A Light for Science

ESRF

European Synchrotron Radiation Facility

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Engineering Developments and Generic Solutions for Upgrade Mirrors at the ESRF

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- Working Group Objectives
- Generic Mirror System
- Building Blocks
- New Generation Hexapod
- Other Projects / Activities
- Conclusion

Working Group Objectives

- **Develop innovative design solutions for :**
- High stability mirror support and pre alignment systems
- UHV compatible mechanisms for fine incidence tuning
- Stiff & precise mirror elevators with bakeout compensation
- Efficient control of thermal deformation
- Standard large vacuum vessels & UHV sealing methods
- Assembly & installation protocols

GENERIC !

Generic Mirror System

- **Develop innovative design solutions for :**
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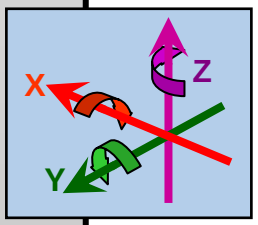
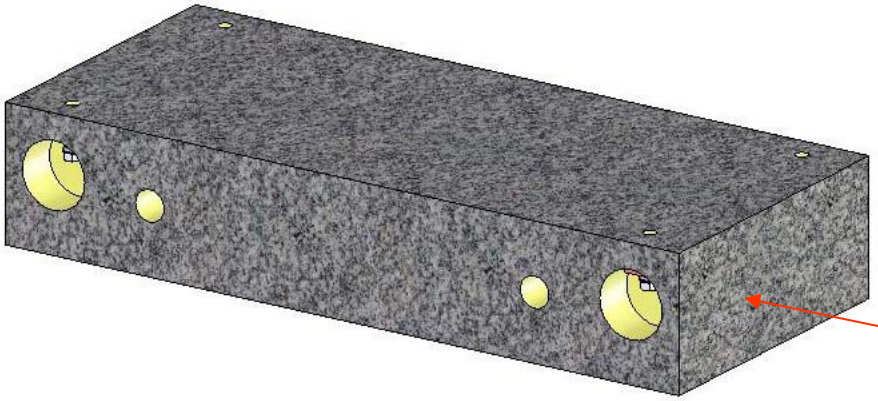
- UHV compatible mechanisms for fine incidence tuning
- Stiff & precise mirror elevators with bakeout compensation
- Efficient control of thermal deformation
- Standard large vacuum vessels & UHV sealing methods
- Assembly & installation protocols

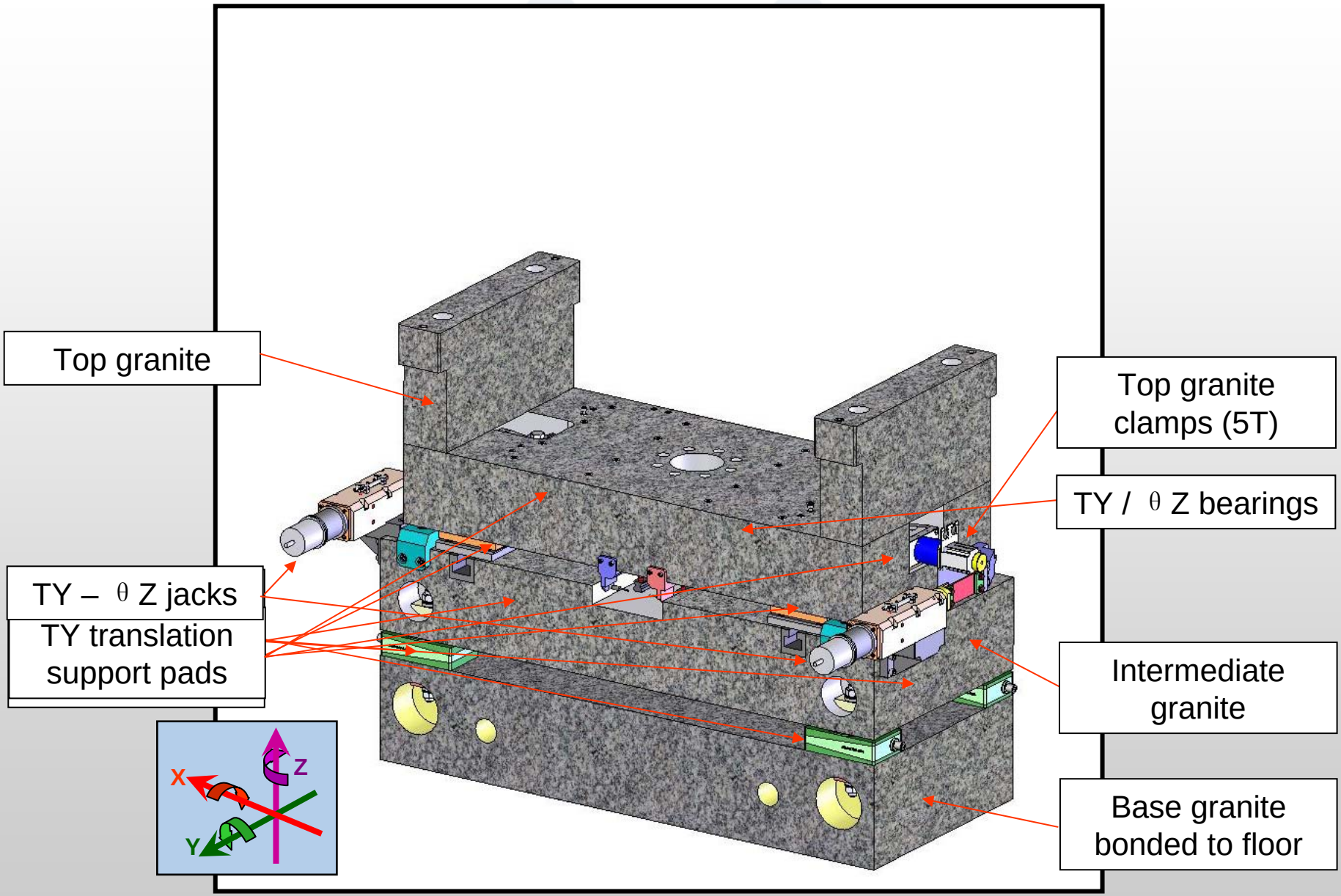
GENERIC !



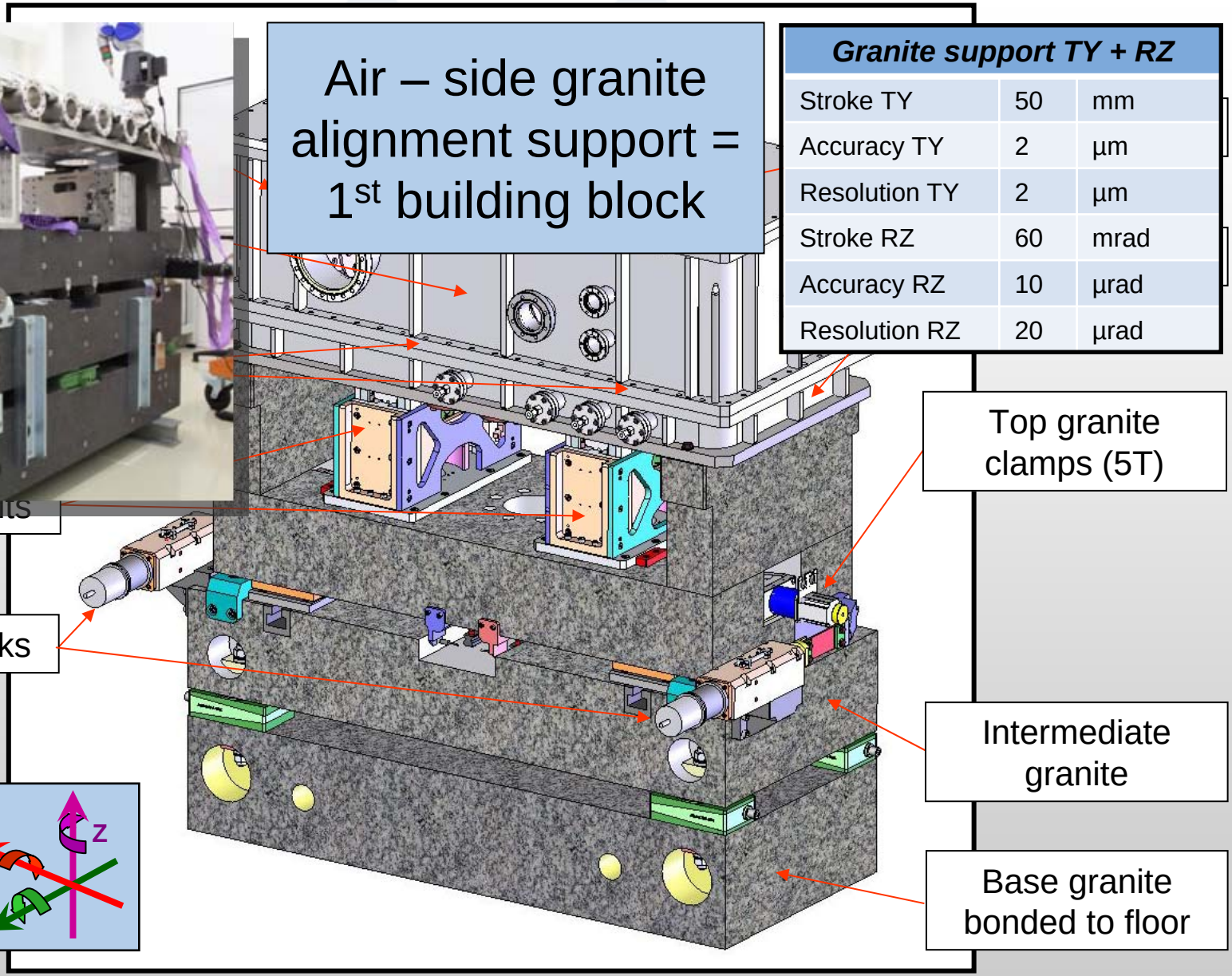


Base granite bonded to floor

Generic Mirror System



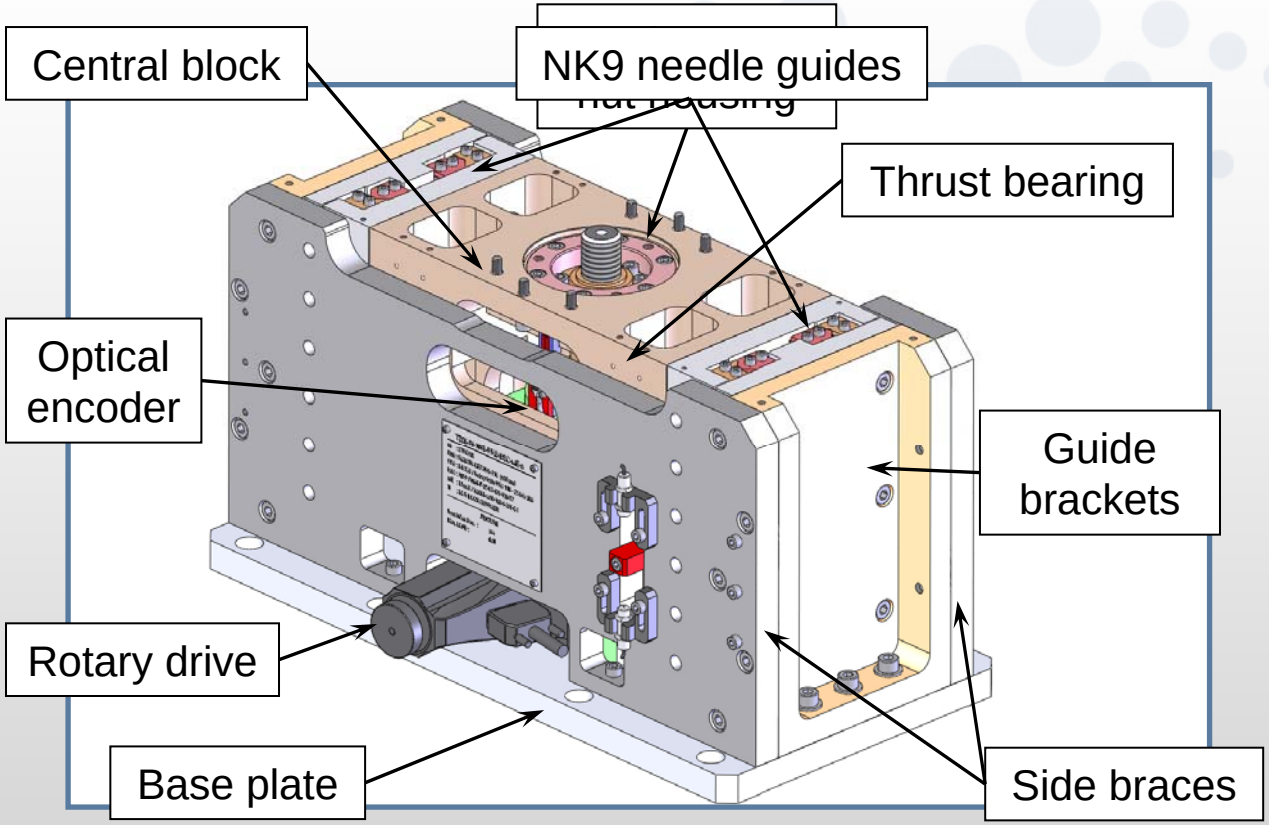
Generic Mirror System



Granite support TY + RZ		
Stroke TY	50	mm
Accuracy TY	2	µm
Resolution TY	2	µm
Stroke RZ	60	mrad
Accuracy RZ	10	µrad
Resolution RZ	20	µrad

Building Blocks

Mirror Elevator – 10 or 50mm travel

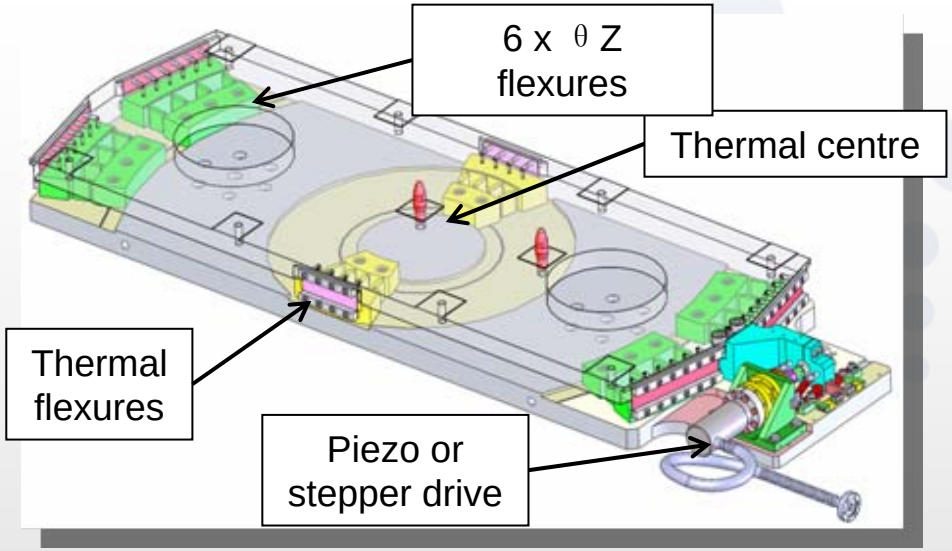


- Horizontally reflecting : mirror coating change (TZ50-50)
- Vertically reflecting : mirror incidence angle (TZ50-10)
- Over constrained design principle = critical assembly
- 15 units already made

TZ50-10 Satellite roller screw		
Stroke	10	mm
Accuracy	1.2	µm
Resolution	6	nm
Optional thermal shielding		

TZ50-50 Ballscrew		
Stroke	50	mm
Accuracy	5	µm
Resolution	40	nm
Lower cost		

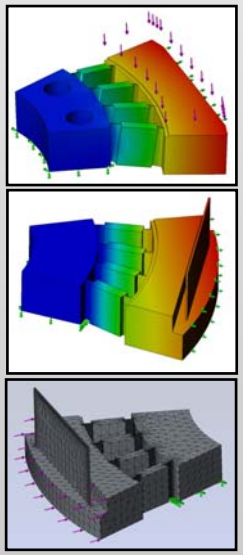
Building Blocks

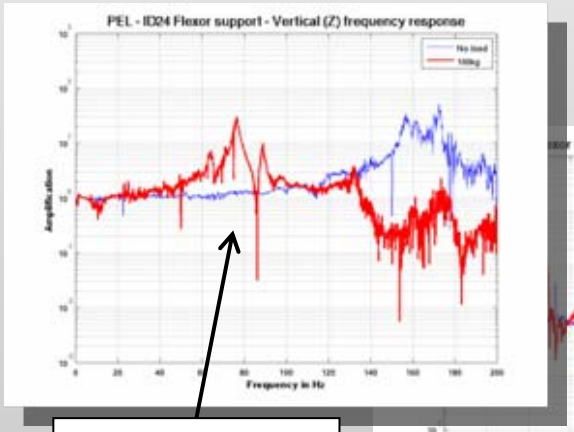


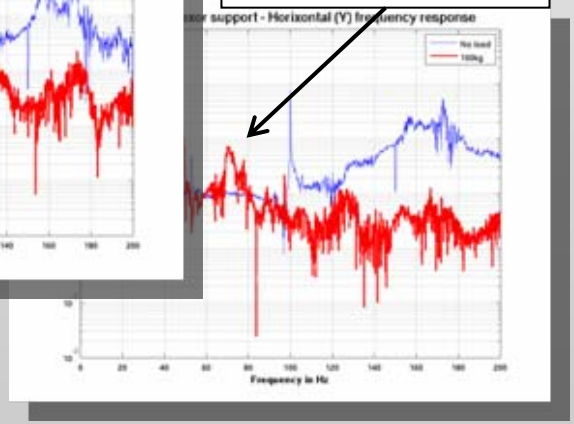
Incidence fine tune for large HR mirrors

Total stroke	***+/- 200***	***µrad***
Overall length	940	mm
Load capacity	120	kg
Repeatability (bidirectional)	2	µrad
Resolution (half motor step)	0.75	µrad
1st horizontal mode (no load)	160	Hz
1st horizontal mode (100kg load)	70	Hz

Stress, displacement, thermal & vibration analysis





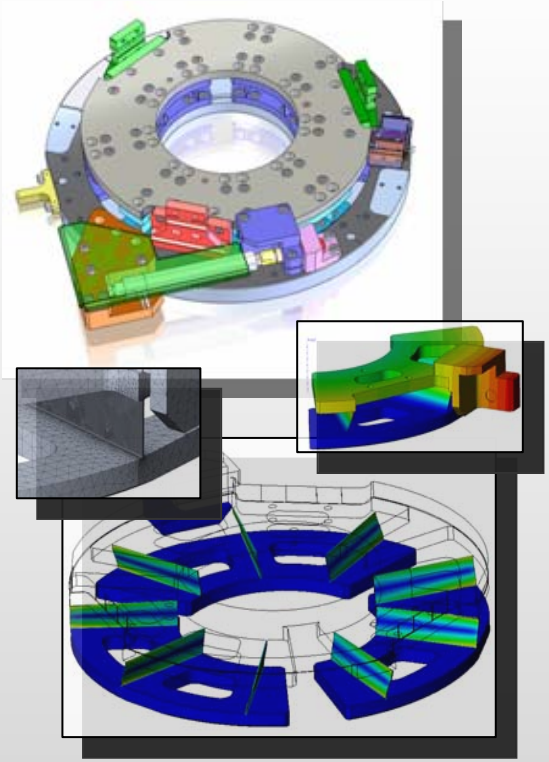


Horizontal 70 Hz loaded

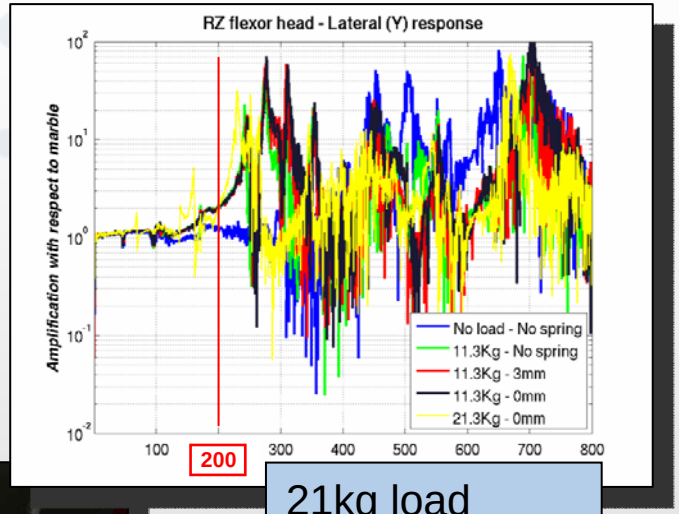
Vertical 76 Hz loaded

Building Blocks

Compact, Closed Loop UHV θ Z Flexure



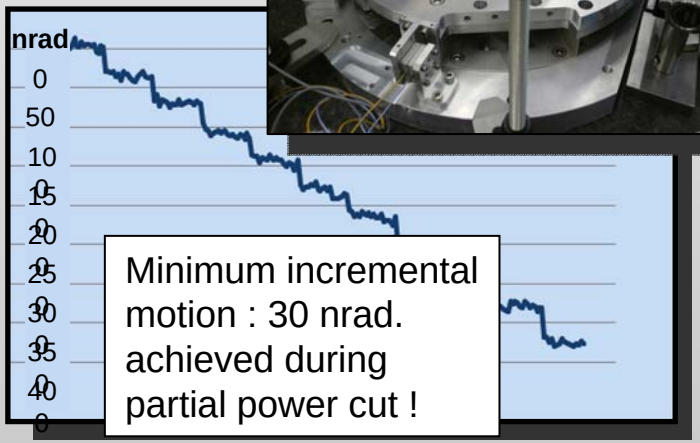
Small UHV θ Z flexure		
Total stroke	+/- 300	µrad
Load capacity	30	kg
Repeatability (unidirectional)	0.4	µrad
Resolution (with piezo drive)	< 50	nrad
1st RF(21kg load)	230	Hz



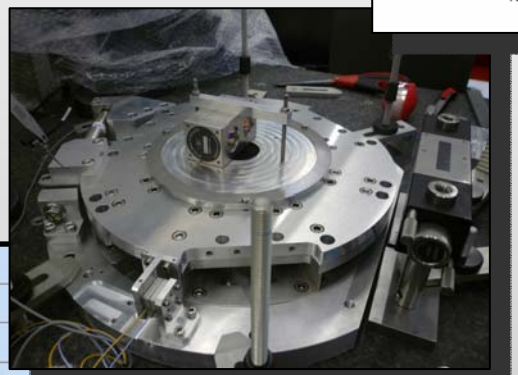
21kg load
1st horizontal mode >200 Hz

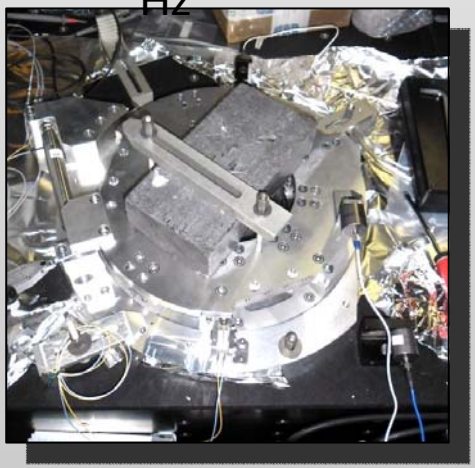
- Material : 7075 T6 alloy
- Blade thickness : 0.8mm
- Multiple drive options
- PI D100 capacitive sensor
- Long term stability tests to be done

Angular resolution plot



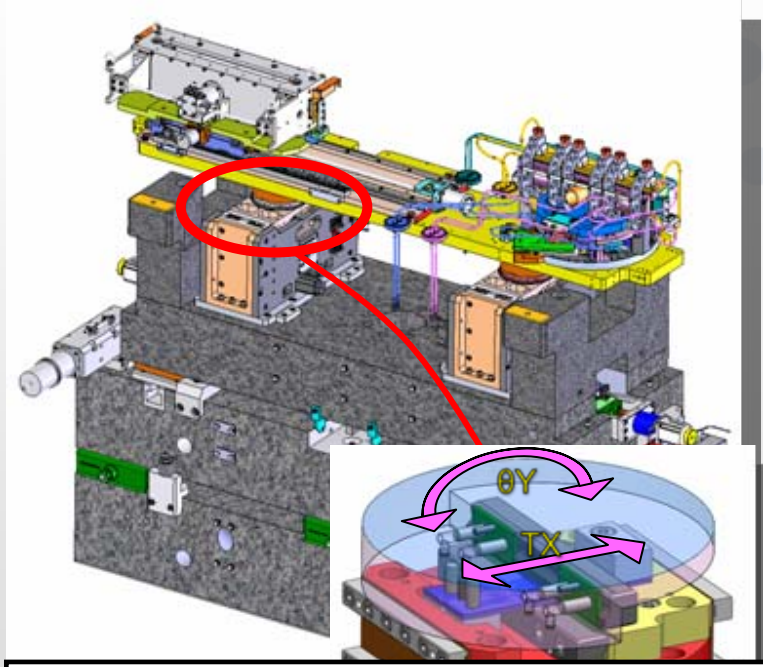
Minimum incremental motion : 30 nrad. achieved during partial power cut !

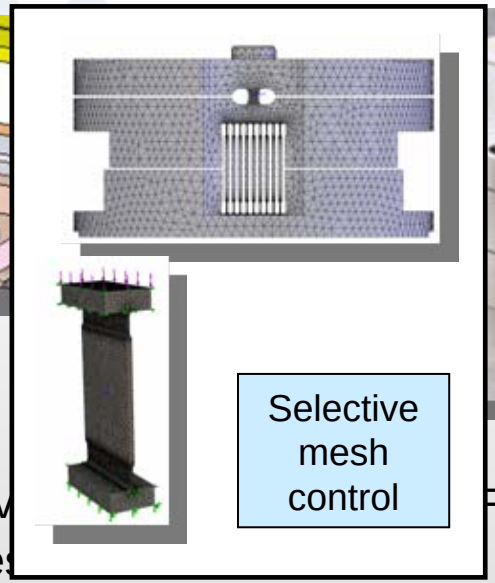


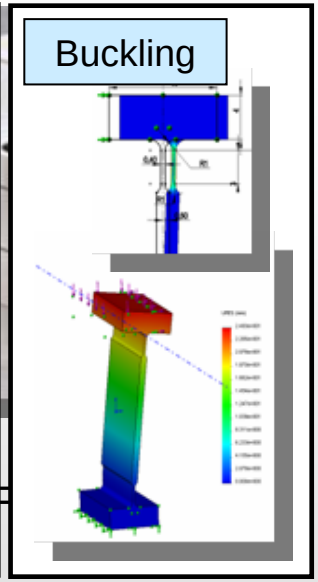


Building Blocks

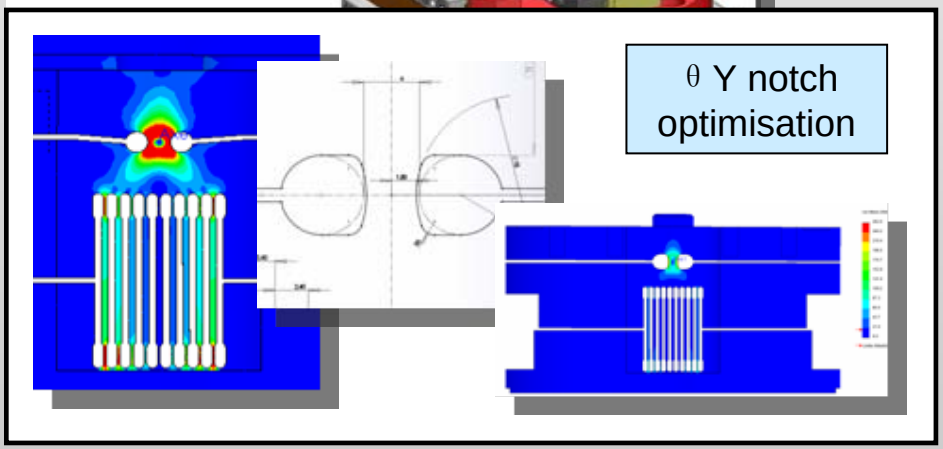
UHV Flexure Compensator for TZ Mirror Elevators

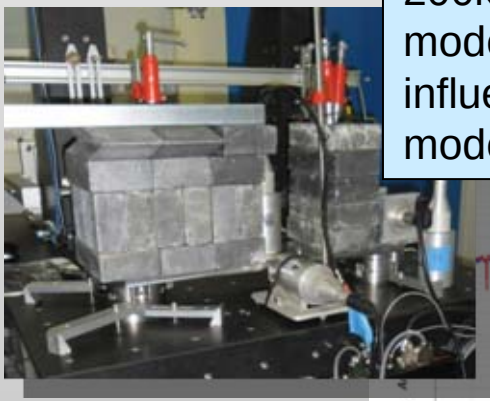




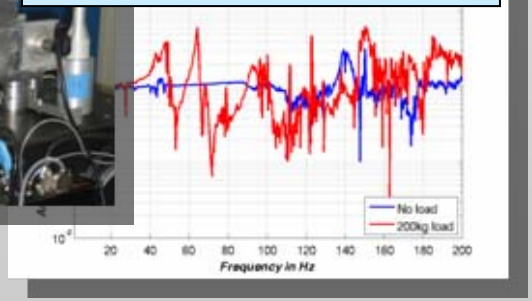


- Latest v
- 9 blades





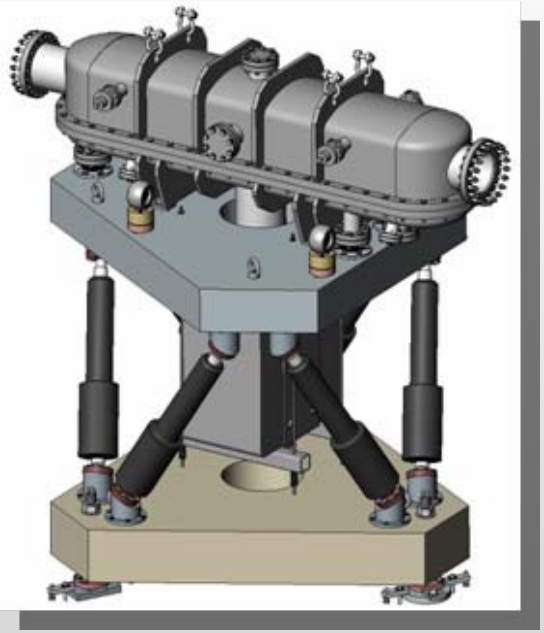
200kg load, 1st horiz mode : 47 Hz (possible influence of floor), 2nd mode : 62 Hz



New Generation Hexapod

New hexapod developed in collaboration with Symetrie (France)

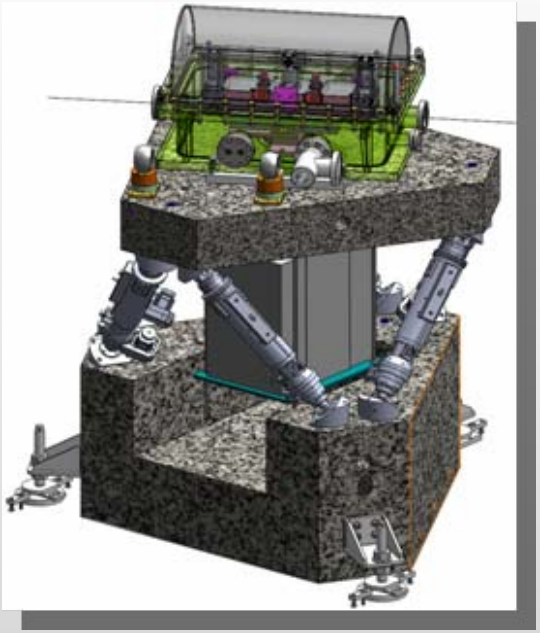
1995



Symétrie

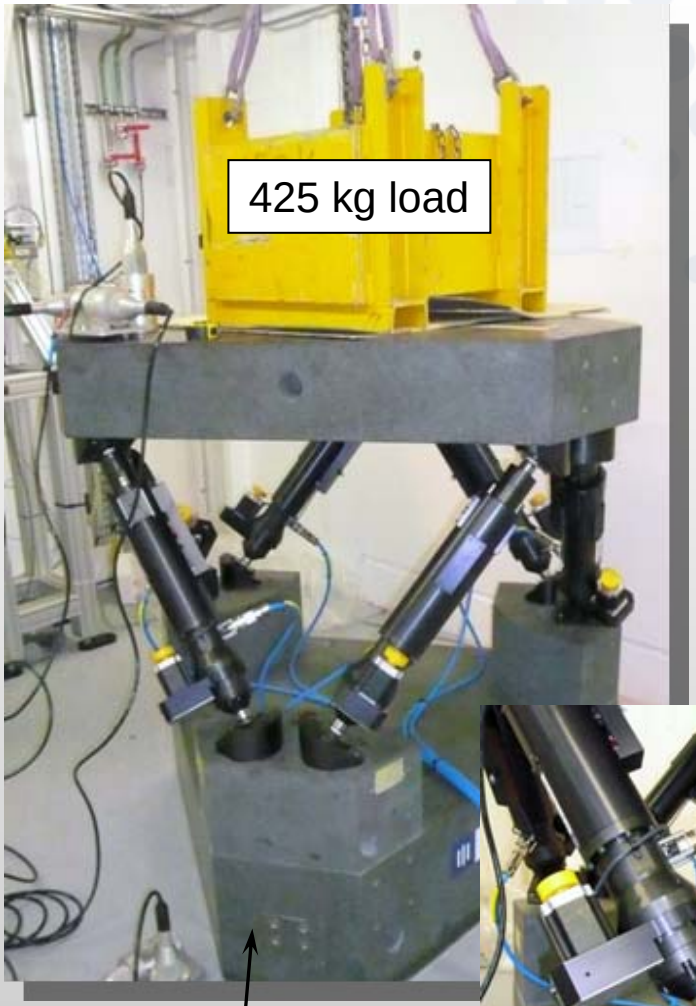
- Stiffer base, bonded to floor
- Shorter legs with lower CTE
- Offset & thermally isolated motors
- Satellite roller screw drive for improved leg stiffness
- Improved jack resolution : Ceramic ball joints, Harmonic Drive reduction gear
- Optimised geometry

2012

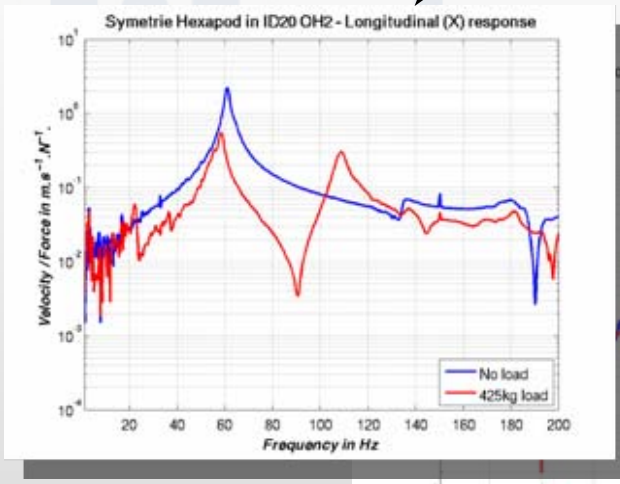


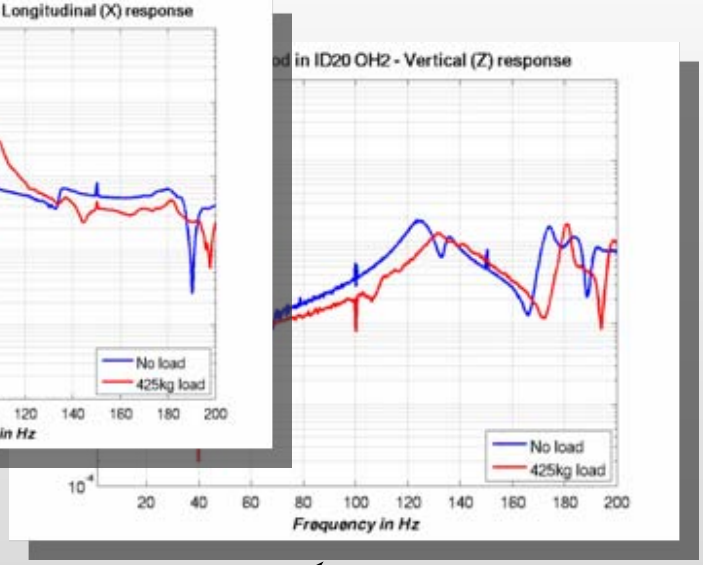
Specs.	*Linear resolution*	*Linear repeatability*	*Angular resolution*	*Angular repeatability*	*1st vibration mode*	*Thermal stability TZ*
Existing 1995	1 µm	2.4 µm	7.5 µrad	11 µrad	29 Hz	11 µrad / 12h
New 2012	0.1 µm	+/- 0.5 µm	0.2 µrad	+/- 2 µrad	55 Hz	2 µrad / 12h

New Generation Hexapod



- 1st horizontal mode (unloaded) : 60.8 Hz
- 1st horizontal mode (425 kg load) : 55.8 Hz





- 1st vertical mode (unloaded) : 124 Hz
- 1st vertical mode (425 kg load) : 131 Hz

(probably due to preloading of ball joints)

Base bonded to floor

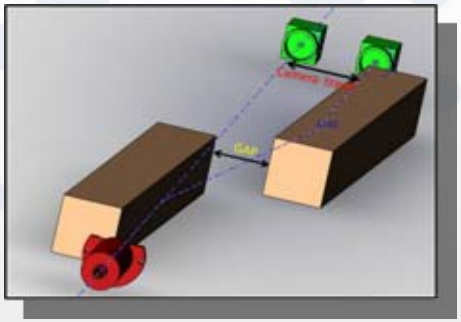
Offset motor drive and ceramic ball joint

Other Projects & Activities

UHV vessels & seals

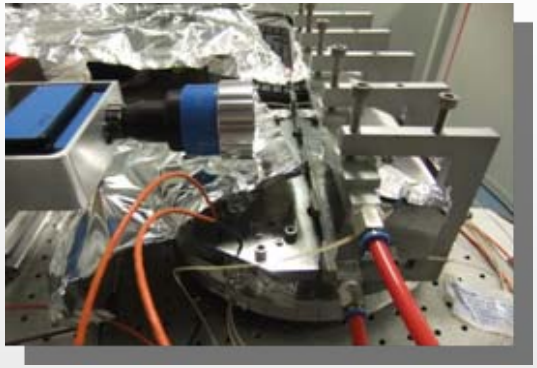
- 2 part vessel, feedthroughs in base, easy access
- 2mm alu annealed wire
- 6.5 x 10^{-10} mbar after several bakeout cycles

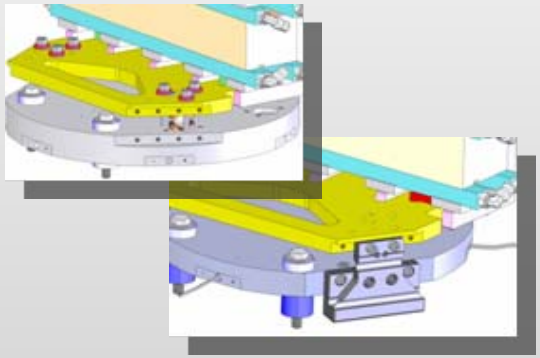
Gap alignment



- Linear resolution 1µm
- Angular resolution 1µrad
- Presentation O. Hignette

Mirror clamping





- Test bench
- Balls or flexures ?
- 20 – 40ºC cycle (chiller)
- FISBA interferometer
- Mirror clamping techniques
- Presentation M. Mattenet

Conclusion

1. Generic design :
   - Standard sub assemblies
   - Batch orders
   - Standard assembly & installation procedures
2. Over constrained design :
   - Higher stiffness
   - Higher accuracy & resolution
3. Systematic FEA, metrology & vibration analysis
4. Full UHV compatibility
   - Flexures
   - Piezos & encapsulated motors

Conclusion

Acknowledgments

Working Group

R. Baker
Y. Dabin
C. Clavel
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Specialists

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O. Hignette

Support

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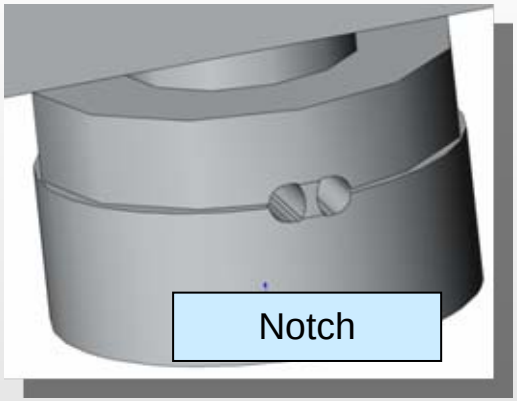
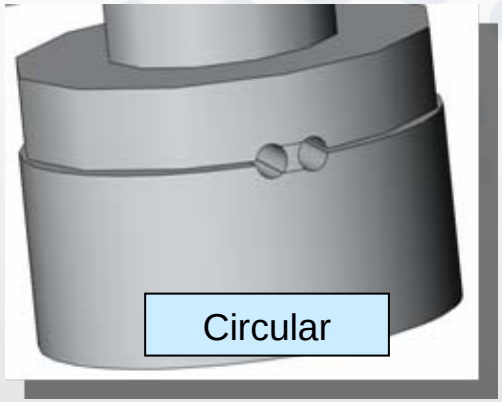
J. Gregoire
G. Malandrino
M. Garrec
…….

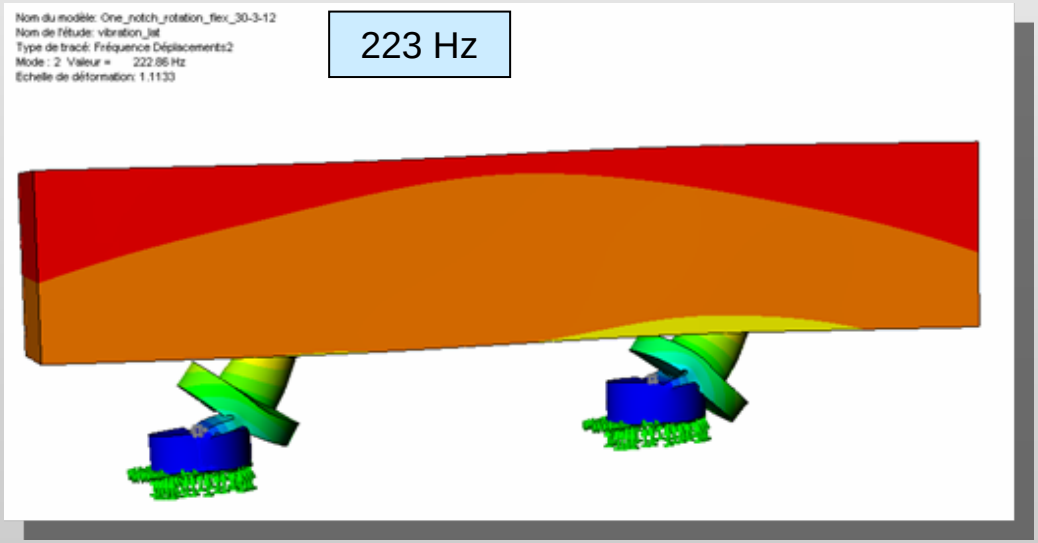
Thank you for your attention

Building Blocks

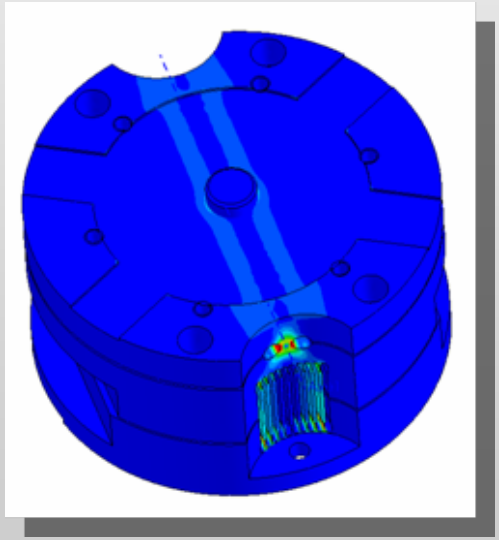
Higher stiffness Monolithic UHV Flexure Compensator for TZ Mirror Elevators (no bakeout compensation)







Stress footprint



12 Mirror systems using WG design principles

[a] MIR-w : Single white beam mirror.
[b] MIR-m : Single monochromatic beam mirror.
[c] DMIR-m : Double monochromatic beam mirror.
[d] ML Mn-w: Multilayer monochromator.
[e] DMIR-w : Double white beam mirror.

FR: Fixed radius [m]
DR: Dynamic radius [m]
SphR: Spherical radius [m]

Table 1. Generic design series of mirrors for the ESRF upgrade program

Beamline	Optic Name	Reflection Plane H:Horz V: Vertical	Absorbed Power [watt]	Distance To Sample [m]	Reflecting surface aspect	Architectural Solution G-Bench: Hexapod
UPBL 11	MIR-w[a]	V	850	50	Flat	G-Bench
(ID24)	DMIR-w[a]	H	850	45	Flat-Flat	G-Bench
ID06	DMIR-m[c]	H	0	30	Flat-DR:20	G-Bench
UPBL6	MIR-m[b]	V	0	50	Flat	Hexapod
(ID20)	MIR-w[a]	V	200	60	FR:xx	G-Bench
UPBL4	ML Mn-w[d]	H	160	155	FR:2000	G-Bench
(ID16)	DMIR-w[e]	H	653	135	Flat-DR:1000	G-Bench
ID10	DMIR-w[e]	V	400	30	Flat-FR:xx	G-Bench
	DMIR-w[e]	H	625	60		Hexapod
UPBL7	MIR-m[b]	V	0	50		Hexapod
(ID32)	MIR-m[b]	V	0	40		Hexapod
	MIR-m[b]	H	0	30		Hexapod
UPBL9a (ID02)	DMIR-w[a]	H	800	60	Flat-Flat	G-Bench
UPBL1	DMIR-w[a]	H	900	125	Flat-Flat	G-Bench
(ID01)	ML Mn-w[d]	H	200	115	Flat-Flat	

Choice of materials – a closer look

Stable environment, minimum bending

Material	C.T.E.
	α 10^{-6}/°C
Zerodur	0,1
Invar	1.5
Si	3.9
SiC	4.3
Granite	8
Corroplast *	10
Mild steel	12
Copper	16.6
St. St.	17
Brass	20
Aluminium	23
Peek	70

Material	Distortion
	α /k
Si	0.02
SiC	0.02
Copper	0.04
Zerodur	0.07
Invar	0.14
Aluminium	0.15
Brass	0.18
Mild steel	0.28
Corroplast *	0.45
St. St.	1.04
Granite	2.86
Peek	280

Fast reaction, punctual sources

Material	1/Diffusivity
	ρ.Cp/k
Copper	8.5
SiC	9
Si	11
Aluminium	14
Brass	29
Mild steel	77
Corroplast *	163
St. St.	220
Invar	355
Granite	734
Zerodur	1421
Peek	1690

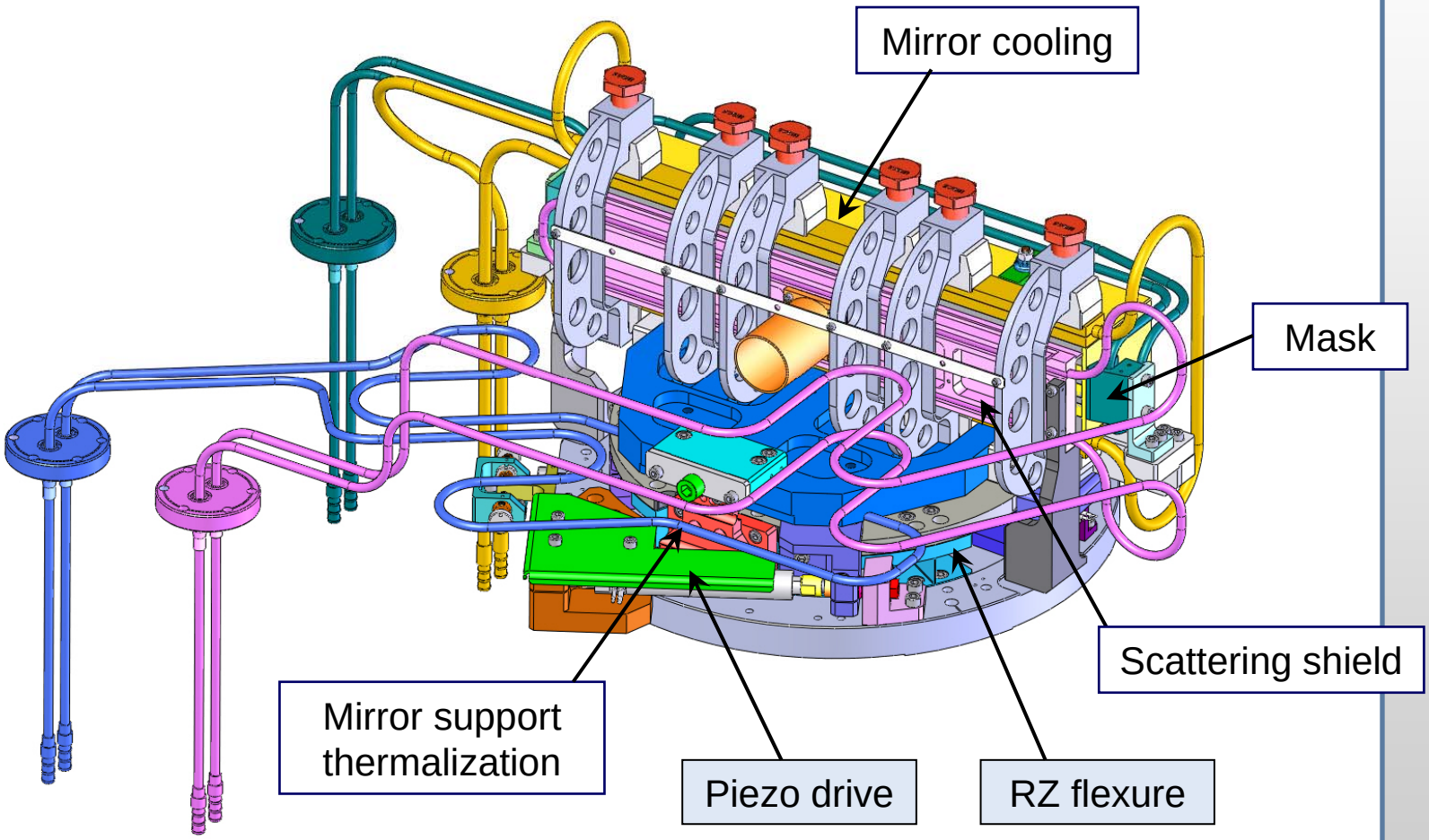
Best compromise?

Material	Diff. x dist.
	α .ρ.Cp/k^2
SiC	0.16
Si	0.2
Copper	0.35
Aluminium	1.9
Brass	5.3
Mild steel	21.5
Invar	50.7
Corroplast *	220
Zerodur	355
St. St.	734
Granite	1421
Peek	1690

- Disadvantages with low CTE materials are :
  - Cost !
  - Availability
  - Poor structural properties
  - Incompatibility with commercial products
  - Difficult or impossible to machine
  - Poor thermal conductivity

* *Corroplast : low carbon hard stainless steel from Thyssen, lower α, higher k than 304 grade stainless steel*

If manufacturing cost is considered, common engineering materials are best

Other solutions – Thermalization

UPBL4 UHV double mirror system – 1st mirror. High local heat load on mirror & surrounding mechanics (750W)