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Helical undulator progress

TILC-09 18th April 2009

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On behalf of the Helical collaboration

Scope of presentation

Undulator leaks

- Had an inherent weakness in existing design
- Hard to provide operational Vacuum required by ILC beam tube.
- Both magnets are now retrofitted with bimetal joints on both ends.
- Leak fixes is complete.

Prototype rebuild

- 4m Module rebuild
- Alignment
- Active alignment module

Powering tests

- Results of recent powering test

Summary and plans

Initial manufacturing spec

Following an extensive **R&D programme** and **modelling study** the following specification was developed for the undulators:

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
Manufacturing tolerances	
radial tolerance	+/-20um
periodicity tolerance	+/-50um
Axis straightness	+/-50um
NbTi wire Cu:Sc ratio	0.9
Winding block	9 layers 7 wire ribbon

This defines the shortest period undulator we could build with a realistic operating margin.

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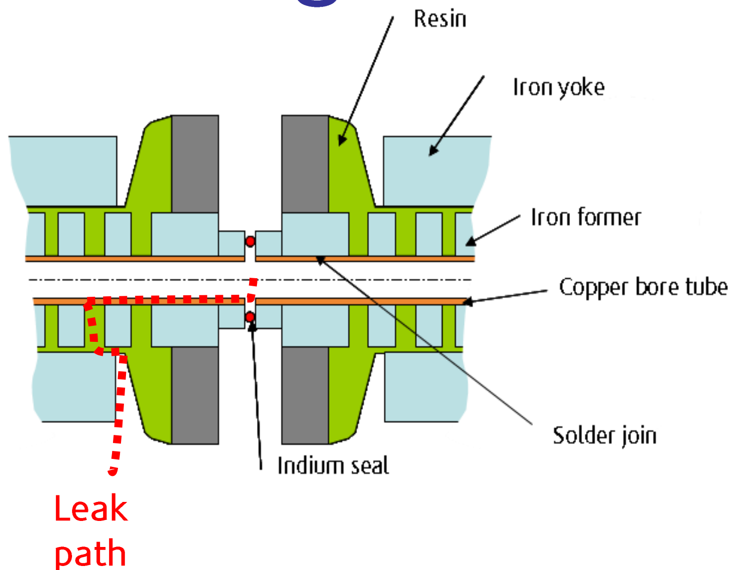
Magnet Leaks



Leak testing

Not at a normal interface

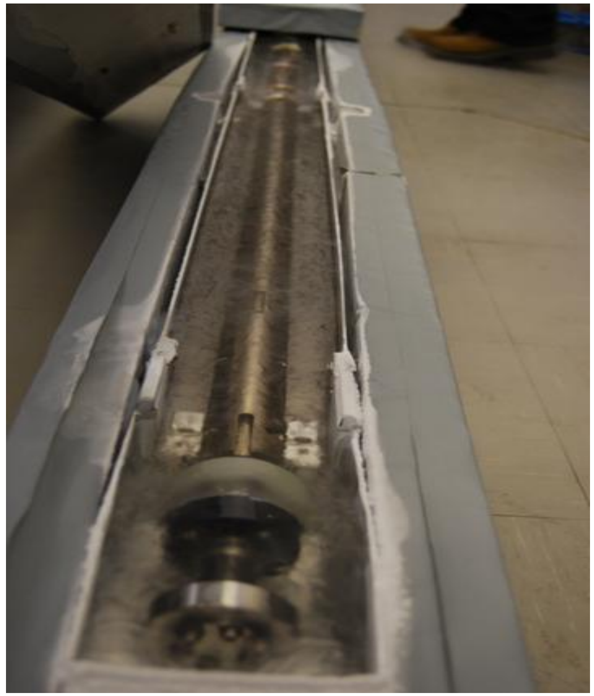
Through the magnet structure through resin along copper bore to point where the magnets join, passes between iron and copper

Through a final solder joint.

These leaks were not evident at 300K or during initial test cycling to 77K.

After repeated cycling 1 by 1 these solder joints have ruptured

Inherent flaw here, solder does not seem resilient when cycled



Magnet Leaks

Leak fix

Looked at different solutions

Most promising was a silver soldered copper-iron Bi metal ring

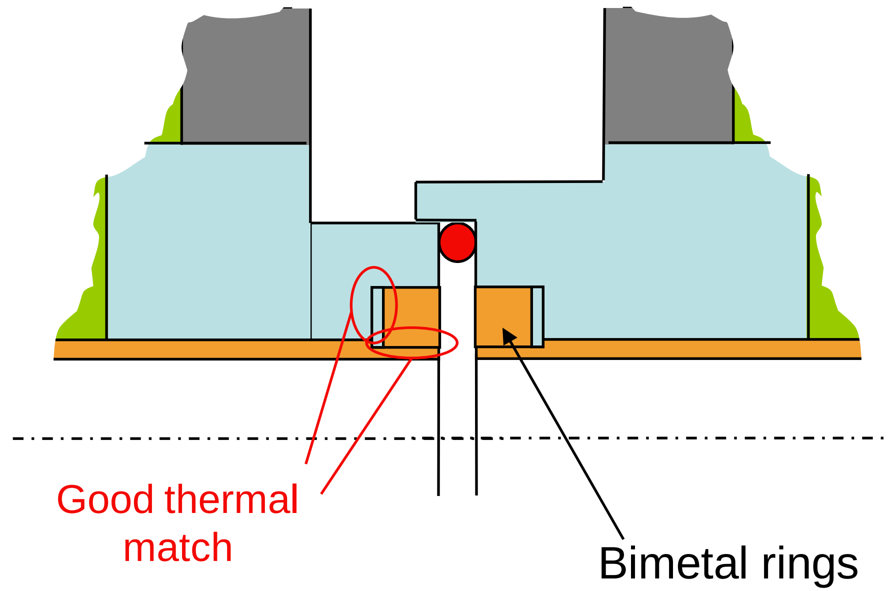
Soldered in position using cerobenze

The goal here is to minimise the thermal stress on the cerobenze joint by matching the thermal contractions of the different materials

Implemented this solution on some test pieces and it has survived 20 thermal cycles.

Finally remachined magnets and implemented on all magnet joints.

Each magnet joint then thermally cycled and tested 10+ times



Magnet Leaks

Re-testing magnets

Build confidence in leak fix.

Multiple thermal cycles

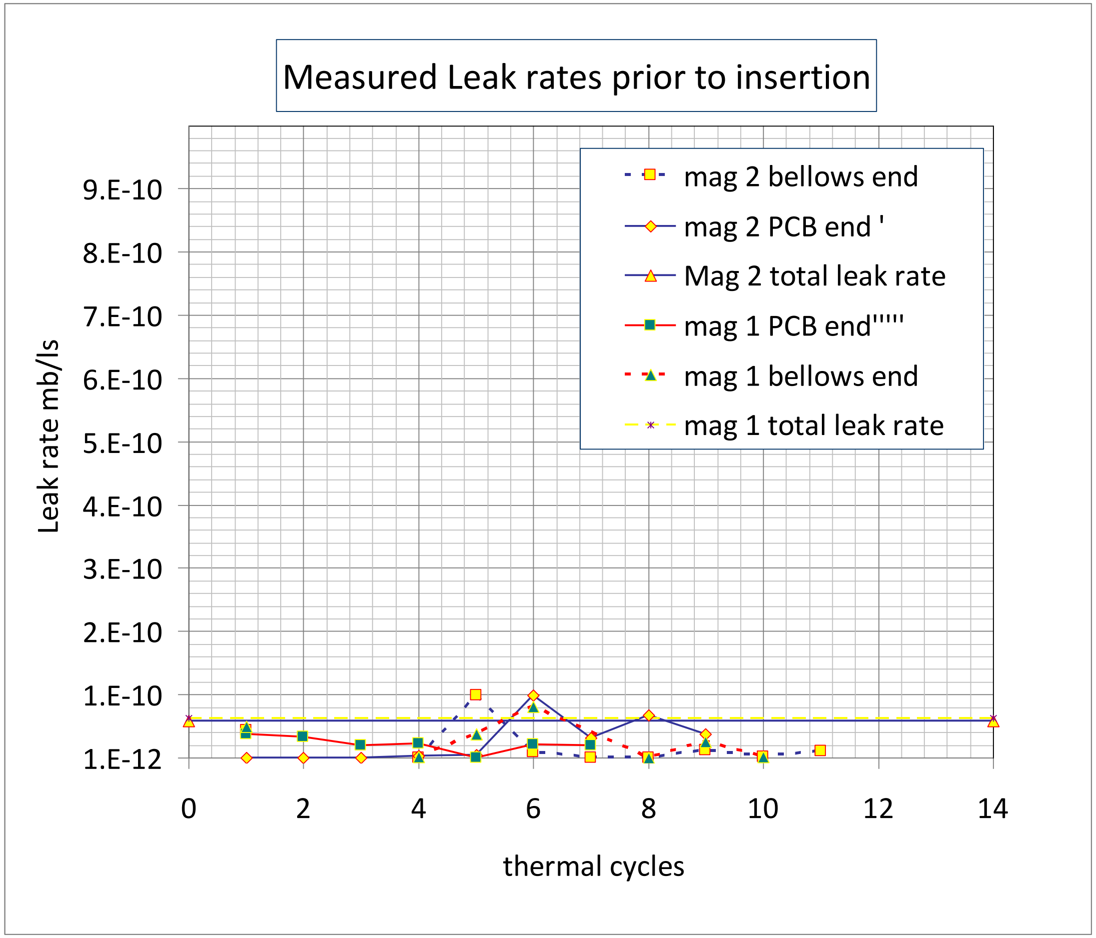
Magnet 1 leak rate <6e-11mb/ls

Magnet 2 leak rate <6e-11mb/ls

These leak rates are hard to measure with the existing setup in the lab .Hard to immerse the magnets and contain the helium, over time the leak checkers become contaminated and automatically register a higher background.

The final leak check of the undulators inside the final vessel at temps <77K is now complete. leak rate <1e-12mb/ls in the beam tube (leak checker limit).

The operational pressure for the ILC is expected to be 1.3E-13mb.



A Starcell or triode pump with a capacity of 20l/s

at the entry and exit to the module allows a leak rate <1e-12 to be accommodated.

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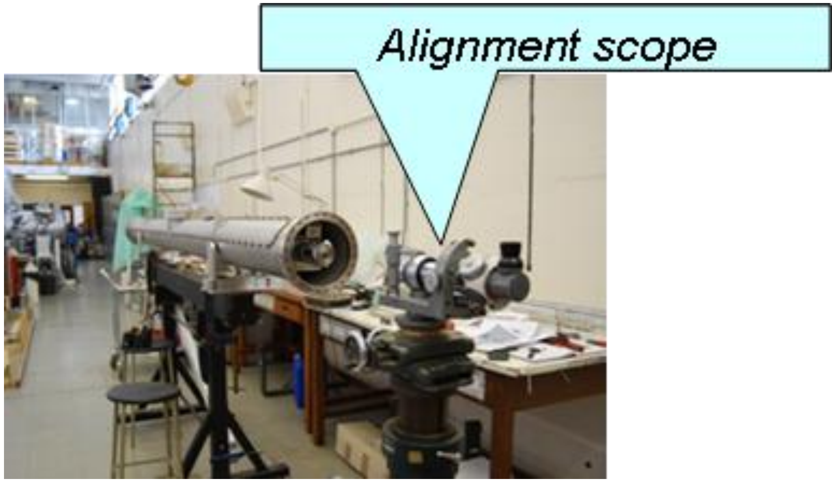
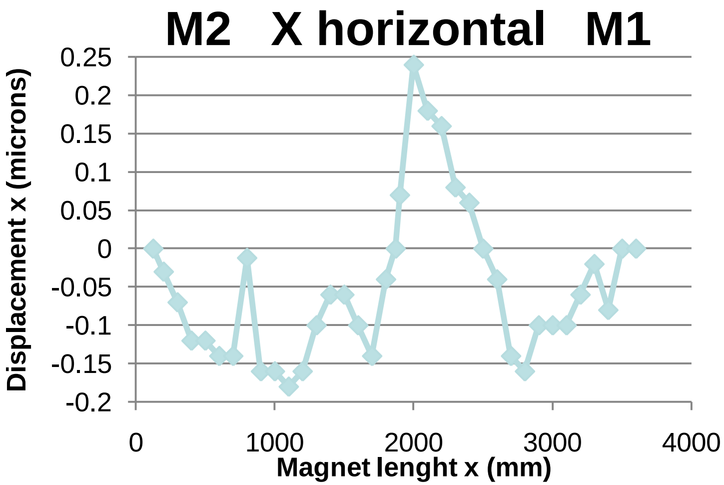
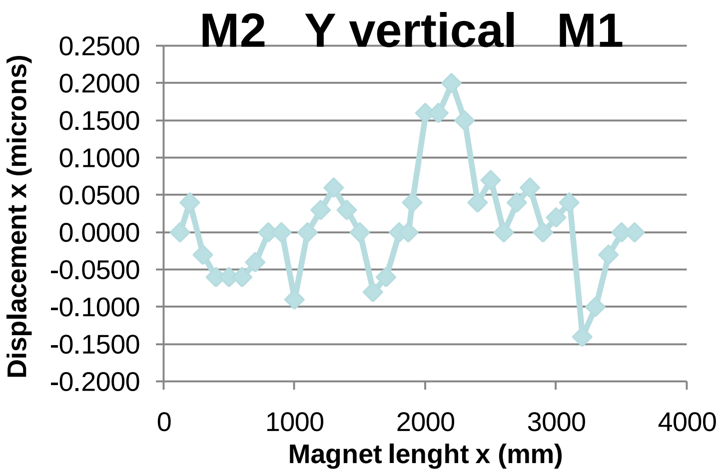
Undulator rebuild

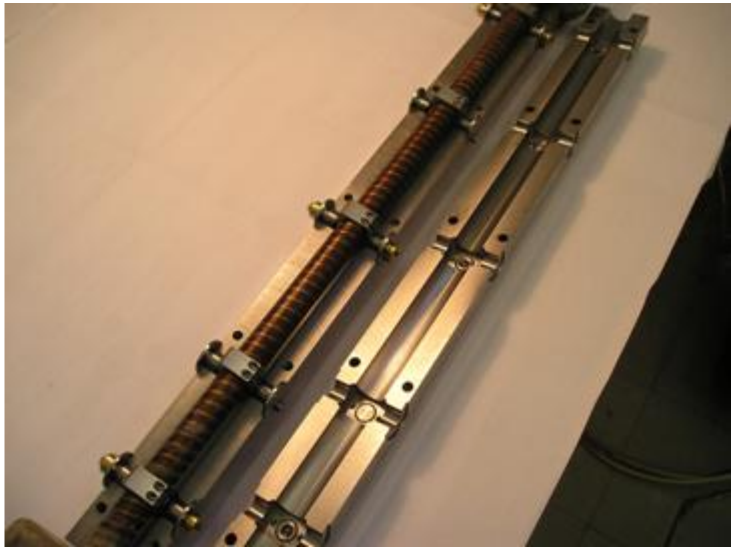


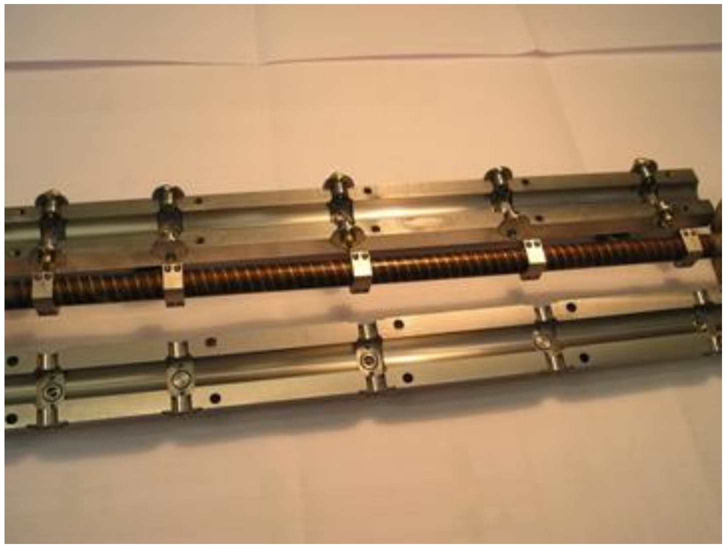
- Magnets inserted in helium vessel
- Realigned magnet axes
  - – alignment not great! +/-250um in X and +/-200um in Y
  - Decided not to invest too much effort here.
- Have developed an active alignment Yoke
- Allows the straightness of the magnet to be aligned to better than 50um.
- In principle the proto type can be retrofitted with this system at a later date.





Alignment system





Active alignment system

Relies on the flexibility of the magnet

Over sized yoke aperture for the magnet allowing 100um clearance

Periodically placed adjustors allowing adjustment in X and Y

after adjustment actuators locked off, a small spring maintains alignment and takes up the thermal contraction when cold

Small contact pads around the magnet to spread contact pressure and avoid damage to winding

All components are magnetic steel to minimise any losses in the iron circuit

Manufactured 1/2 meter long test section

Getting some metrology data with this at the moment

Our initial tests shows we can position the magnet to within +/- 10um at the actuator point

Undulator rebuild

Final leak checks

End of March cooled system to 77K and introduced1barr He gas in to He vessel

At this point performed final a leak check on beam tube, prior to finalising system connections.

This check was more controlled than those used in leak testing r&d. Helium is constrained in Helium vessel .

No Helium leaks detected in beam tube greater than1e-12mb/ls (limit of leak checker).

The required operational pressure of the ILC is 1.3e-13mb(Duncan and Oleg).

With a 10L/s pump per module the current system meets the ILC requirements

ILC requirements

Ref note: "Vacuum System for the ILC undulator", by Oleg and Duncan

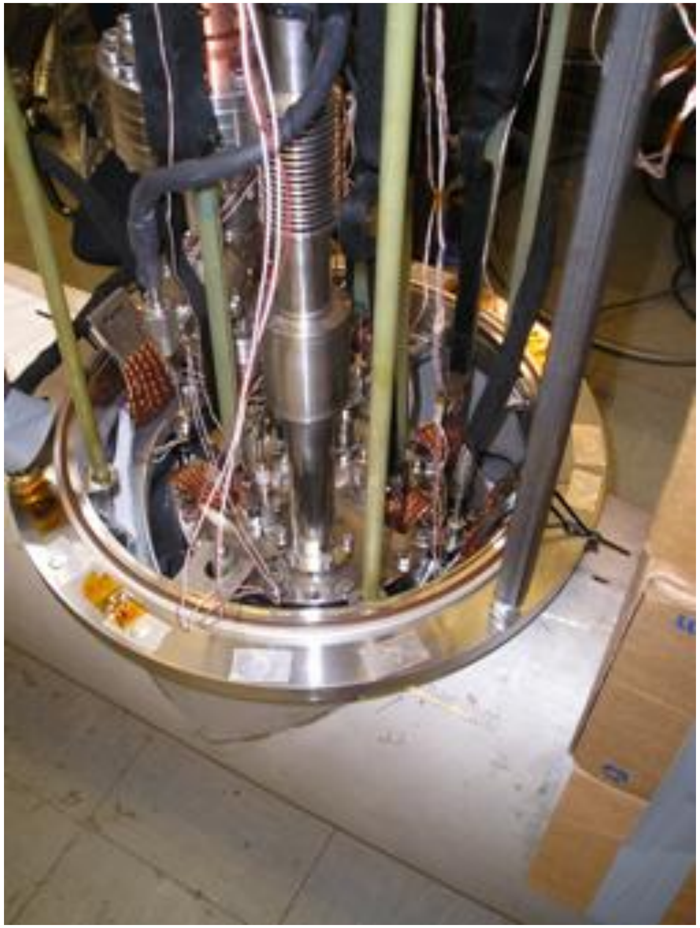
The required operational pressure for ILC beampi 1.3E-13 mb

Leak testing data

Section 4.2 refers to instllation of a small pump "Starcell or Triode " every 15-20m with a pumping speed of 20l/s for small leaks into system

	l/s			
mb/ls	10	20	40	80
1E-10	1.0E-11	5.0E-12	2.5E-12	1.3E-12
5E-11	5.0E-12	2.5E-12	1.3E-12	6.3E-13
1E-11	1.0E-12	5.0E-13	2.5E-13	1.3E-13
5E-12	5.0E-13	2.5E-13	1.3E-13	6.3E-14
1E-12	1.0E-13	5.0E-14	2.5E-14	1.3E-14
1E-13	1.0E-14	5.0E-15	2.5E-15	1.3E-15

Undulator rebuild



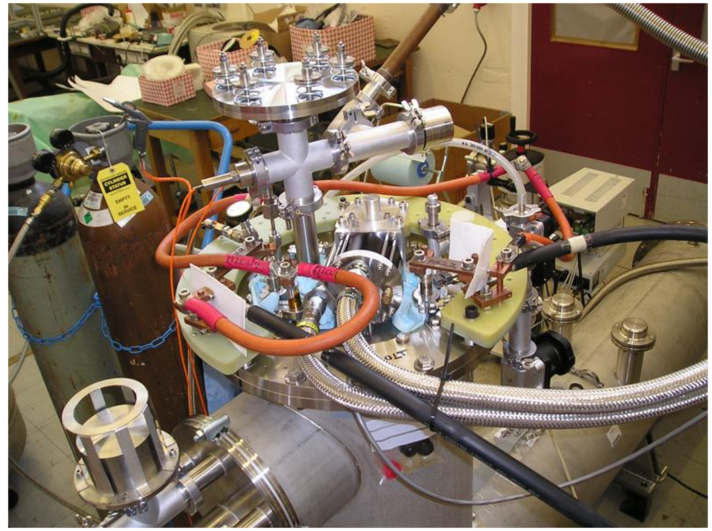
Final rebuild

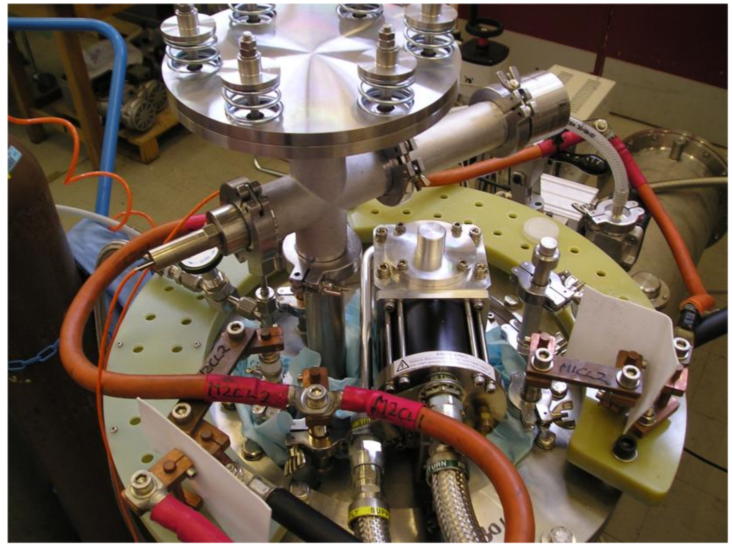
End of March final system connections made.

Photos showing the turret rebuild

Had our 1st cool down in early April

Powering test





Successful magnet powering test

Magnets @4K He liquid level in bath ~80%

Powered magnet 1 independently straight to 260A no quench (note nominal operating current is 215A)

Powered magnet 2 independently to 260A no quench (note nominal operating current is 215A)

Powered both magnets in series directly to 280A no quench left running for 30mins and powered down.

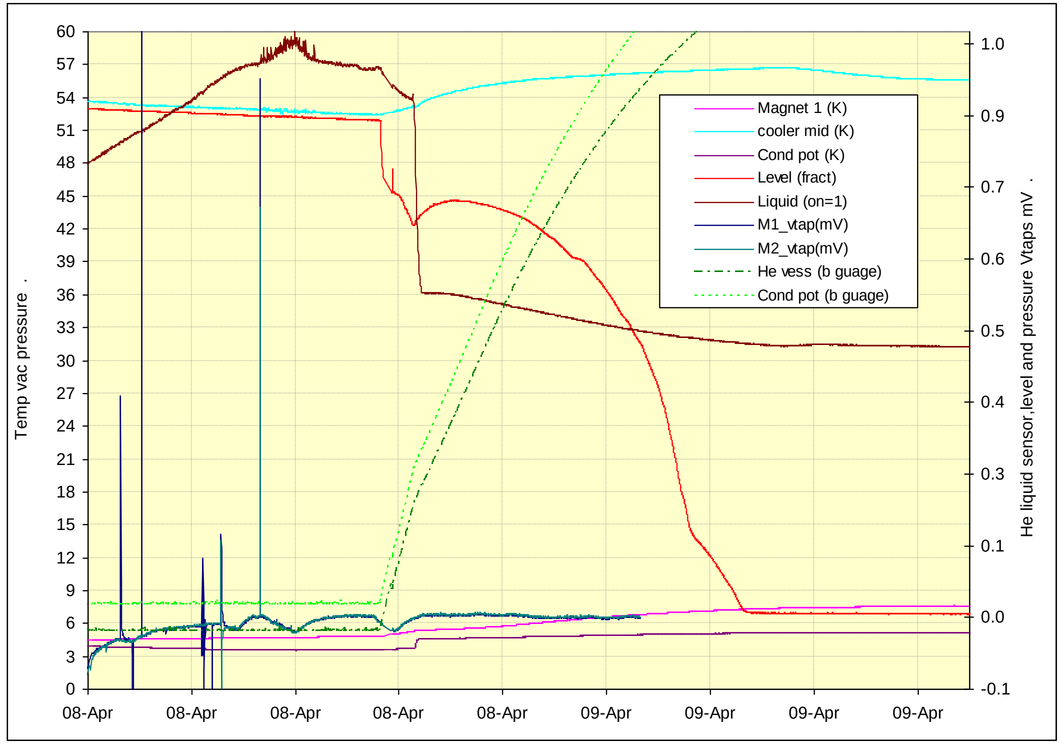
Current leads stable at predicted operating temperatures

Continually leak checking beam tube no helium leaks above 1e-12 mb/ls observed

Powering test

Vent valve open level stable

Vent valve closed system rapidly pressurises



Thermal siphon

Issues with thermal siphon that

Need to be investigated

With vent valve closed

System pressurising rapidly

May have a convection problem in vent line may need a baffle here

But need to analyse data properly

To diagnose.

Generally heat load on 4k system seems to be very small

Current status

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Beam heating test underway

Chain of resistors in evacuated bore

Control the radiative heat load on the

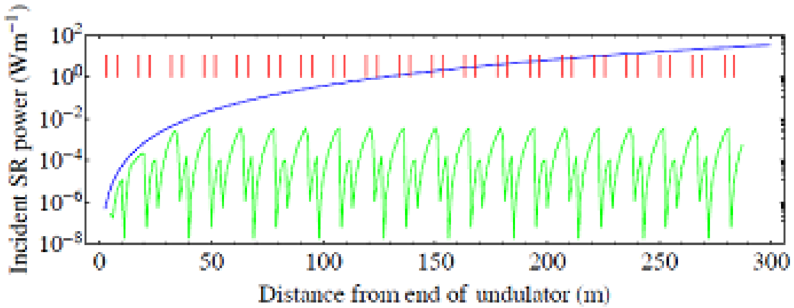
Magnet bore. From Duncans thesis the calculated heat loads span range 0.1 W to 1.4 W per module

Current experiment can apply 0 to 2.5 W inside the bore of the magnet.

The intention is to run the magnets at their nominal field wind up the power in steps until the magnet quenches.

This gives a measure of the peak power the magnets can sustain.

The average power sustainable can be estimated by assessing the parasitic load into the system and measuring the condensation rate of the cooler



Duncan thesis 4.4mm dia collimators down undulator

Synchrotron load per module (W)		
	BDC	RDR
Peak	1.1	0.3
Mean	0.2	0.1
Wakefield heating Wm^{-1}		
fill 1	0.08	
fill 2	0.05	
fill 3	0.02	
Total load per module		
	BDC	RDR
fill pattern 1		
Peak	**1.4**	0.6
Mean	0.5	0.3
fill pattern 2		
Peak	1.3	0.5
Mean	0.4	0.2
fill pattern 3		
Peak	1.2	0.4
Mean	0.3	**0.1**

Summary & Plans

Summary

Leaks fixed

System rebuilt

Magnet powering successful

System stable low heat leak

Issues with condensing system to understand

Plans

Tests to simulate beam heating underway

Testing active alignment system

Trying to sort out some issues with recondensing system

Examine and quantify thermal loads on system

Run at higher currents, determine Ic for system

Look at quench behaviour of magnet 2 in more detail