

Internal Design Review

LCLS Fixed Supports

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and

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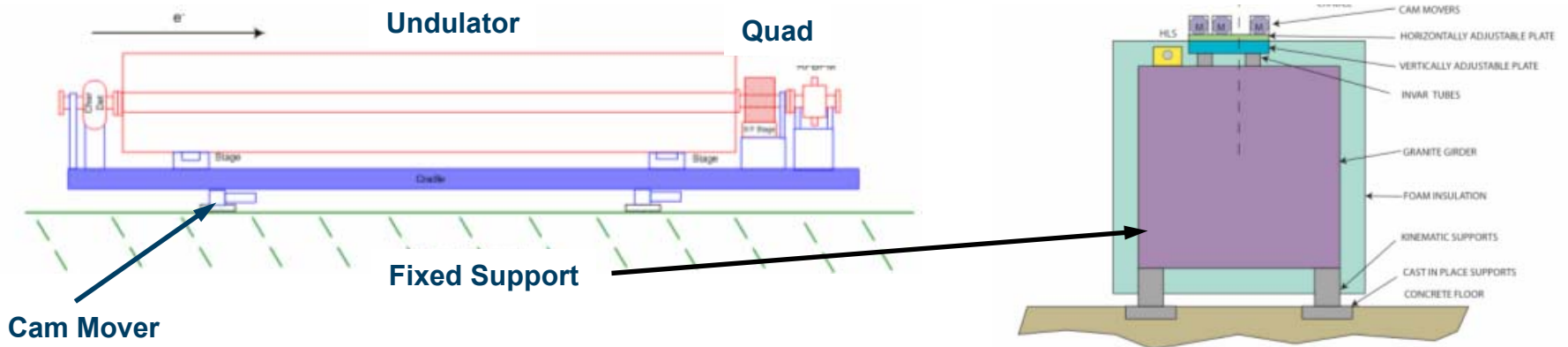
Acknowledgment

*C. LeCocq, R. Boyce, F. Peters
G. Pile, H. Friedsam, E. Trakhtenberg*

Topics

- **Background**
- **Relevant Design Specifications**
- **Present Engineering Design**
 - Thermal Stability
 - Dynamic Stability
 - Alignment : 3 or 4 Support Points
 - Preliminary tests
- **Summary**

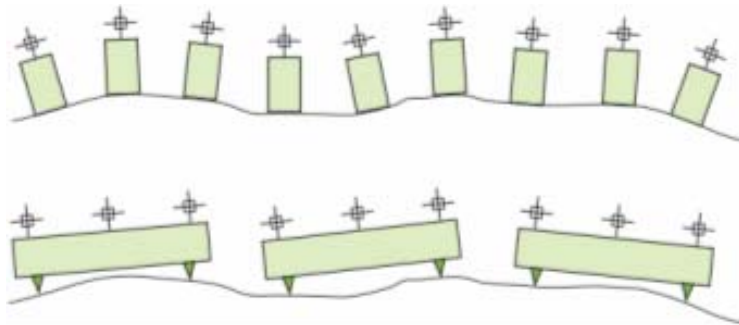
Background



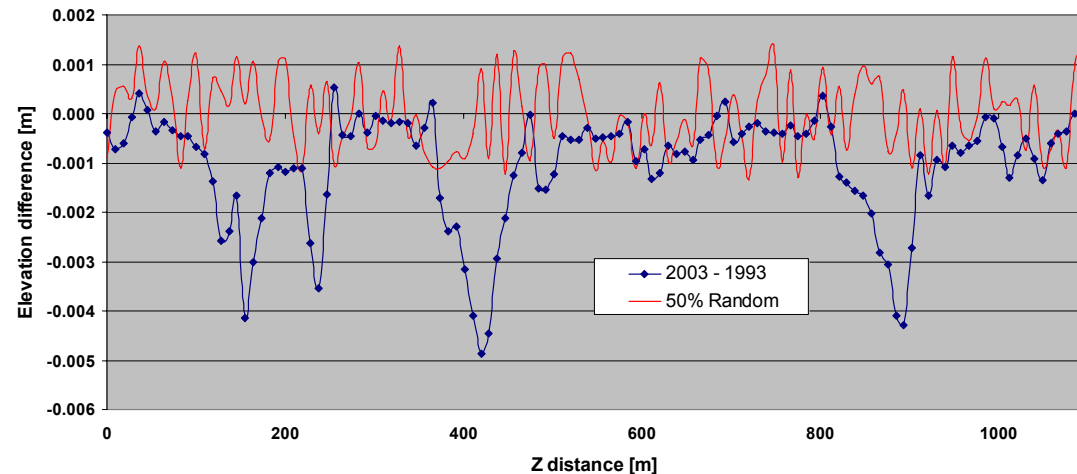
- ❑ 12 meter long granite girder each supporting 3 undulators and 3 quads.
- ❑ Approximate cost of 0.8mx0.8mx12m granite block is \$40,000.
- ❑ Granite girder is to be enclosed in water-cooled thermal insulation.
- ❑ The girder is mounted on kinematic supports.

Phase Error Calculations

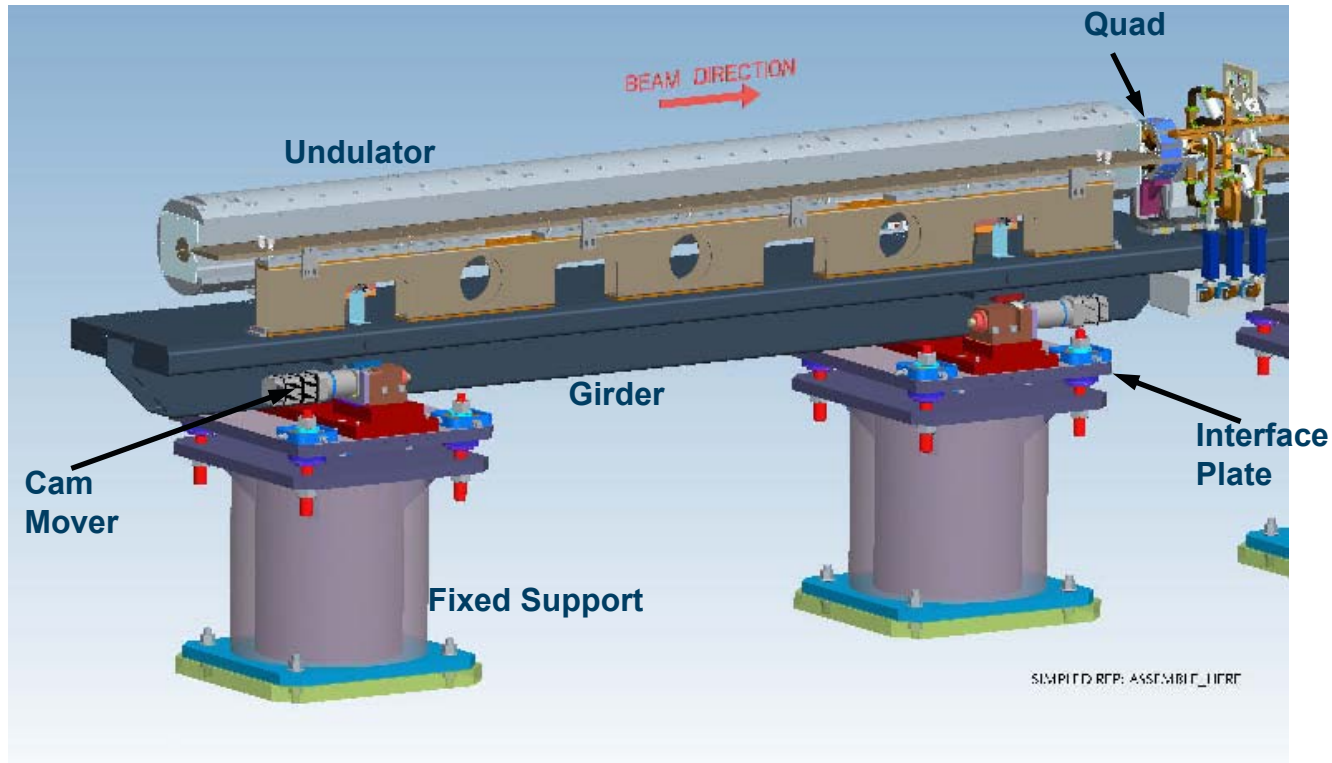
- ❑ Calculations are based on 20 μm uncorrelated (random) floor settlement between BBA sessions.
- ❑ Average APS floor settlement is $\sim 1.5 \mu\text{m}/\text{day}$ (correlated +uncorrelated).
- ❑ Long girders provide no advantage when APS settlement (normalized to 20 μm) is used in the calculations.



APS STORAGE RING FLOOR SETTLEMENT 2003 - 1993



Girder-Undulator Assembly with Fixed Supports



Present Design of the Fixed Support and Interface Plate

Relevant Design Specifications

LCLS Specification PRD #1.4 -001

- Short term (10 h) BPM and quad stability: $\pm 2 \mu\text{m}$
- Long term (24 h) BPM and quad stability: $\pm 5 \mu\text{m}$
- BPM and quad stability to position sensors : $2 \mu\text{m}$

- Max. horizontal earthquake acceleration: 2 g
- Max. vertical earthquake acceleration: 1g

-
- Relative floor settlement at 10 m (LCLS-TN-04-14): $\sim \pm 1 \mu\text{m} / \text{day}$
 - Undulator tunnel temperature stability: $\pm 0.5^\circ \text{C}$
 - Max. floor settlement (LCLS-TN-04-14): $\pm 25 \text{ mm}$
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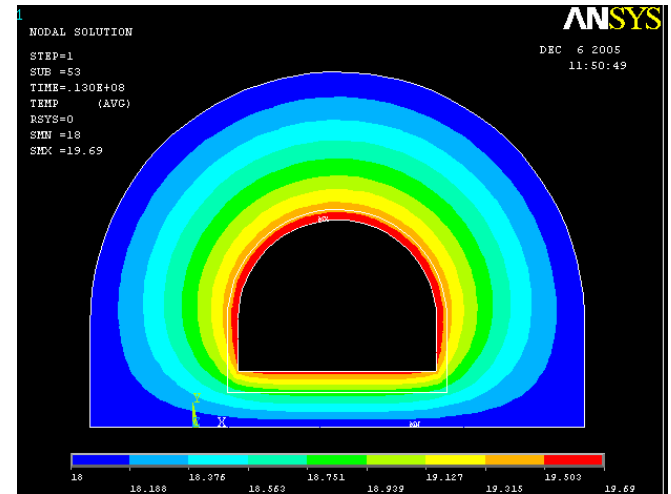
Engineering Specifications:

- Separation of horizontal and vertical alignments (given up recently)
- $\pm 1/2''$ (12.7mm) beam direction alignment
- $\pm 1/2''$ (12.7mm) transverse alignment
- Height adjustment: $\pm 1''$ (25.4 mm)
- Mechanical alignment tolerance: $< 20 \mu\text{m}$

Thermal Stability

Transient Heat Transfer to Sandstone

	Density Kg/m ³	Specific heat J/Kg-K	Conductivity (W/m.K)
Concrete	2000	880	1
Sandstone	2000	880	1.5

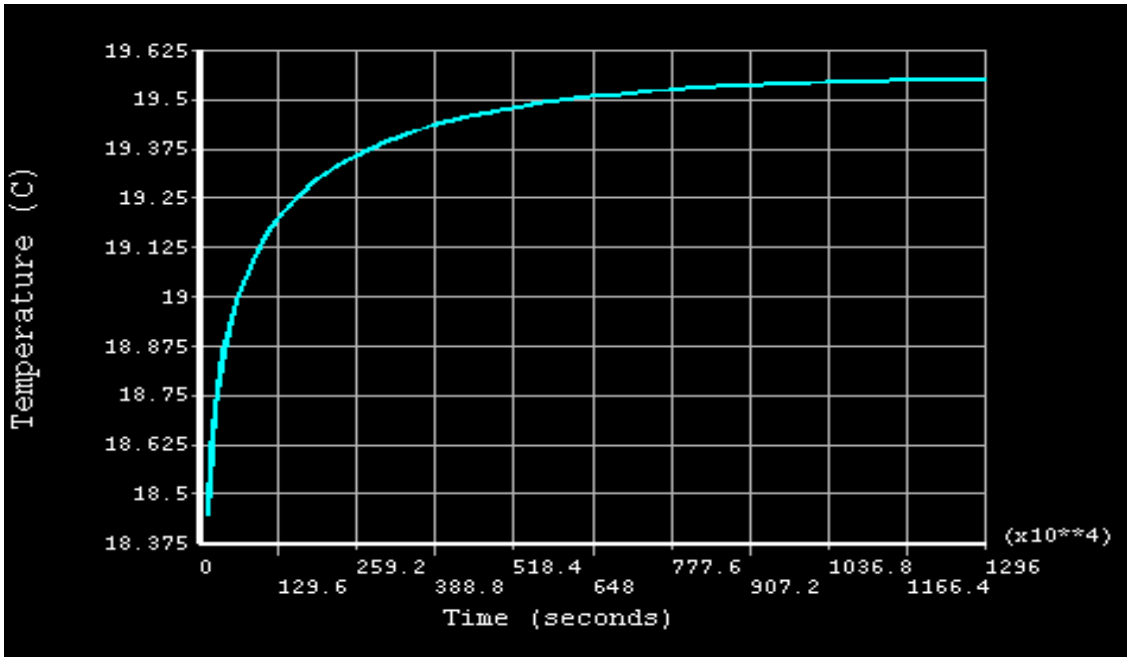


Temperature Contours

Large thermal mass and low thermal conductivity of concrete/sandstone ensures thermal stability of the floor once steady state is reached.



Attach fixed supports to the floor



Initial Sandstone Temperature = 18 °C

Spatial (Longitudinal) Temperature Stability

Tunnel Temperature Stability: $\pm 0.5\text{ }^{\circ}\text{C}$

Heat Balance in the LCLS Tunnel

Present Design

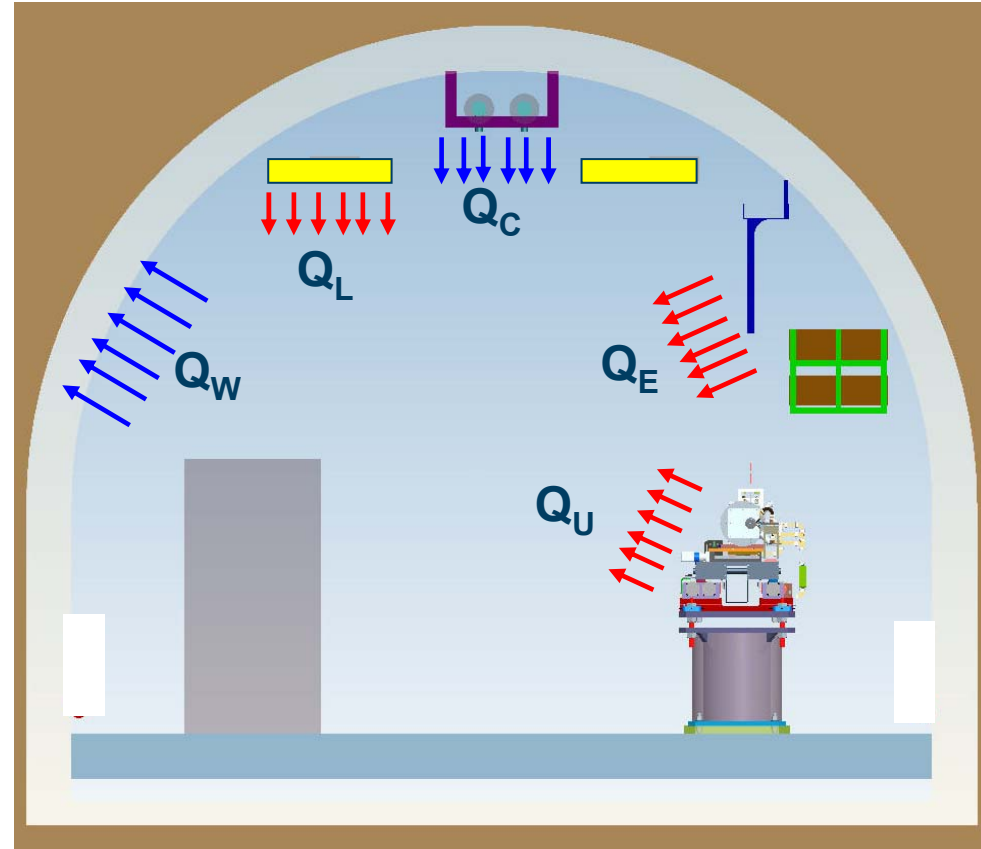
Q_W = heat dissipation in the tunnel wall and floor

Q_C = heat dissipation in chilled lines

Q_U = heat input from undulator components

Q_L = heat input from lighting

Q_E = heat input from electronics



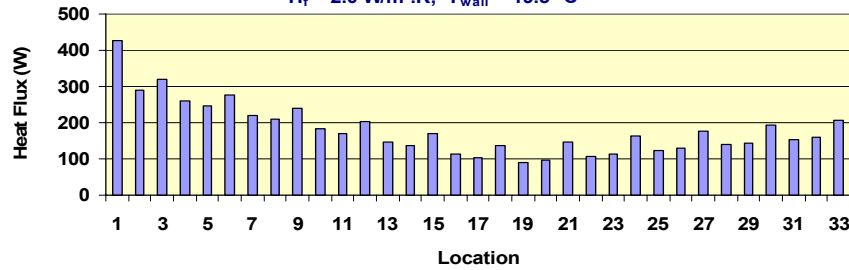
Heat Imbalance:

$$\Delta Q = Q_U + Q_L + Q_E - Q_W - Q_C \quad (\text{for each undulator length})$$

Longitudinal Temperature Stability

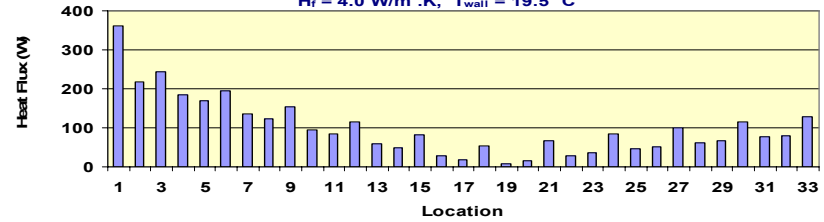
Unbalanced Heat Flux

$H_f = 2.0 \text{ W/m}^2\cdot\text{K}$, $T_{\text{wall}} = 19.5 \text{ }^\circ\text{C}$

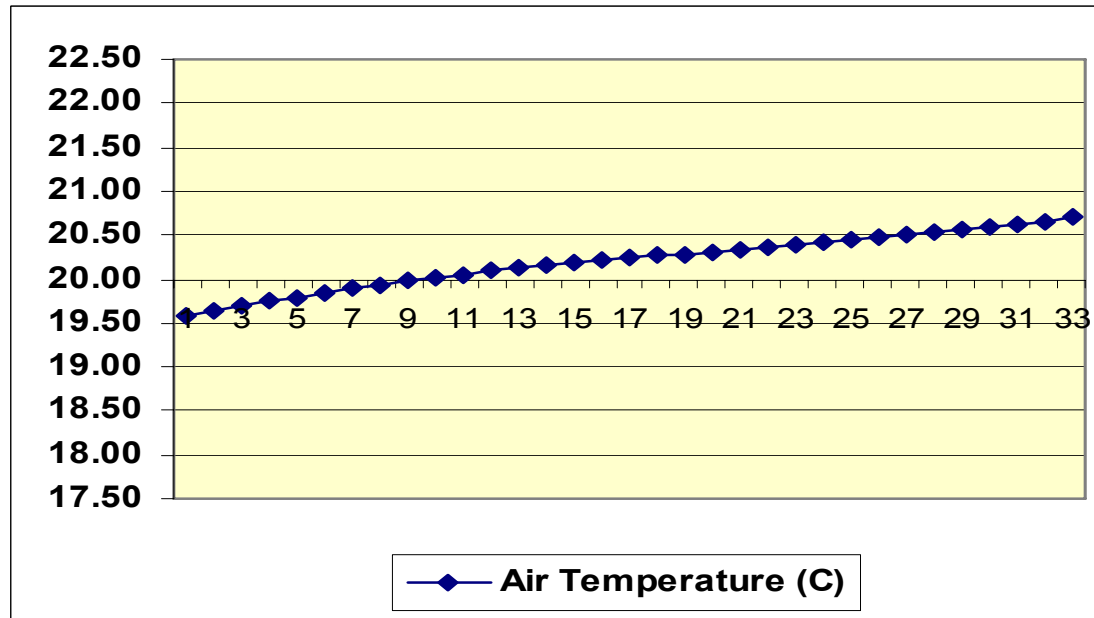


Unbalanced Heat Flux

$H_f = 4.0 \text{ W/m}^2\cdot\text{K}$, $T_{\text{wall}} = 19.5 \text{ }^\circ\text{C}$



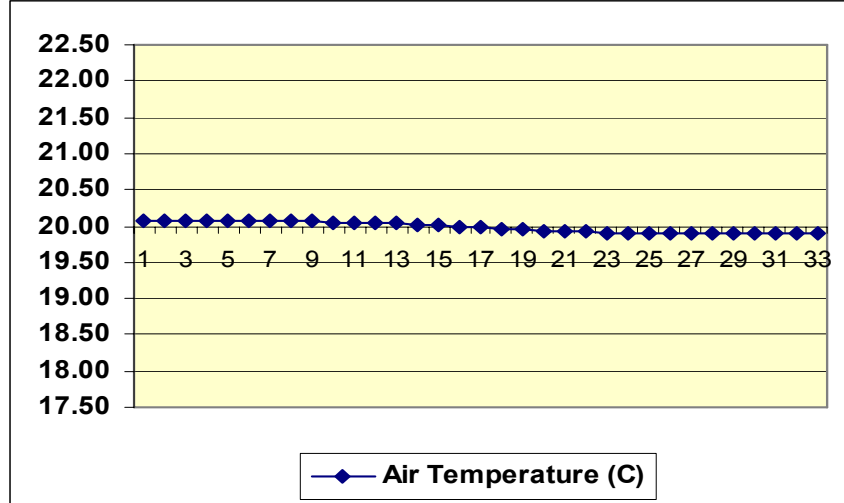
$H_f = 3 \text{ W/m}^2\cdot\text{K}$



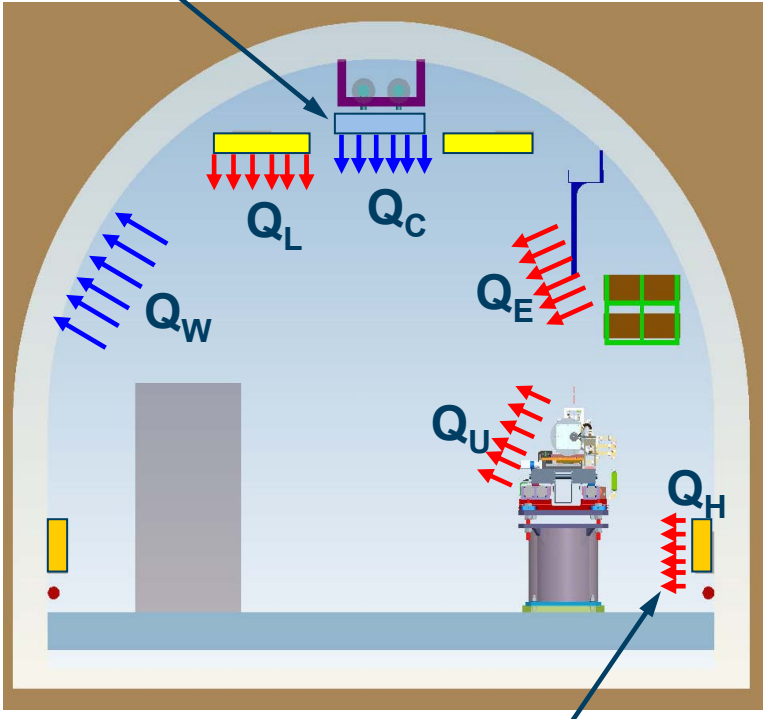
◆ Air Temperature (C)

Longitudinal Temperature Stability

Add radiator panels and resistive heaters.



Radiator Panels



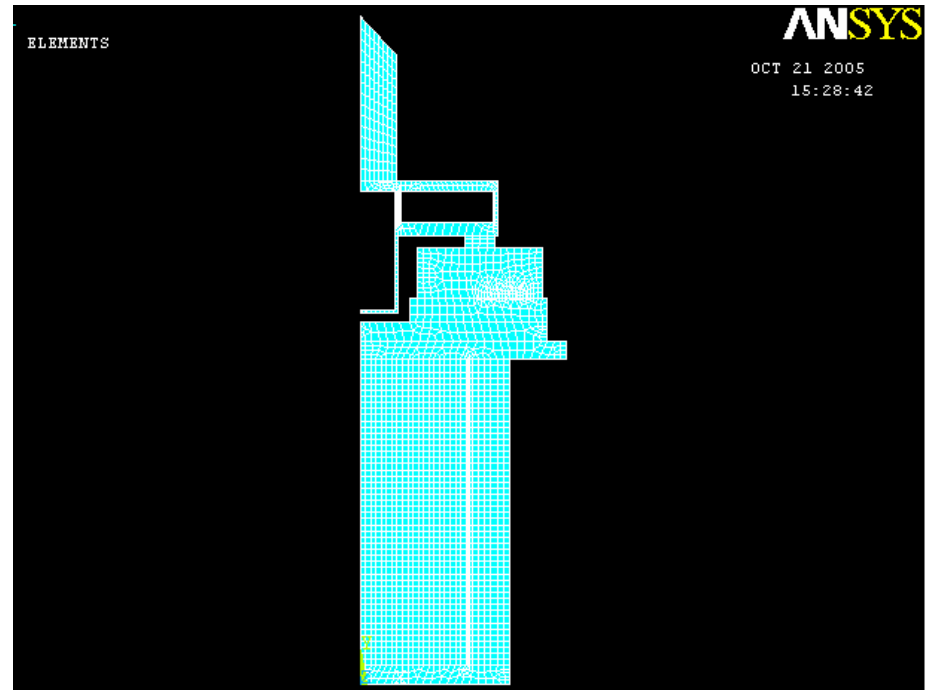
Resistive Heaters

- Longitudinal temperature stability of the tunnel can maintained to within ± 0.1 °C.
- Marginal impact on the thermal stability of the fixed supports.

Temporal Temperature Stability

Short term (10h) BPM and quad position stability: $\pm 2\mu$

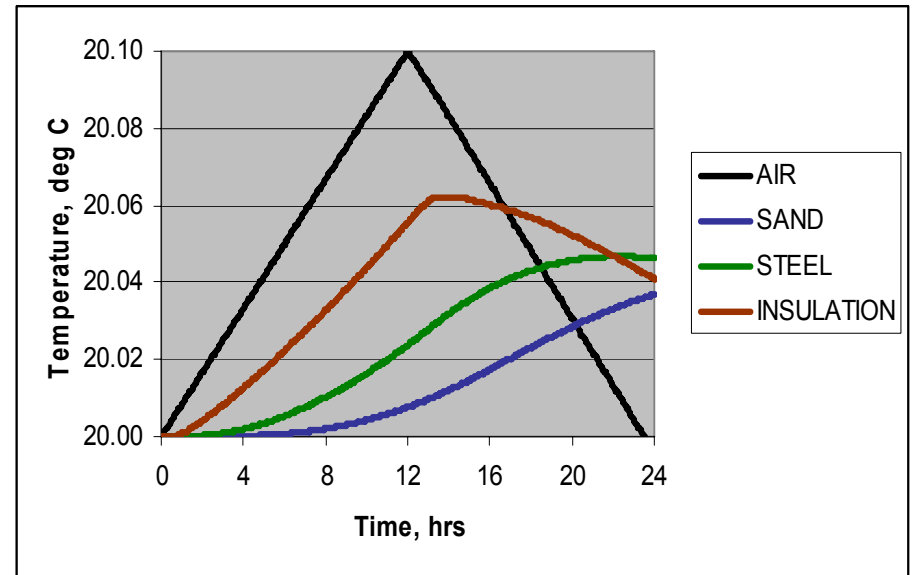
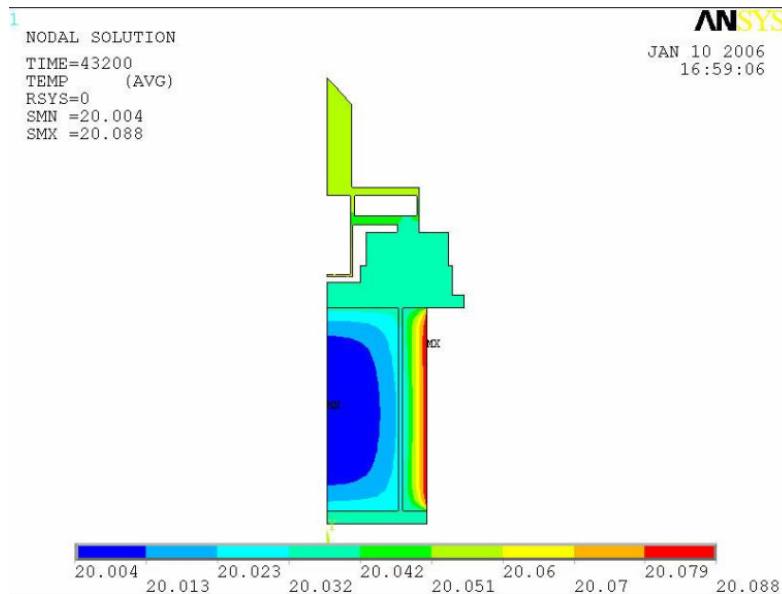
Assume that the floor and air temperatures change by $0.1\text{ }^{\circ}\text{C}$ over 12 hours.



Material Properties:

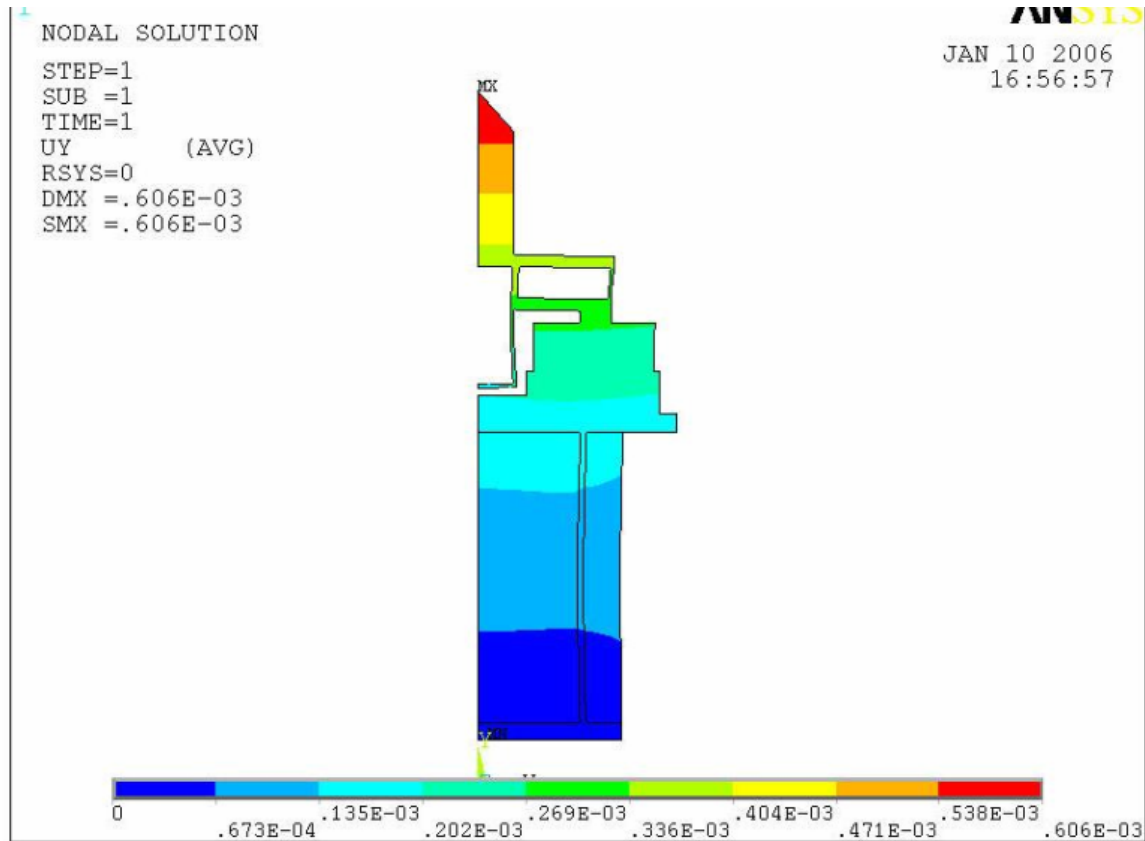
	Density (Kg/mm ³)	Specific heat (J/Kg- ^o C)	Conductivity (W/mmK)	Young's Modulus (GPa)	Poisson's ratio	CTE $\mu\text{m/m-}^{\circ}\text{C}$
Mineral wool insulation	1.28E-7	920	0.00004	40	0.25	9
Mild steel	7.8E-6	470	0.052	200	0.25	9.5-12.6
Sand	1.494E-6	1172.3	0.00051	40	0.2	10

Finite Element Thermal Analysis



Thermal insulation and sand reduce the fixed-support temperature rise by a factor of 2.

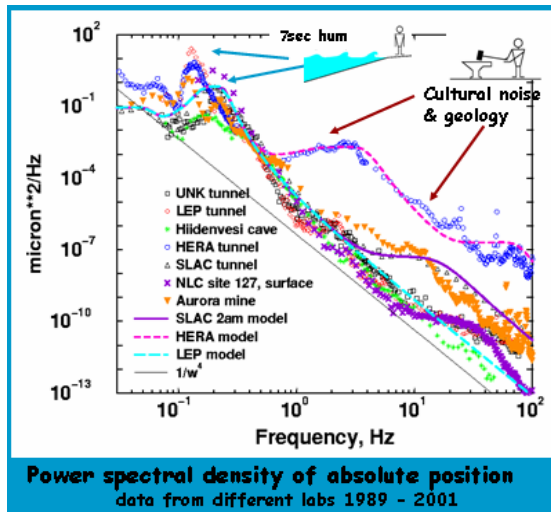
Finite Element Thermal Analysis



BPM and Quad positions change by 0.6 μm .

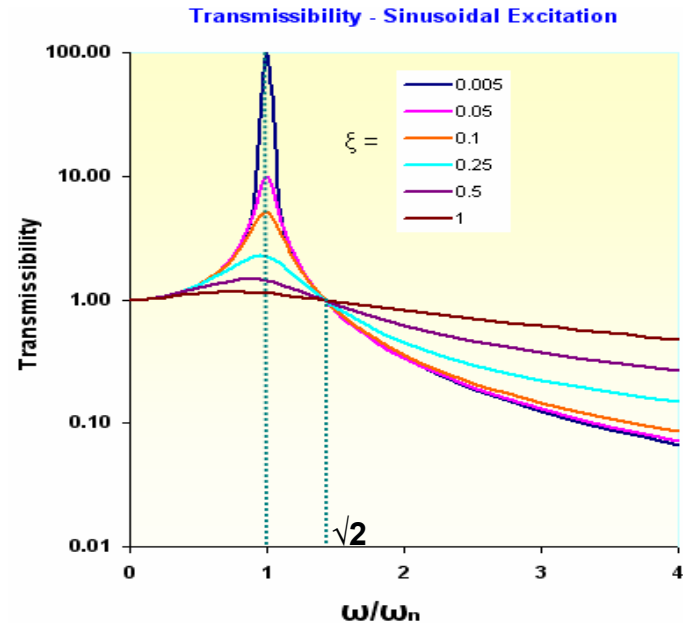
Dynamic Stability

- Vibration tolerance for the undulator quadrupoles: 200 nm (rms 0-100 Hz)



Seryi [2003]

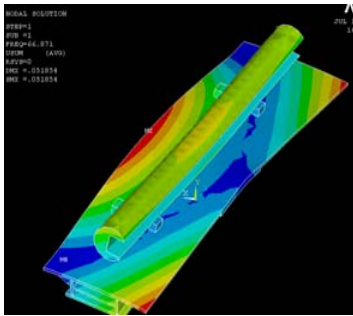
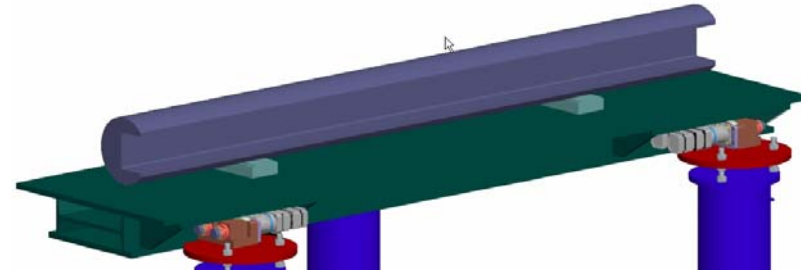
http://www.desy.de/~njwalker/uspas/coursemat/pp/unit_8.ppt#10



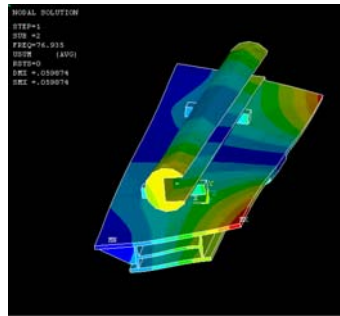
- Resonances above 30 Hz do not significantly affect dynamic stability.
- Viscoelastic damping pads can be used if there are resonances in 4 – 20 Hz range due to cam movers and translation stages.

Dynamic Stability – Girder Resonances

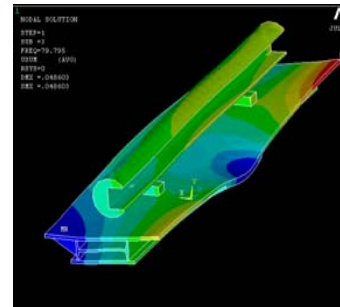
(Previous Design)



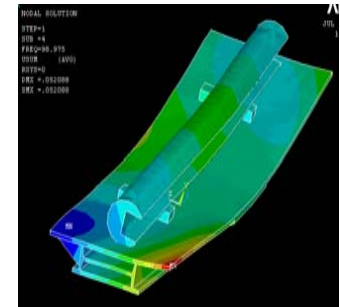
Mode-1 (67.9 Hz)



Mode-2 (76.9 Hz)

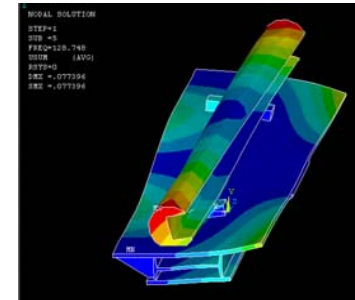


Mode-3 (79.8 Hz)



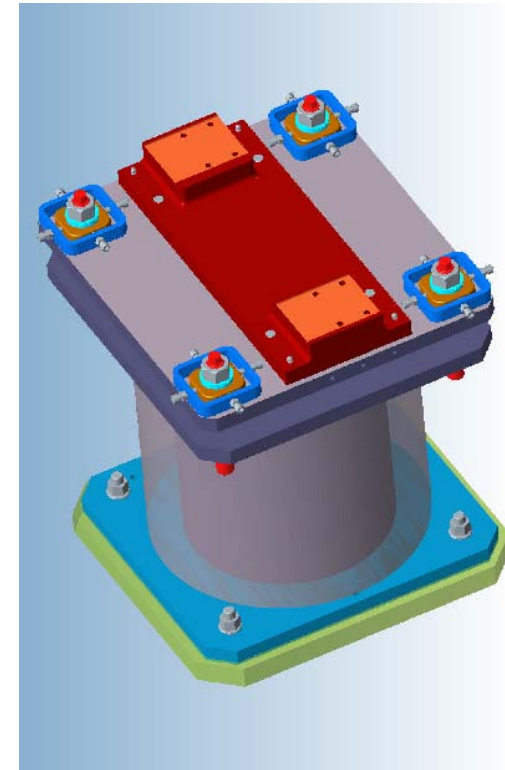
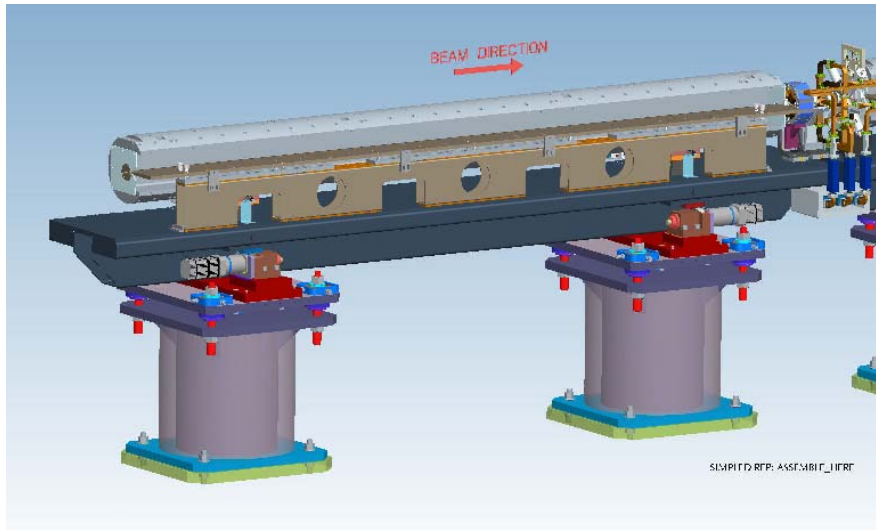
Mode-4 (99.0 Hz)

- The first four modes correspond to girder deformations (flexure, torsion, flexure, and flexure).
- Mode 5 corresponds to undulator torsion.



Mode-5 (128.8 Hz)

Alignment : 3 or 4 Support Points



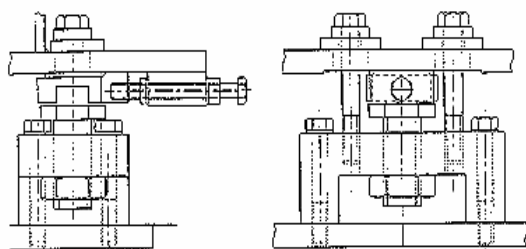
4 support points:

Pros - Improved dynamic stability and no interference with the girder.

Cons - An over-constrained system requiring more time for alignment.

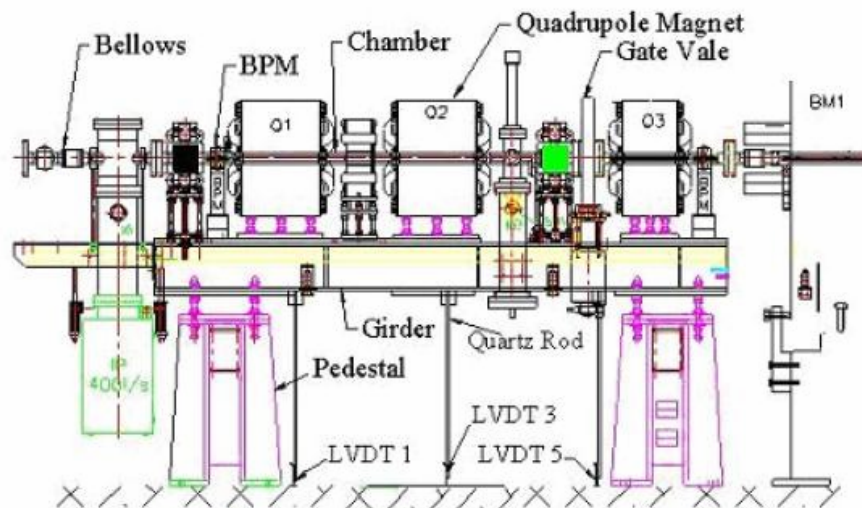
SPring-8 and SRRC Girder Support Systems

Spring-8



SPring-8 Alignment

SRRC



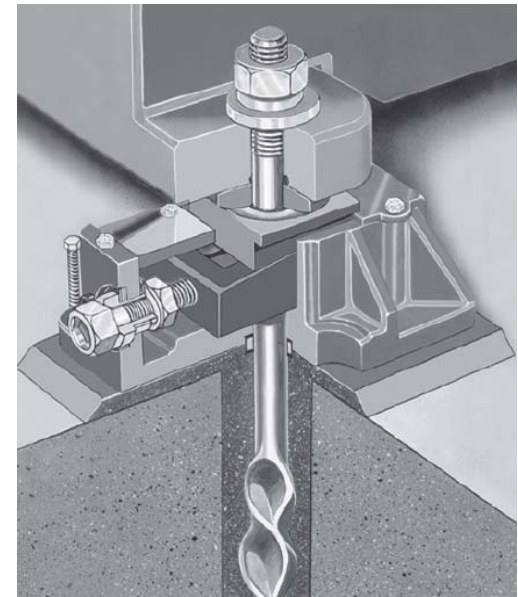
Dynamic Stability of Various Girder Support Systems

Horizontal Motion Band Power (2-50 Hz) and Band Power Amplification

Facility	Floor (nm)		Quad (nm)		Amp. Undamped	Amp. Damped
	Undamp.	Damp.	Undamp.	Damp.		
ALS	16		201		12.6	
APS	37 (1)	25	291 (1)	51	7.9	2.0
ESRF	47 (2)	30	102	40	2.2	1.3
SPRING-8	25 (3)		48 (3)		1.9	
SRRC	71 (3)	73	126	92	1.8	1.3

Reference: Sharma et al., "Ground Vibration Problems at the Light Sources," GMV Workshop, November 6-9, 2000, SLAC

Anchoring and Alignment of a High-Precision 5-Axis Machining Center



Unisorb RK4 Fixator

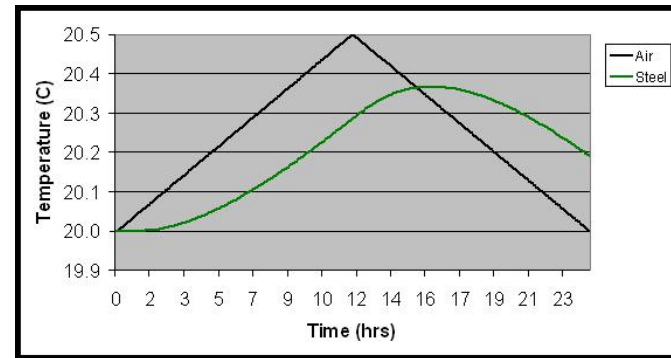
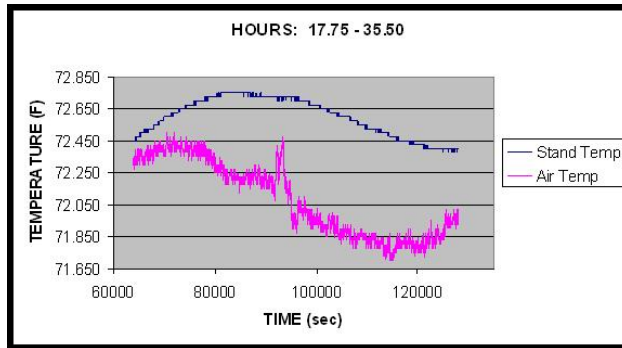
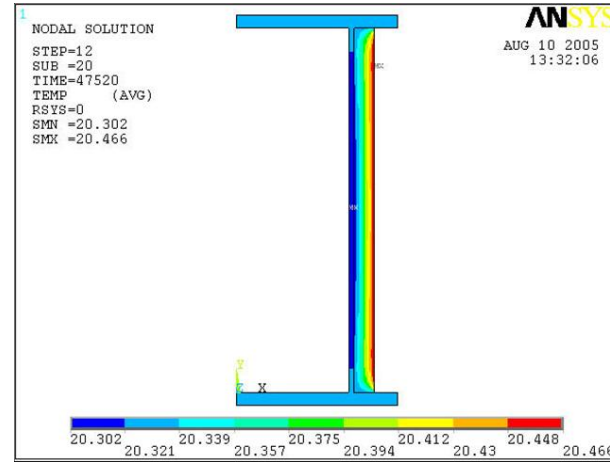
Alignment and Lifting Tests



- ❑ Repeated tests showed that it was possible to level the top plate and set the height to within $\pm 10 \mu\text{m}$.
- ❑ Effort: 2 – 3 minutes for one mechanical technician with feedback from a designer.
- ❑ AirGo Air-Jacks can be used to take partial weight off the threaded rods.



Comparison with Experiment



Time = 12 hrs	Experimental	FEA
ΔT air (°C)	0.5	0.5
ΔT steel (°C)	0.33	0.37

Summary

- ❑ **The design of the fixed supports for the girder-undulator system was modified to improve stability, assembly and alignment.**
- ❑ **Vertical alignment was moved to the top of the support stand.**
- ❑ **Support stands are grouted directly to the floor for thermal stability.**
- ❑ **ΔT of ± 0.1 °C results in BPM and quad displacements of 0.6 μm .**
- ❑ **Fixed supports for 2 girder-undulator assemblies are in fabrication.**