	W/m	0.081	0.052	0.022

We will be simulating this in the tests with a resistor chain in the bore to assess influence on magnet

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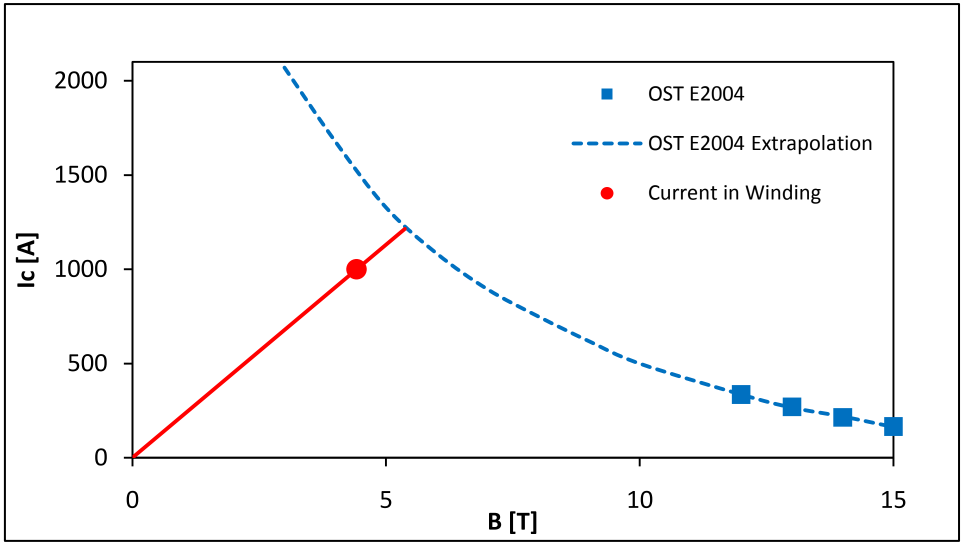
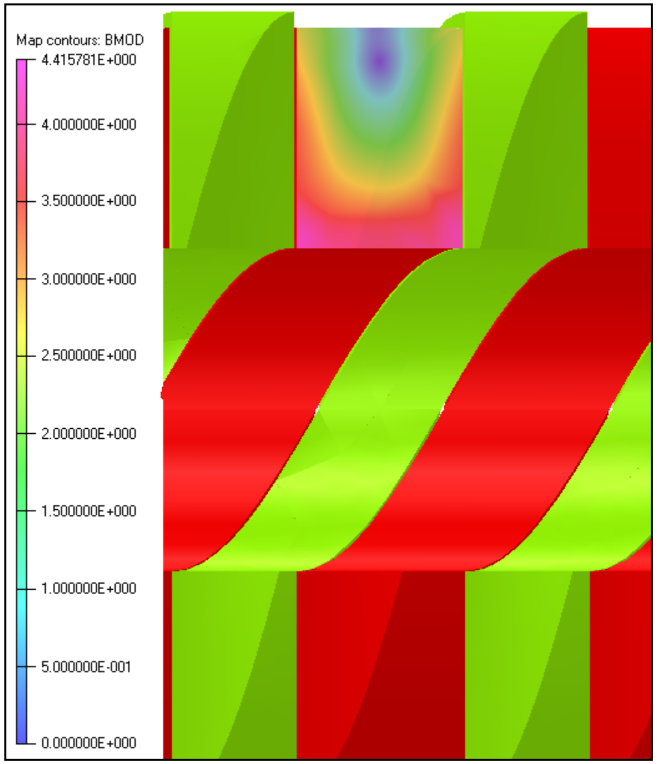
Application of Nb_3Sn

Wire in the undulator will see fields of around 4T – this is quite low for Nb3Sn and there was some concern that there may be stability problems due to flux jumping.

Stability can be improved by good stabilisation of the wire.





Field strength and Ic at 1 kA.
Winding ID: Ø6.35 mm.
Field on axis: 1.54 T.
Peak field in conductor: 4.42 T.
Operating at 82% of Ic.

Nb_3Sn Procurement

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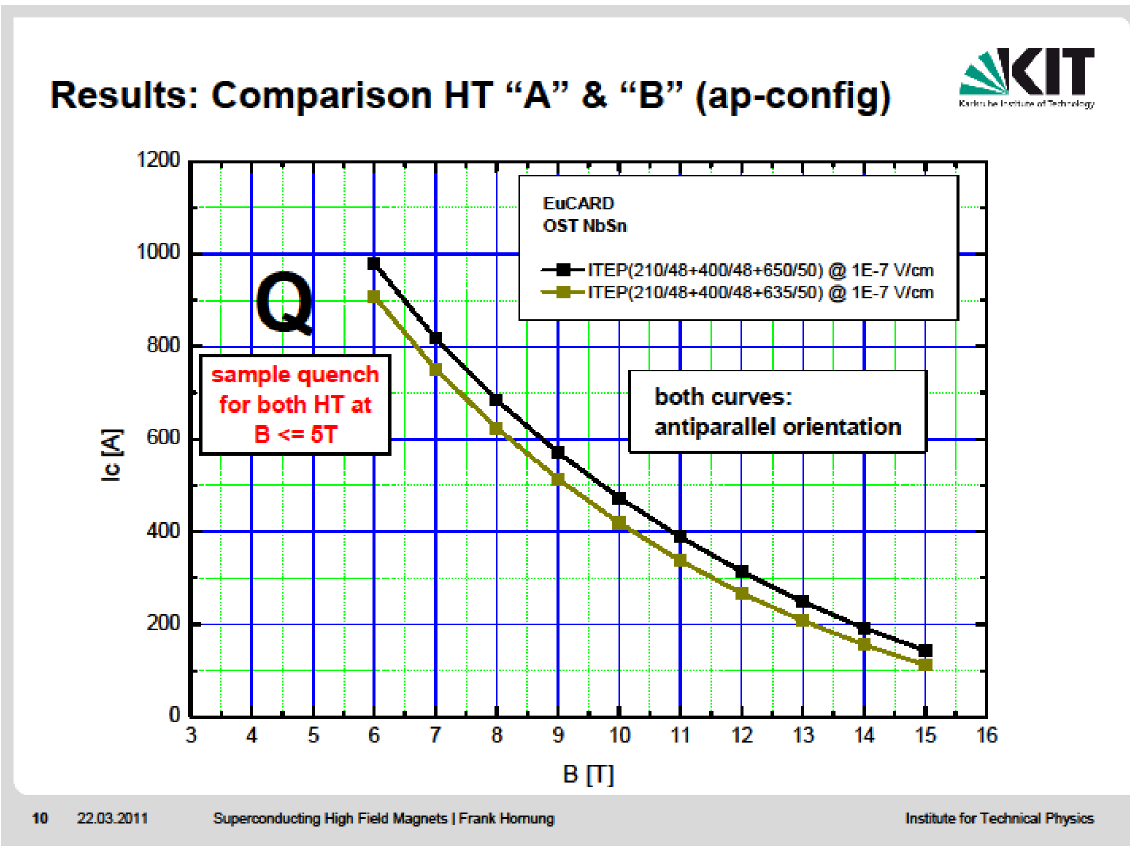
EuCARD

- The helical undulator design has a small winding groove due to the small repeat period.
- For large magnetic field, need maximum current density in winding, but many wires within winding to limit current in each wire (better for Cryogenics).
- Need Nb_3Sn wire to have maximum performance commercially available with as small diameter as possible – there is a worry over low field stability (see later)
- Have purchased 1 km of Ø0.5 mm (Ø0.63 mm with glass braid) E2004 RRP wire from OST.
  - Recommended heat treatment:
    210°C/48hr + 400°C/48hr + 650°C/50hr
  - Heat treatment can be modified to improve RRR of copper and hence the low field stability (tried 635/50).

Application of Nb_3Sn

We have had the superconducting wire tested at Karlsuhe Institute of Technology and found (as we feared) that it is unstable at low fields:



We have two samples tested which have undergone different heat treatment to assess influence of stabilising copper RRR

Application of Nb_3Sn

Stability parameter gives an indication of how the wire will behave *:

$$B = \frac{\mu_0 J_c^2 d^2}{4C(T_{bath} - T)} < 3$$

Still investigating this and struggling with some parameters but it looks as though the effective filament diameter is too large for use in a helical undulator. Looking for wire technology advances

Where

- Jc is the critical current at T
- T is the transition temperature
- Tbath is the bath temperature
- C is the volumetric heat capacity of the superconductor
- d is the filament diameter.

This parameter should be less than 3 for stability.

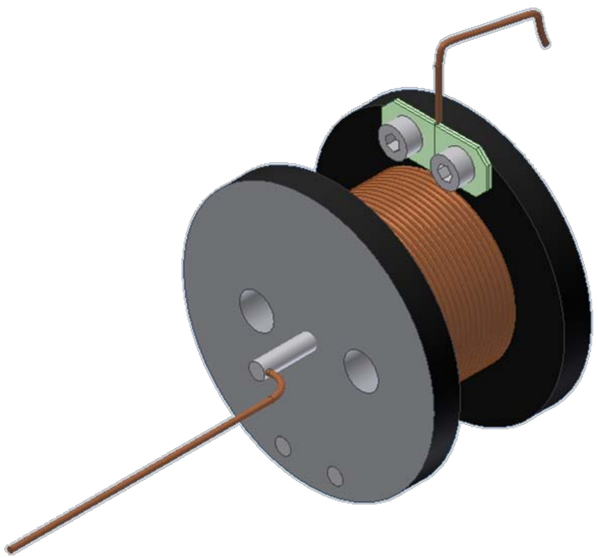
* Romanovskii, V, Physica C 310 (1989), 392- 399

Insulation development

Ground plane insulation tests using a small bobbin and constant tension.

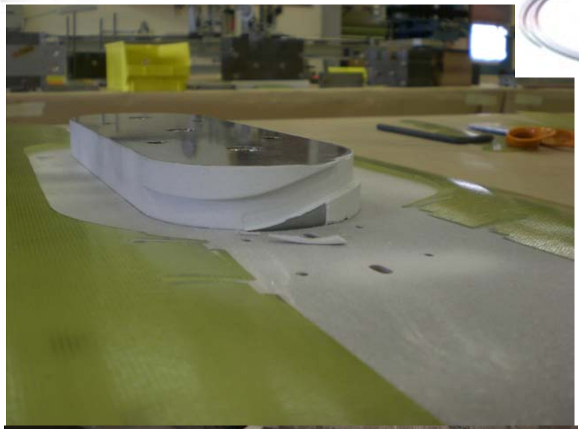
This type of test has several advantages:

- Known constant force between wire and specimen.
- Coil has much greater contact area than a single point so has more chance of finding pinholes or other weaknesses in coating.
- Build up of coating will be evident in corners.
- Abrasion between wire and specimen will demonstrate wear resistance of coating
- Relatively simple and cheap to make specimens.
- The geometry will show if there are any directional or shadow affects from coating processes.

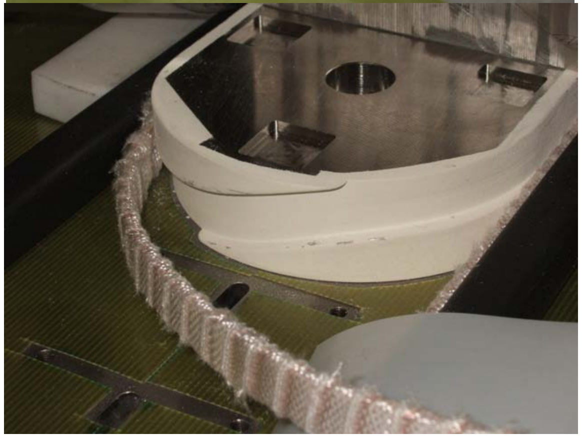


Insulation development

Plasma Sprayed Alumina – this is a directional spray process that requires several sprays from different angles to get full coverage, this leads to a non-uniform coating build up (1.5mm ~ 10x specified thickness in places) and high stress within the Alumina causing it to fracture easily.



This is refractory paint basically Zirconia + a binder – a lot less of the build up problems but very little wear resistance and comes off in critical places during winding



Diamond Like Carbon – good locally but seemed to have pinholes (maybe due to poor surface preparation) so that globally it was shorting.

Development programme is continuing.........

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Summary

Where we are:

- Results from the tests on the 4m helical look good
- Working to address minor issues to achieve zero loss in cryostat
- Planning tests to look at influence of wakefield heating on the magnet

- Nb_3Sn development not looking too promising because of low field stability issues
- Insulation system development continuing – important for a number of projects
- Vital that it is thin for the use of Nb_3Sn in the helical otherwise advantage over NbTi is quickly lost

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END