Development of a Short Period Cryogenic Undulator at RadiaBeam

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References
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F. H. O'Shea, *et al.* IPAC'13 paper WEPWA081, pp. 2298–2300.
F. H. O'Shea, *et al.* NAPAC'13 paper THPAC36, pp. 1217–1219.
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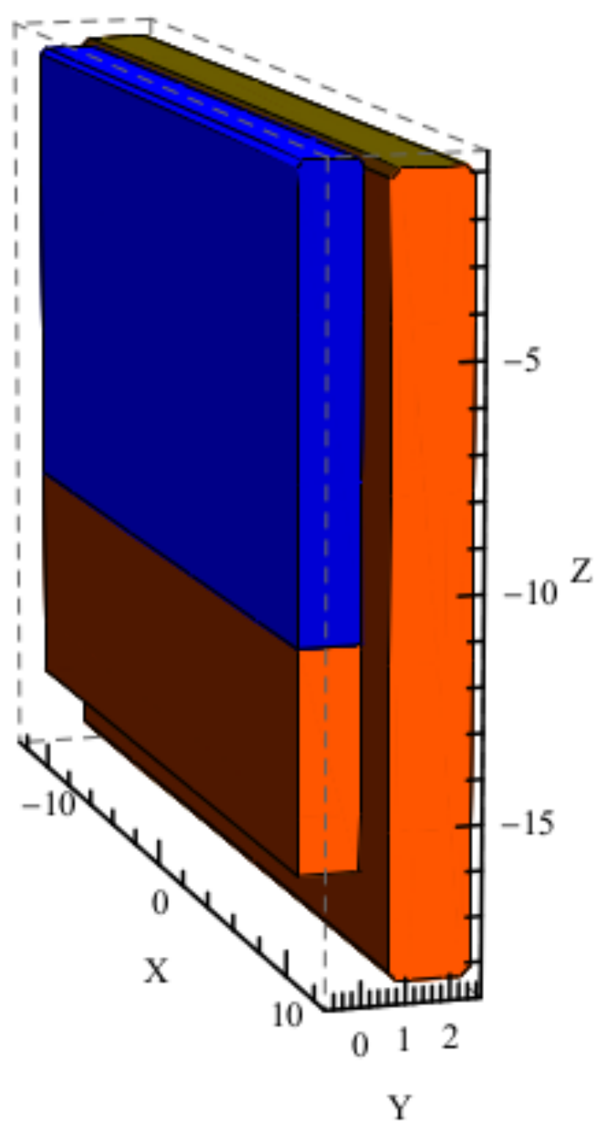
Abstract

RadiaBeam Technologies has developed a 7-mm period length cryogenic undulator prototype to test fabrications techniques in cryogenic undulator production. We present here our first prototype, the production techniques used to fabricate it, its magnetic performance at room temperature and the temperature uniformity after cool down.



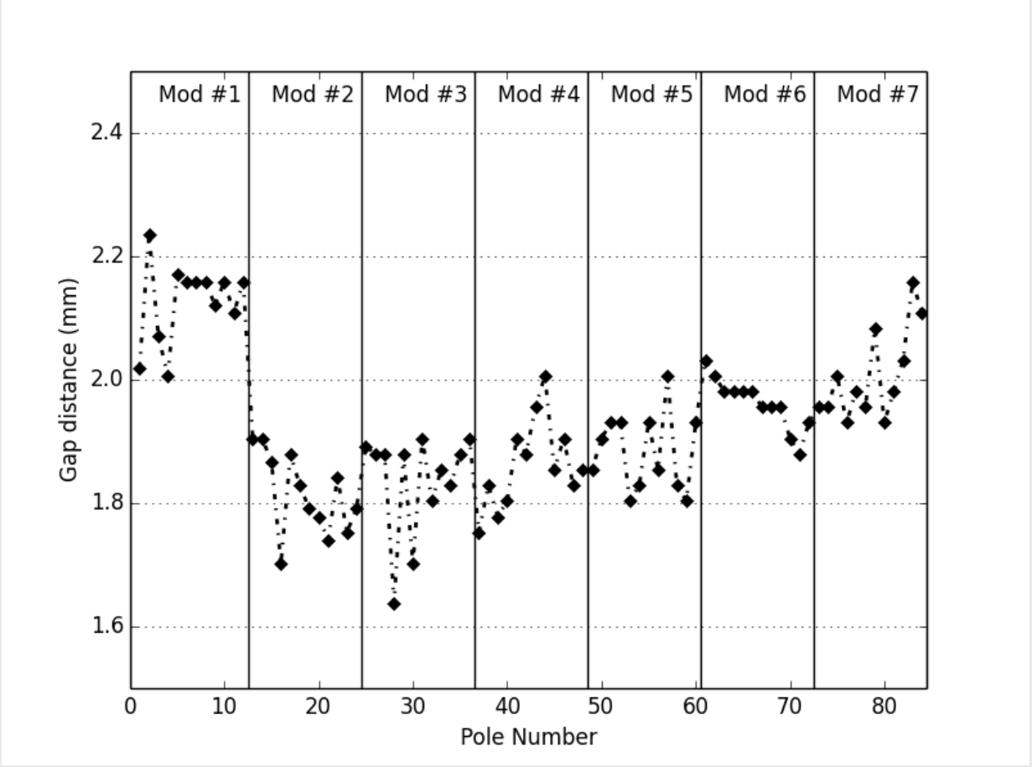
Dim.	Poles	Main Mag.	Back Mag.
x (mm)	21.0±0.1	24.5±0.1	24.5
y (mm)	1.45±0.05	1.95±0.04	1.35
z (mm)	11.0±0.1	17.4±0.025	6.9
θ_x (mrad)	0±9.5	0±4.5	N/A
θ_y (mrad)	0±2.3	0±2.5	N/A
θ_z (mrad)	0±5.7	0±4.0	N/A

Magnetic Elements as shown in Radia

Original goal was to make a hybrid undulator using textured dysprosium poles which has high saturation (3.4 T) induction below 90 K. Individual samples would perform very well, but consistently developing the texture was impossible without in-house magnetic moment measurement equipment. We decided to test the engineering and manufacturing of the undulator separate from the dysprosium development. We used vanadium permendur for the poles instead. Details on (mostly) material development in references.

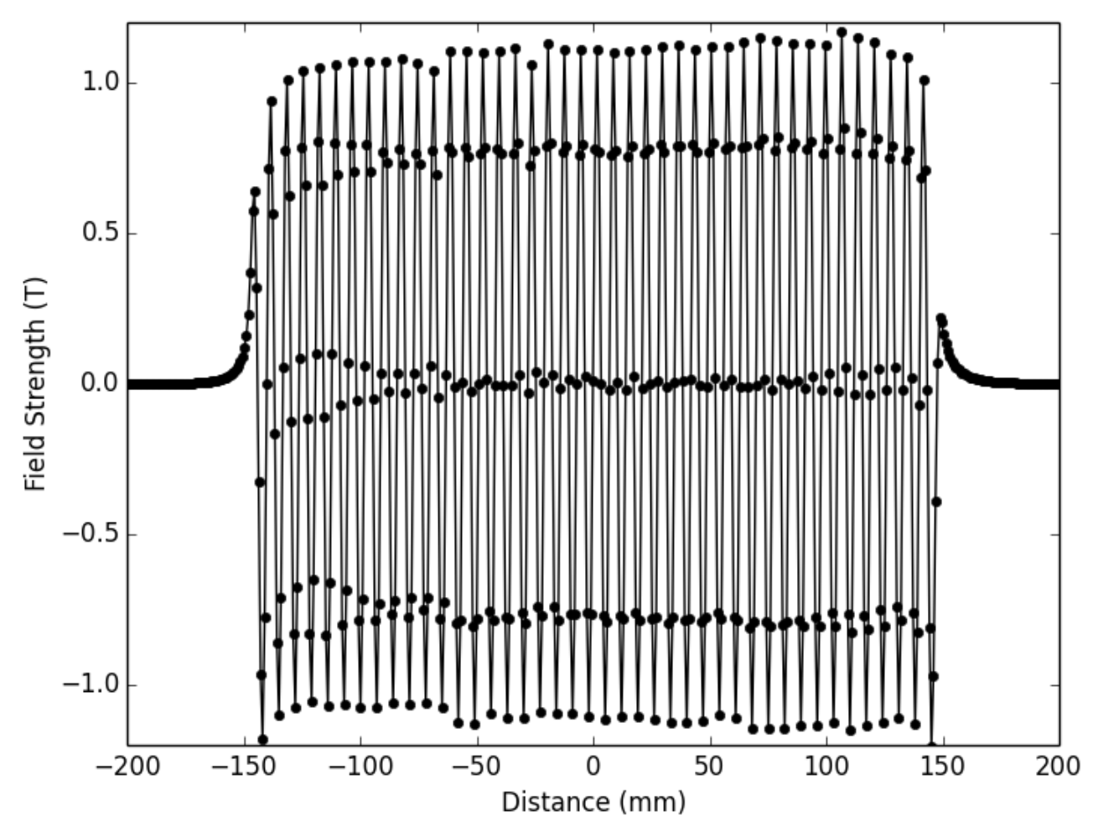
Fabrication

To make sure the height of the poles is consistent, the poles were installed in the modules with dummy steel pieces replacing the magnets and the poles are ground to the desired height, in-situ.



The dummy backing magnets were a little short and this resulted in the poles being too tall (the poles sit on the dummy magnets during grinding) and the mean gap size is 1.87 mm.

Field Measurements (room temp)



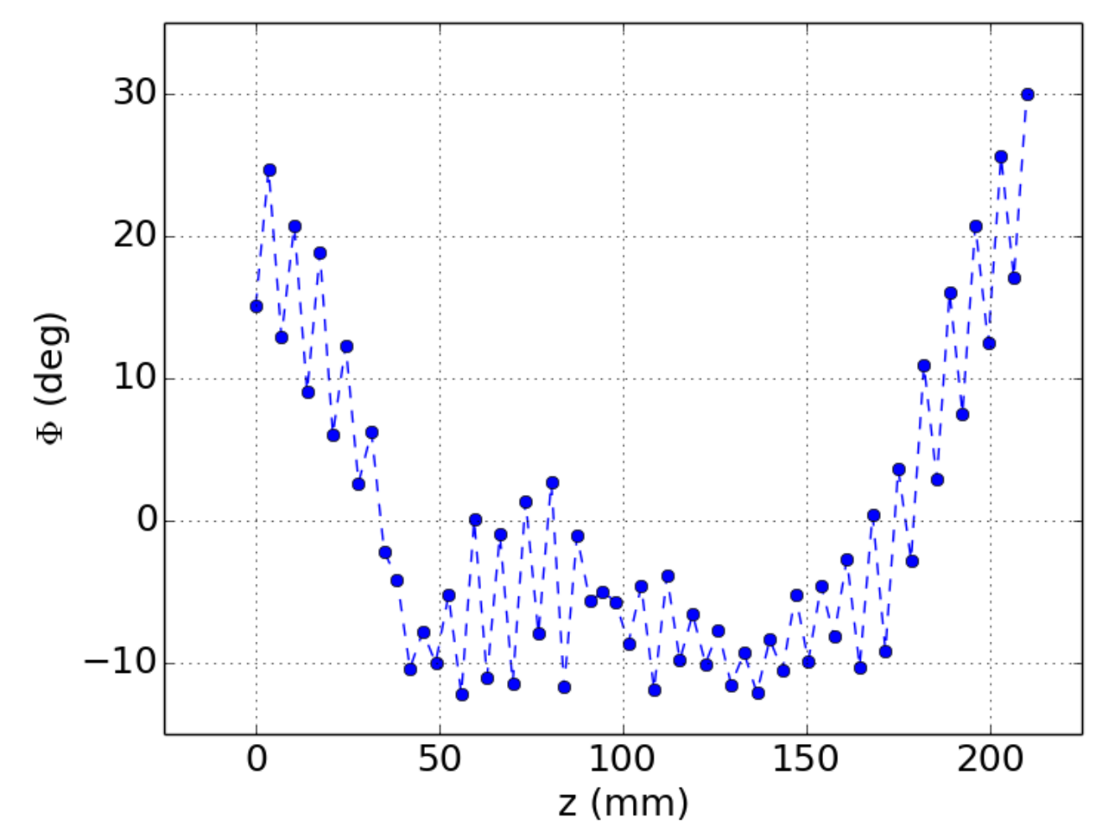
Field along the axis of the undulator

B_{peak}= 1.11 ± 0.03 T, B_{eff} = 1.1 T

Correlation with the pole gaps ρ=0.8.

No sorting performed.

Und. Performance (room temp)



Phase error along the undulator

σ_ϕ = 11.1° → 7.1° (correct gap taper)

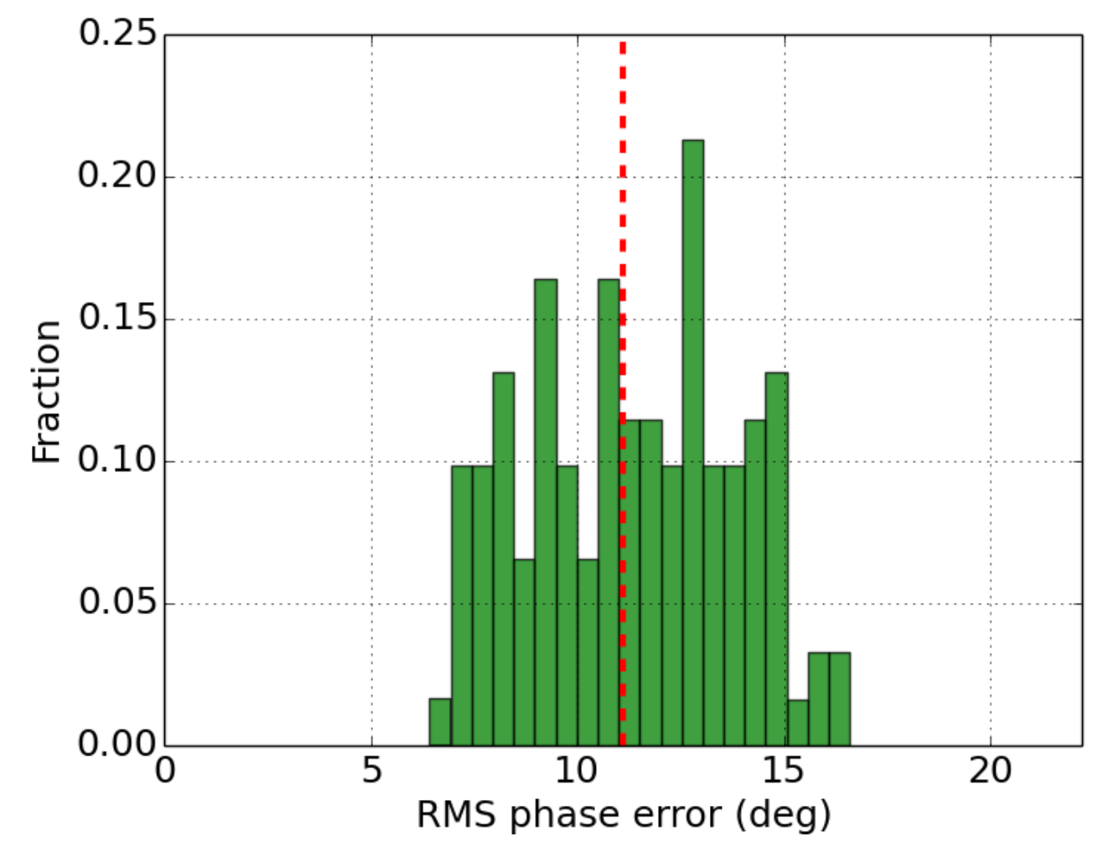
1 GeV electron on straight path.

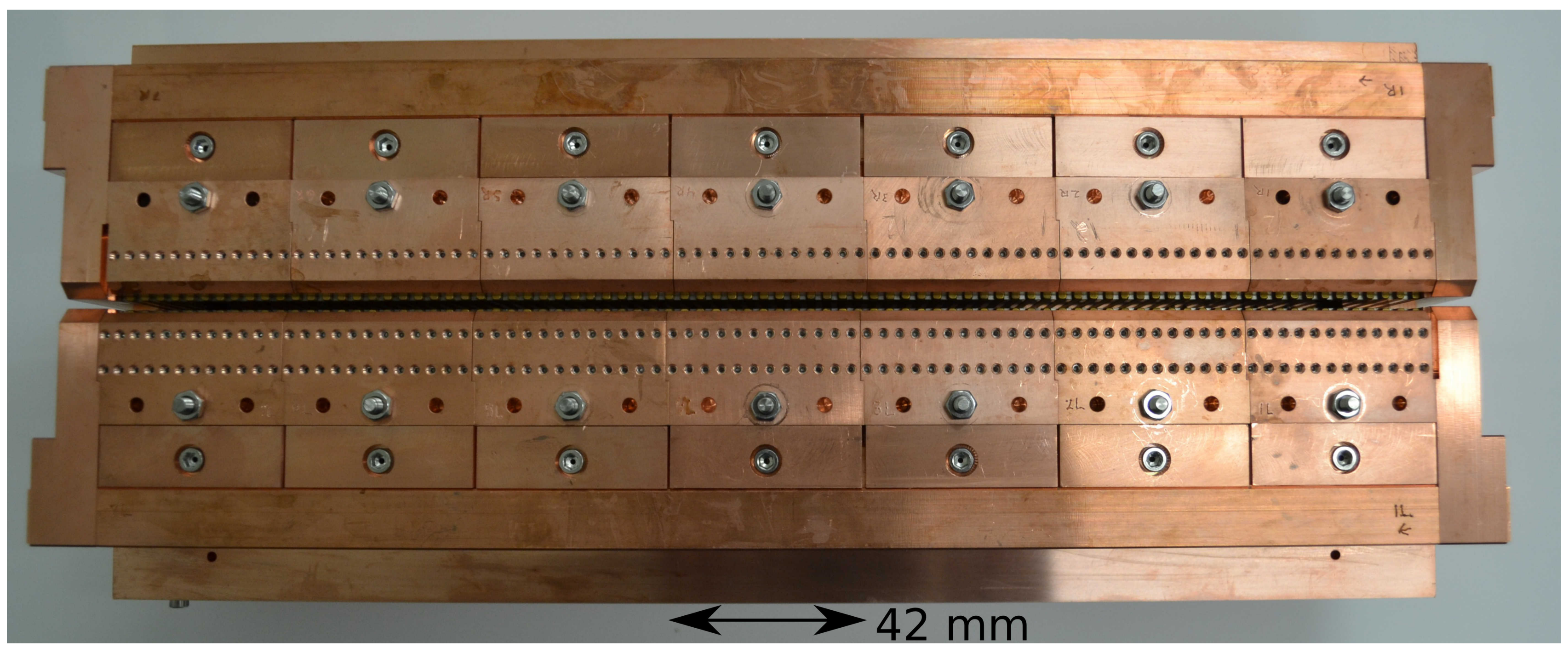
Only middle 5 modules.

Sort the modules (in simulation)

5! permutations of the inner 5 modules, track the 1 GeV electron through all of them. The minimum RMS phase error solution is 6.4° before correction. Fixing gap taper and sorting modules likely to lead to few degree RMS phase error.

(Red, dashed line is the undulator as constructed. Totally "average.")





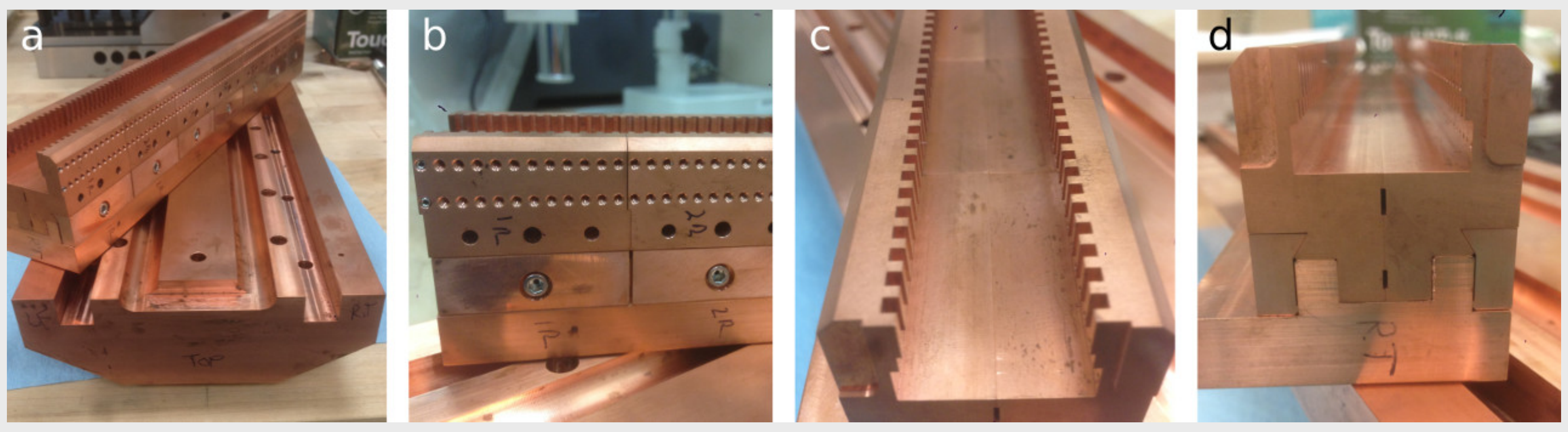
The completed undulator.

7 mm period hybrid, vanadium permendur / (Pr,Nd)FeB undulator.

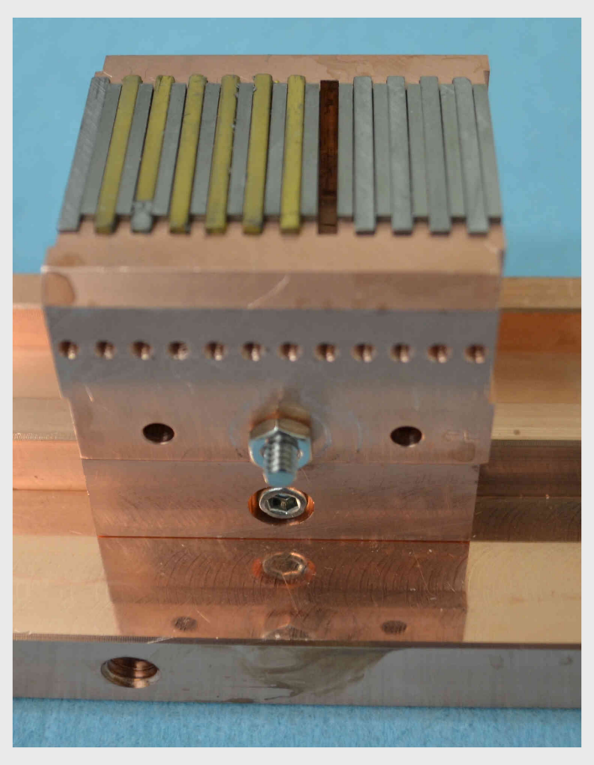
B_{eff} = 1.1 T / K = 0.7 / gap = 1.87 mm.

42 periods / 7 modules with 6 periods.

Manufacture

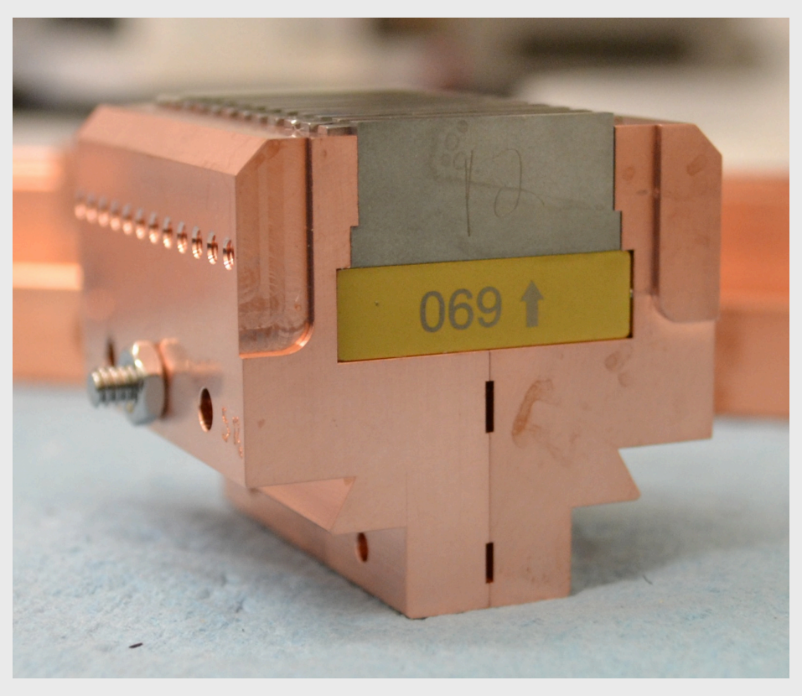


Images of the various strong back parts before assembly. Modules are installed on rails to form a jaw, jaws are installed in the main strong back to form the undulator.



Assembly of the modules:

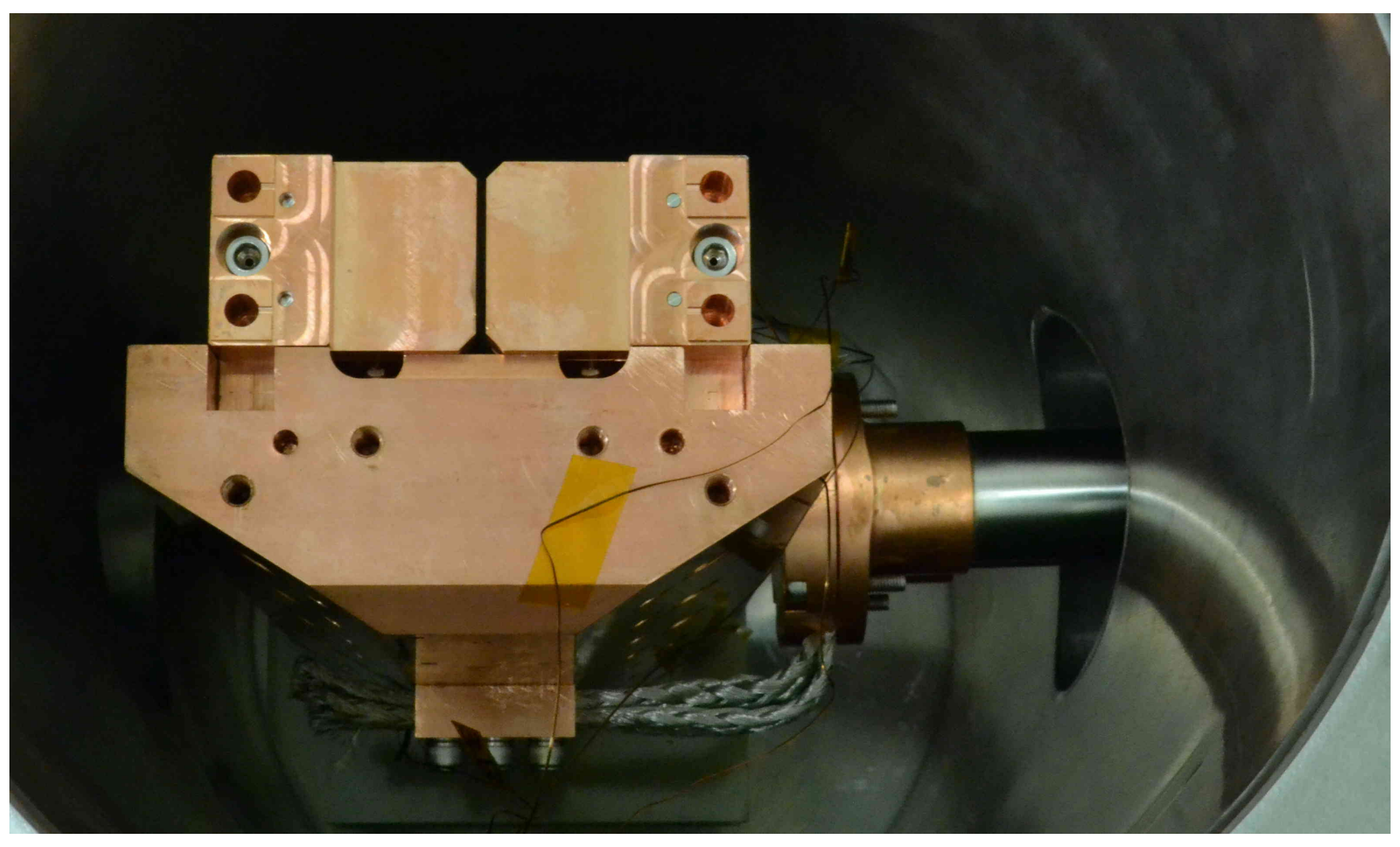
1. Install poles using steel dummy magnets for the main magnets.
2. Secure the poles and backing magnets using the set screws.
3. Remove the dummy magnets with a magnetic tool (pull force) one at a time.
4. Press the magnets into the open slots to replace the dummy magnets.
5. Secure main magnets with the set screws.

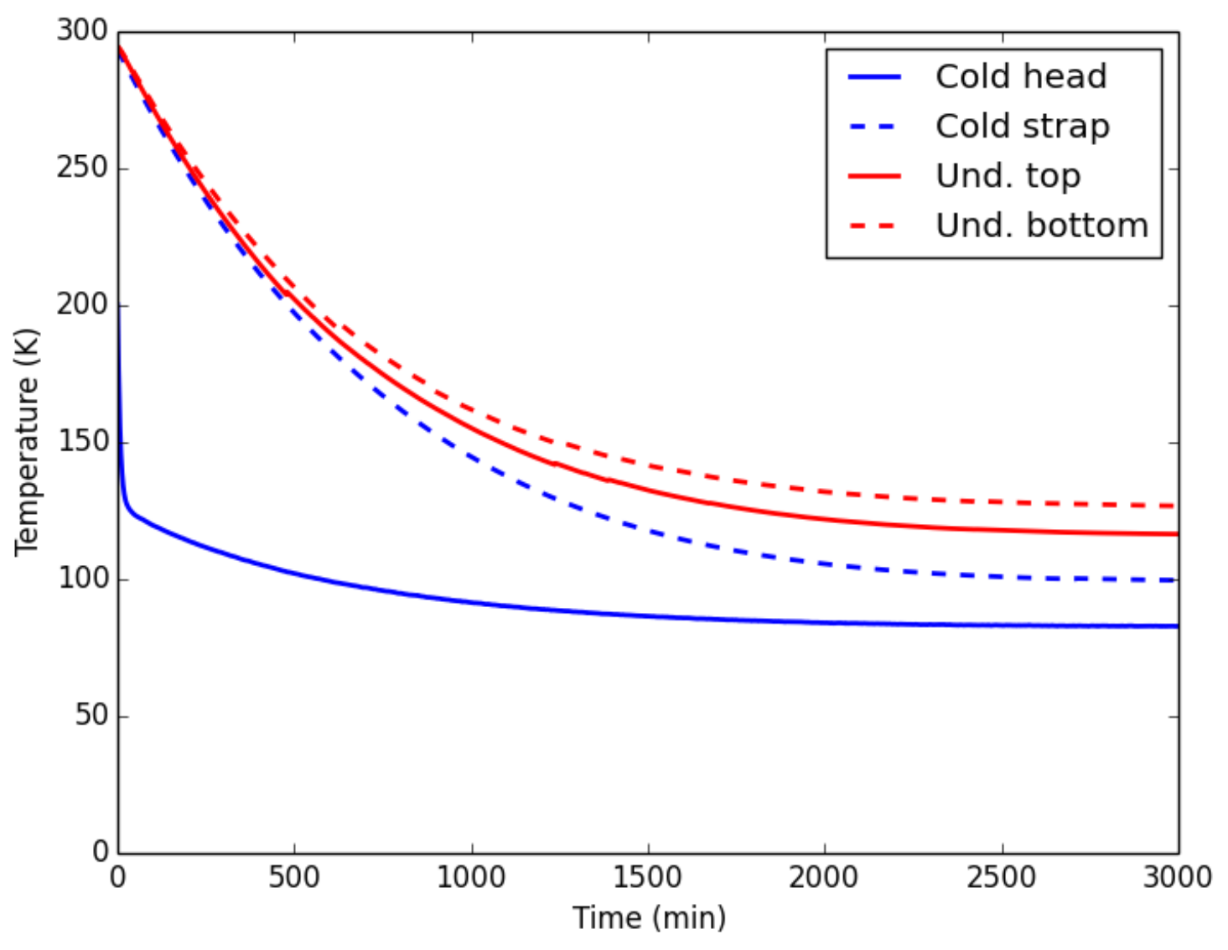


Cryogenic testing

Installed undulator in vertical vacuum vessel. Space constraints meant the cold head had to be installed horizontally. Manufacturer estimated a 20% drop in cooling power. This is a vast under estimate.

However, weak cooling power clearly showed that an end-to-end temperature gradient. Thus, thermal contact between copper parts needs to be improved.





RadiaBeam Technologies brings high impact, innovative technologies from the laboratory to market. Our current product line includes accelerator components, diagnostics, and turnkey accelerator systems. Our active R&D program includes novel accelerator technologies, innovative photonics systems, and commercial applications of accelerators.

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