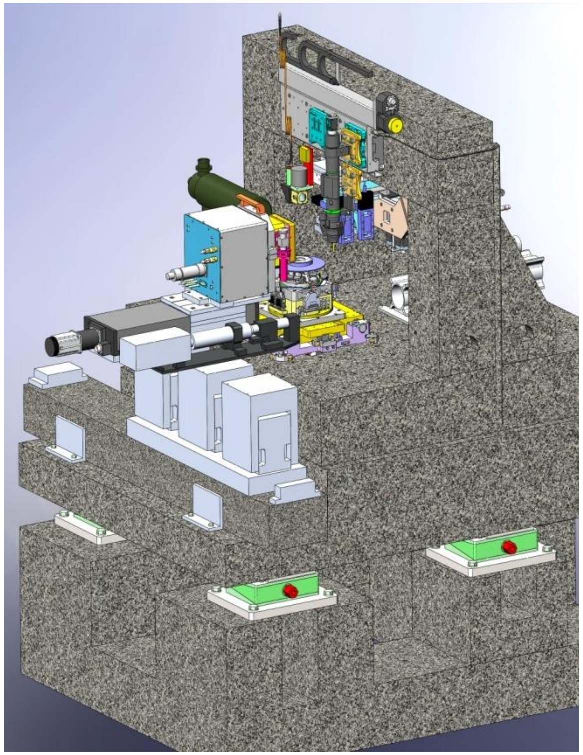
ESRF | The European Synchrotron

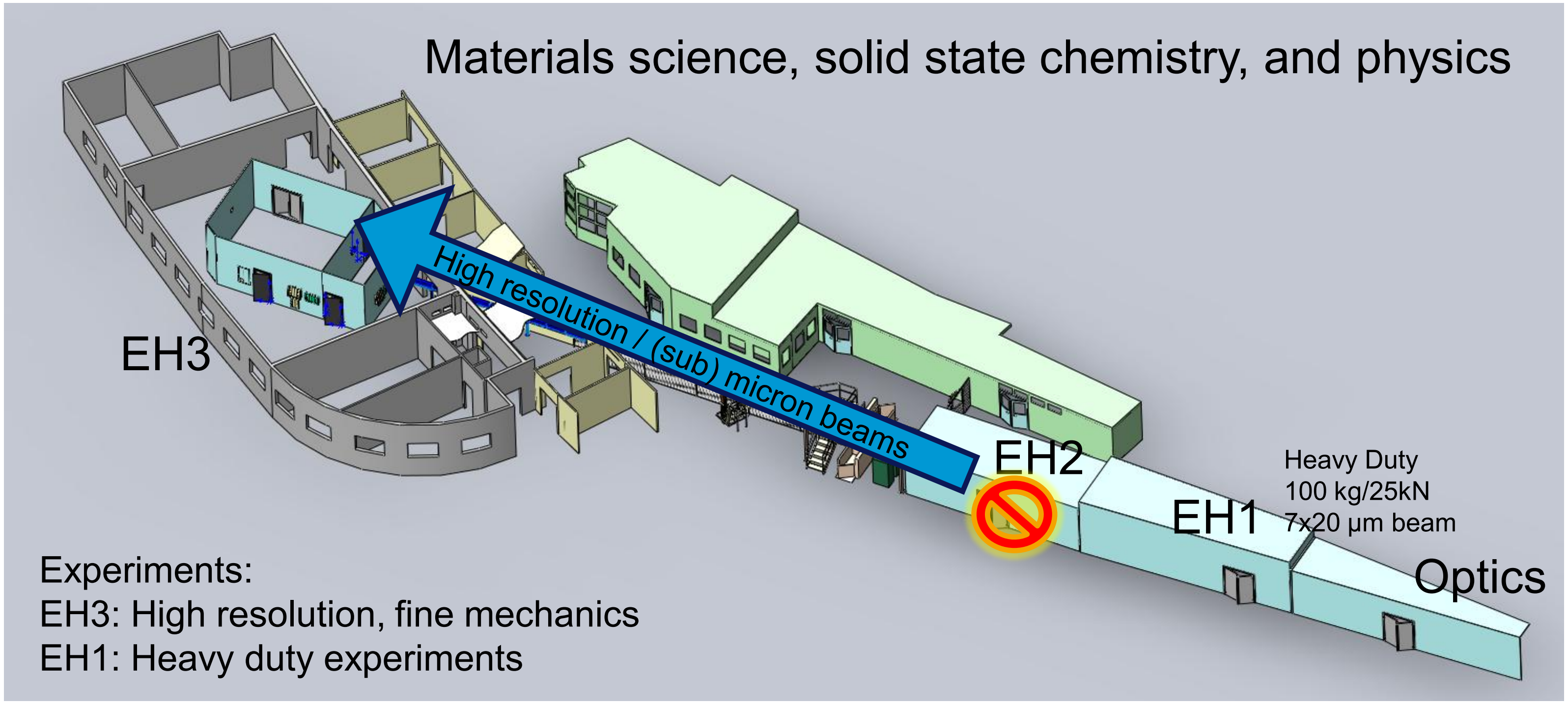


The New ID11 Nanoscope end-station A Nano-Tomography Scanner

A focus on the sample positioning stages

I. ID11 Beamline
II. Design architecture
III. A rotation stage with nanometer-level performance together with an electrical slip-ring
IV. A specific high precision linear stage
V. Conclusion and perspectives

I. ID11 OVERVIEW



Imaging techniques on the Nanoscope :

Nano X-Ray Diffraction Computed Tomography (XRD-CT)

Diffraction Contrast Tomography (rotation of a 3D sample)

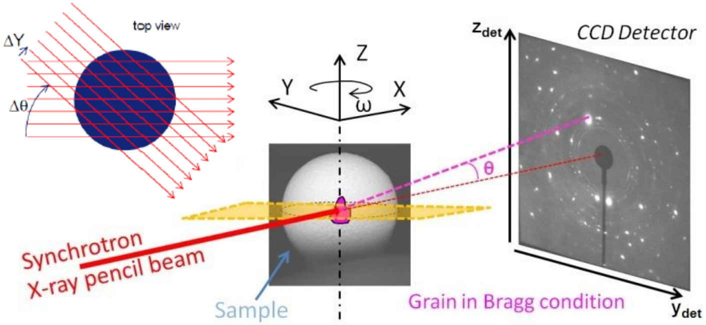
Fluo tomography (combination of scan and rotation)

X rays

Energy from 18 to 65 keV

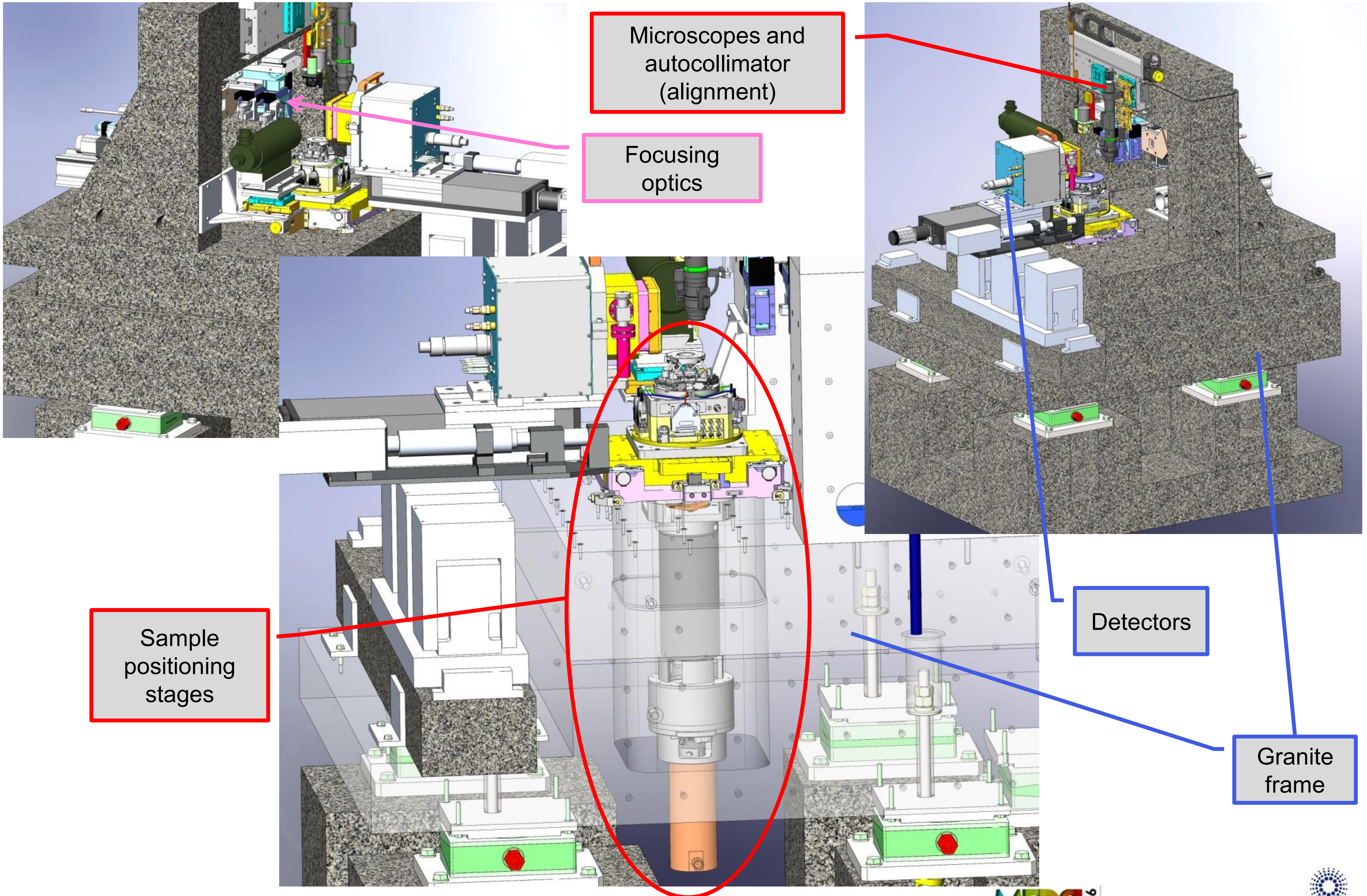
Final focalisation by a set of Nano Focusing Lenses

Typical focal spot size ~100nm

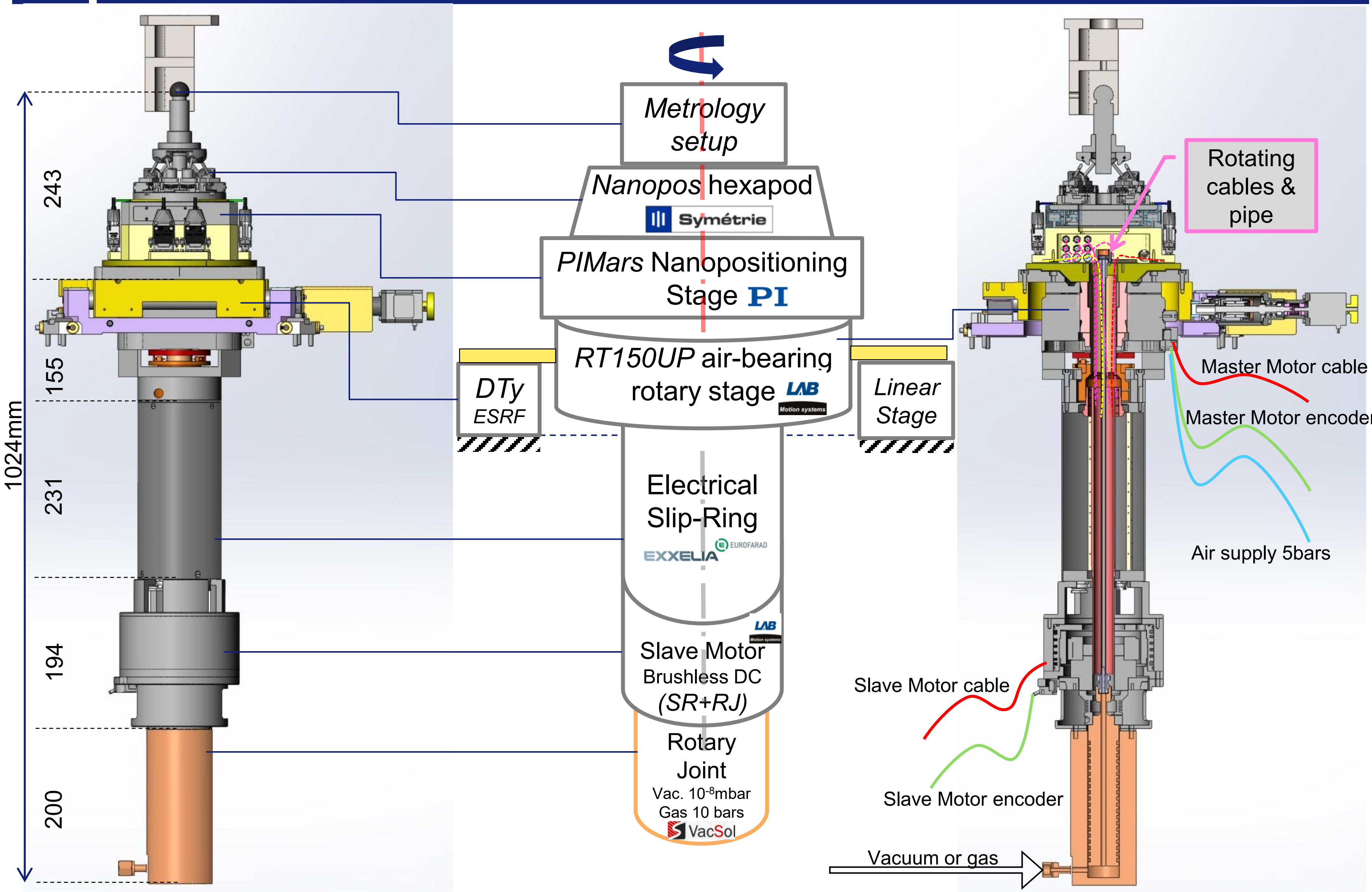


XRD-CT technique – Continuous scan in ω and incremental positions of the Y-axis

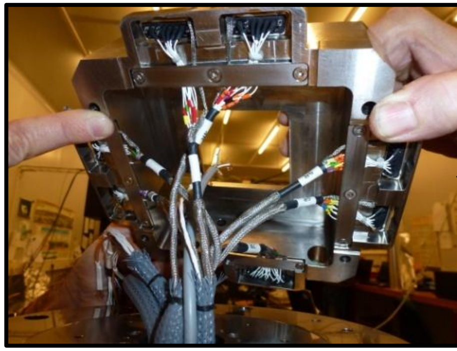
II. Design architecture - Nanoscope end-station



II. Design architecture - Nanoscope – sample positioning stages

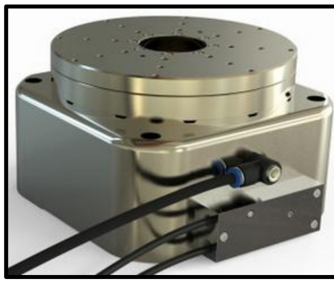


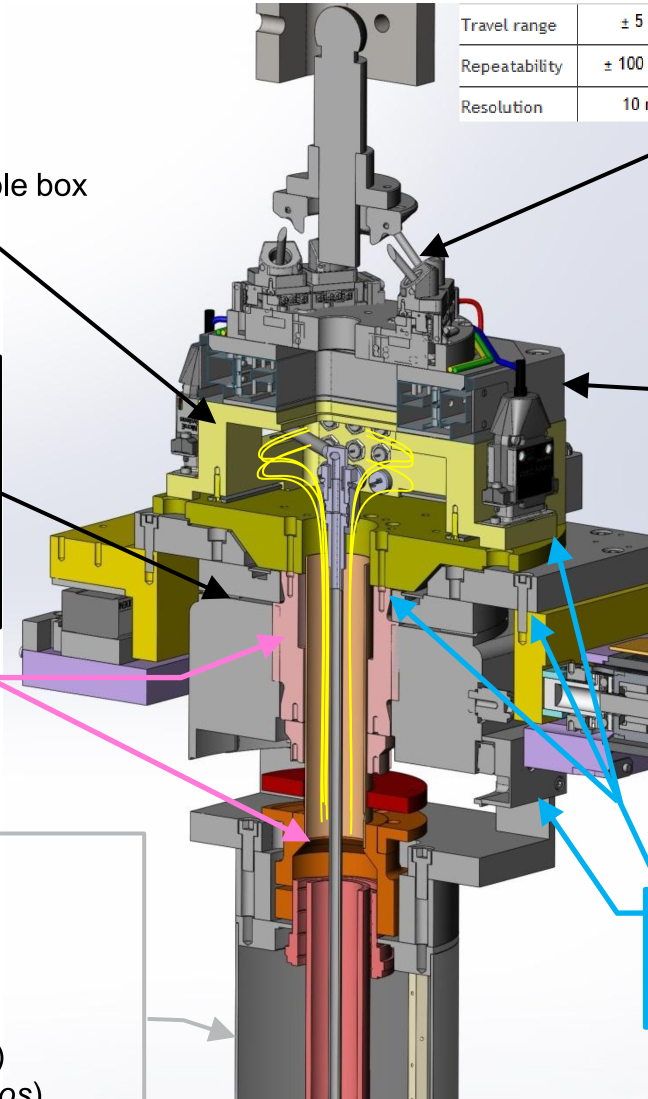
III. Design architecture - Rotation stage and slip ring



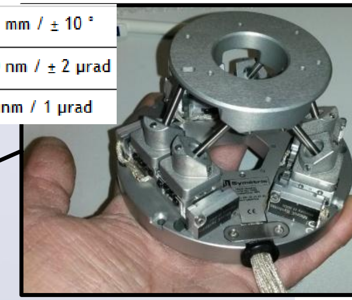
Cable box

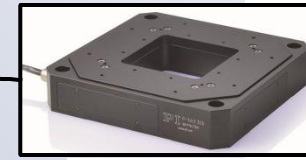
Air bearing		
Max. axial load	726	N
Max. radial load	264	N
Axial stiffness	242	N/µm*
Radial stiffness	88	N/µm*
Tilt stiffness	204	Nm/mrad*
Radial error motion	<20	nm LSC**
Axial error motion	<20	nm LSC**
Air consumption	<20	Nl/min
Total mass	15.2	kg
Material	Stainless steel	





Travel range	± 5 mm / ± 10 °
Repeatability	± 100 nm / ± 2 µrad
Resolution	10 nm / 1 µrad





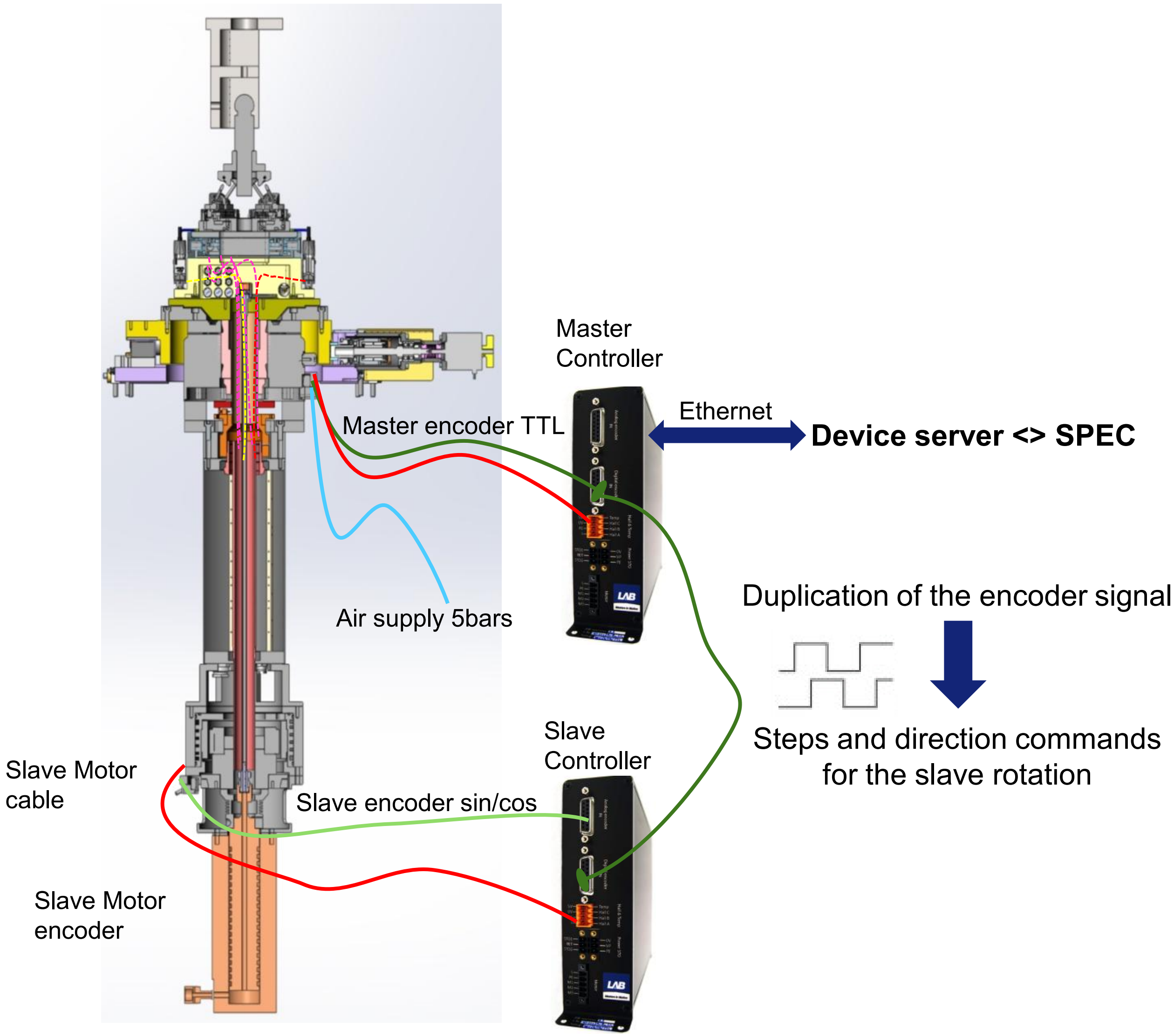
Integrated sensor	Capacitive
Travel range XYZ	150mm^3
Repeatability	2nm^3
MIM	0.8nm^3

NO mechanical coupling between the slave and the master rotor (except the stiffness of the cables)

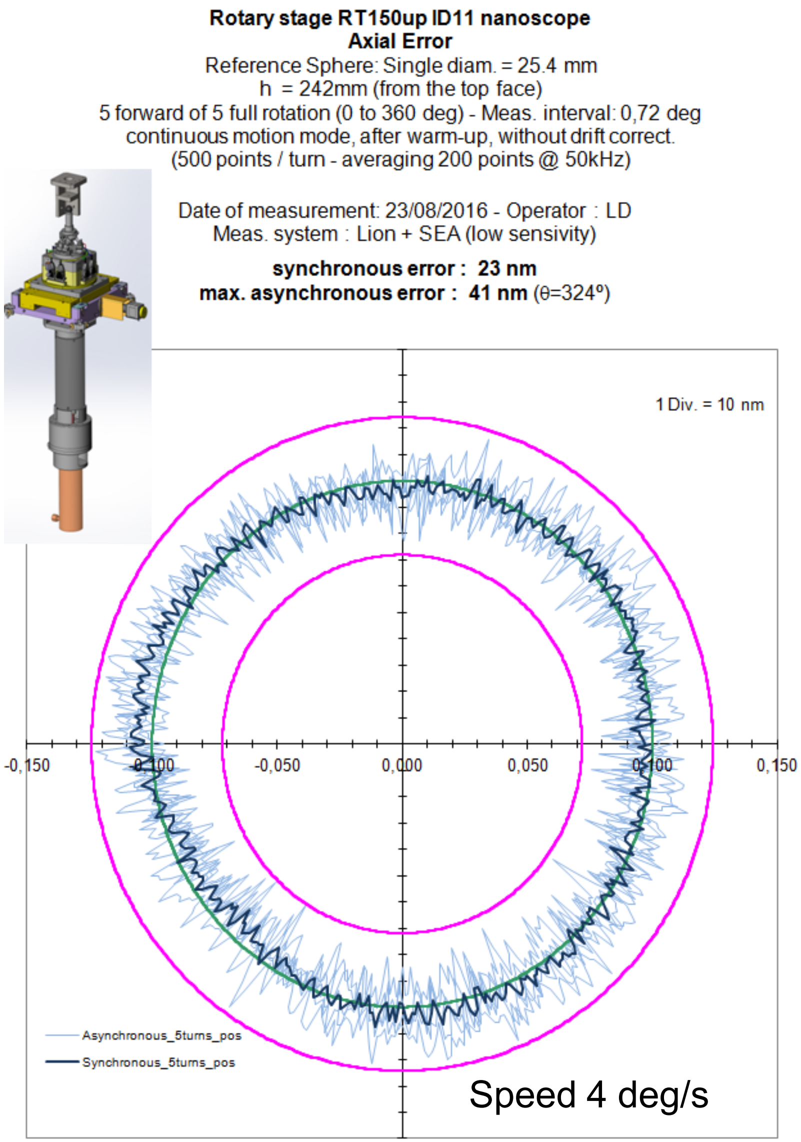
Very good flatness of interfaces required [1-5] µm

Slip-ring :
Standard ball-bearings
Resistive torque < 1Nm
101 electrical ways for :
-Capacitive probes 30kHz (PIMars)
-Piezo actuators -30/135V (PIMars)
-Piezo motors ±48V 10kHz (*Nanopos*)
-RS422 encoder signals 1MHz (*Nanopos*)
-15 auxiliary signals

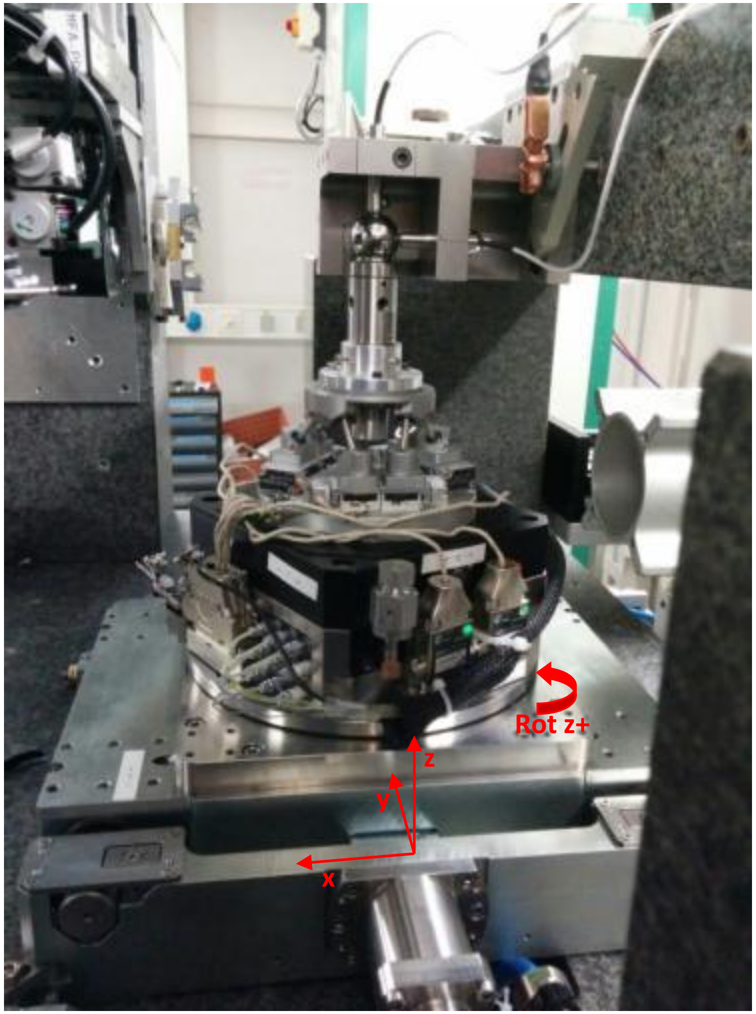
III. Control Architecture – Rotation stage



III. Rotary stage – Metrology in BL working conditions



Speed 4 deg/s



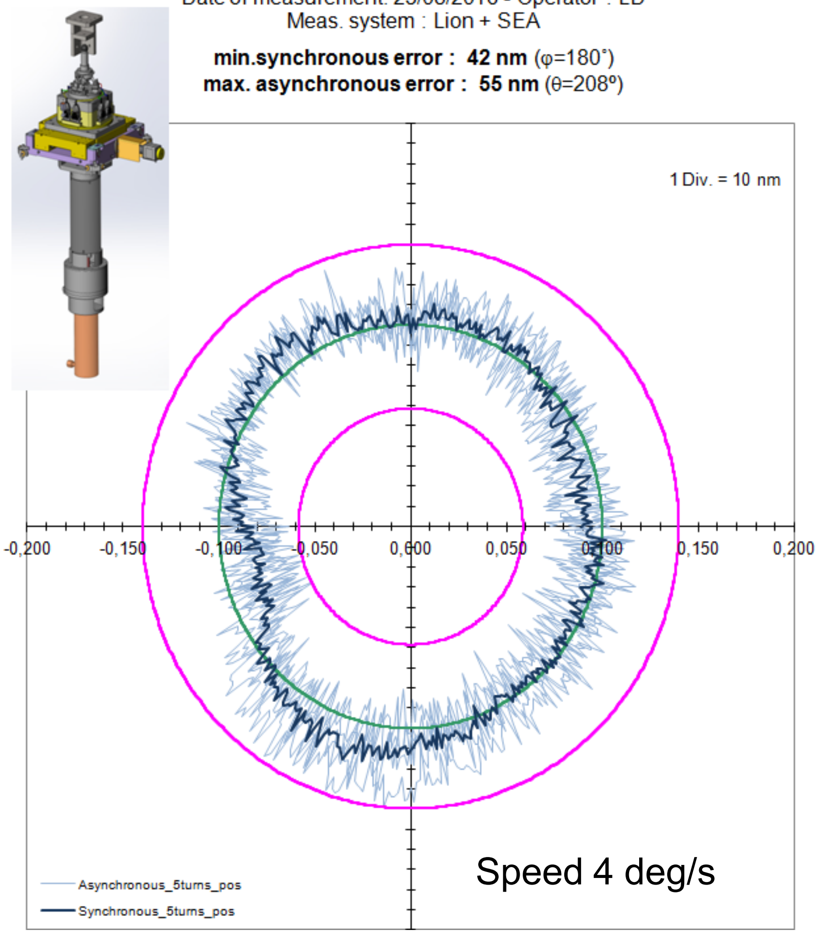
All sample stages activated in closed-loop
Dty-Rotation-PIMars-Nanopos

III. Rotary stage – Metrology in BL working conditions

Rotary stage RT150up ID11 nanoscope
Radial Error
Rotating Sensitive Direction
Reference Sphere: Single diam. = 25.4 mm
h = 242mm (from the top face)
5 forward of 5 full rotation (0 to 360 deg) - Meas. interval: 0,72 deg
continuous motion mode, after warm-up
(500 points / turn - averaging 200 points @ 50kHz)

Date of measurement: 23/08/2016 - Operator : LD
Meas. system : Lion + SEA

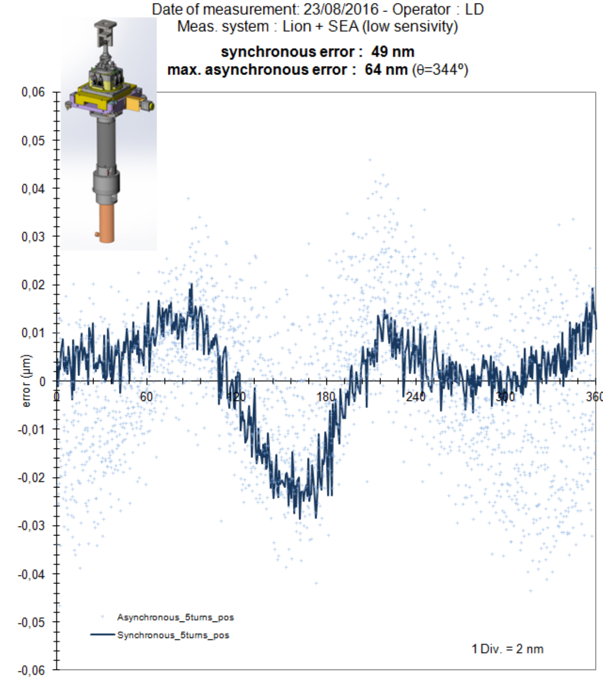
min.synchronous error : 42 nm (φ=180°)
max. asynchronous error : 55 nm (θ=208°)



Radial Error
Fixed Sensitive Direction Y
Reference Sphere: Single diam. = 25.4 mm
h = 242mm (from the top face)
5 forward of 5 full rotation (0 to 360 deg) - Meas. interval: 0,72 deg
continuous motion mode, after warm-up, without drift correct.
(500 points / turn - averaging 200 points @ 50kHz)

Date of measurement: 23/08/2016 - Operator : LD
Meas. system : Lion + SEA (low sensivity)

synchronous error : 49 nm
max. asynchronous error : 64 nm (θ=344°)

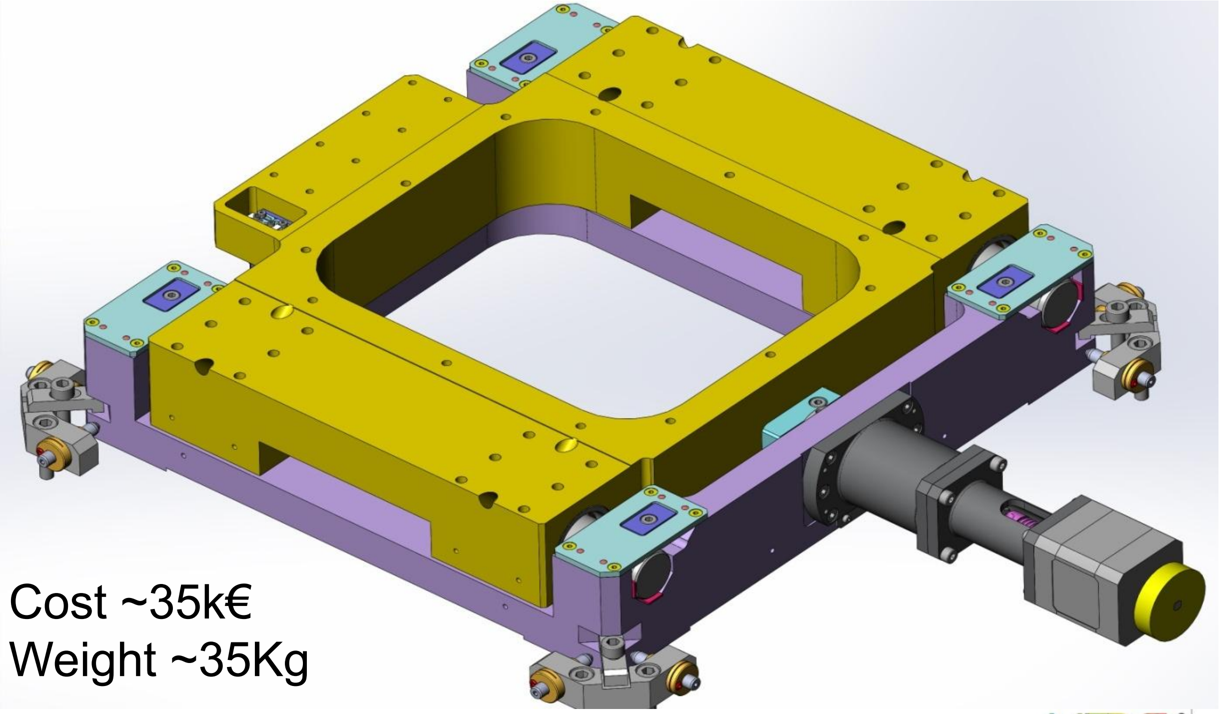


Asynchronous errors (repeatability) are larger than expected

➢ **Mainly induced by an internal thermal drift in the RT150up** (already visible during the characterization of the rotary stage standalone)

IV. DTy – A high precision Linear Stage designed and assembled at ESRF

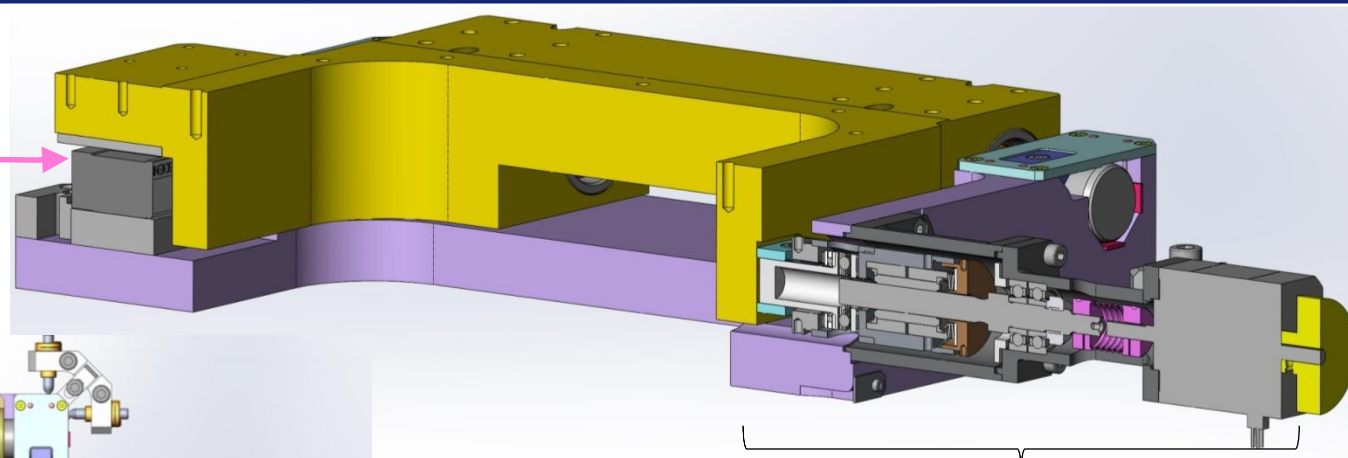
DTy stage	SPECIFICATIONS (@ POI H ~250mm)
Stroke	10 mm
Speed	1mm/s
Carried load	37 kg
Accuracy	3 µm
Repeatability bidirectional (full stroke)	4 µm
Repeatability bidirectional (stroke 100µm)	**10 nm**
MIM	**10 nm**
Straightnesses full stroke	**10 µm**
Repeat. Straightnesses FS	**1 µm**
Pitch error full stroke	**5 µrad**
Repeat. pitch error FS	**0.5 µrad**

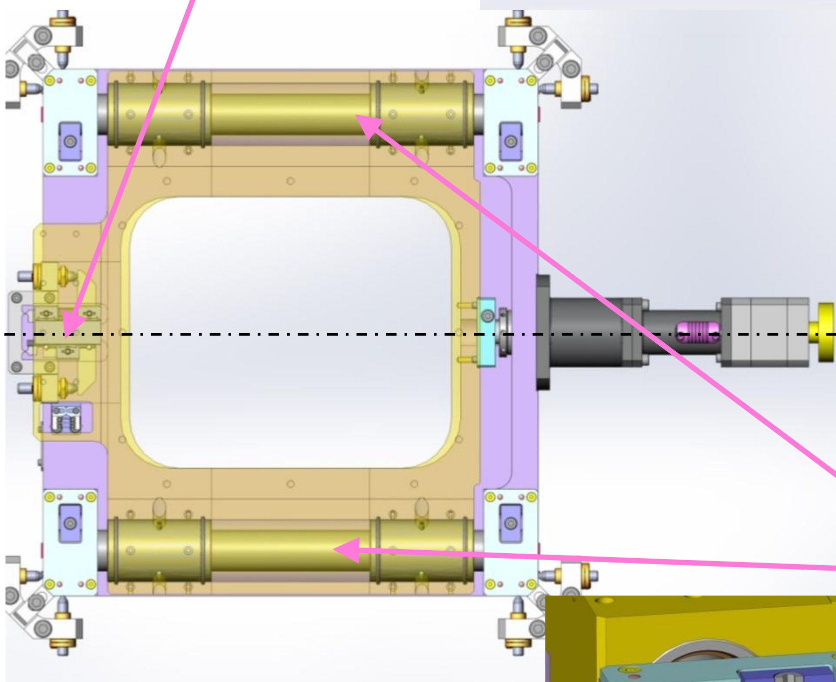


Cost ~35k€
Weight ~35Kg

IV. DTy Linear stage – Mechanical Design

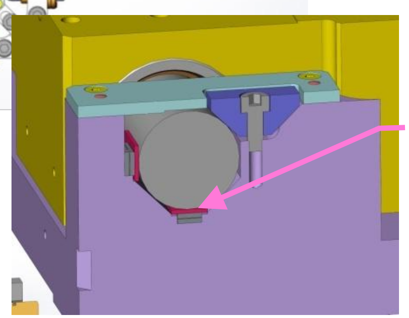
Heidenhain LIP281 encoder
Accuracy 20nm/10mm
Signal period 512nm
Interpol.x400 + quad : 0.32nm
Integration along the symmetrical plane





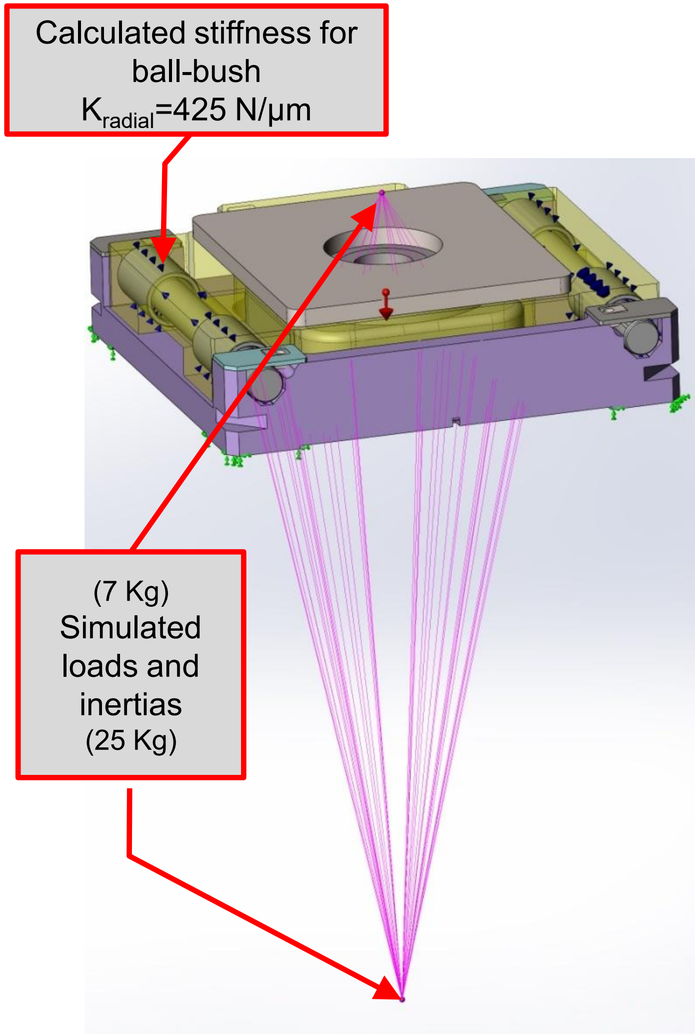
Stepper motor + satellite roller screw *Rollvis* + Oldham joint (balls) for alignment decoupling
No reduction gear
Standard stepper motor 400 steps/turn
Rollvis : pitch 1mm, preload adjusted during the integration

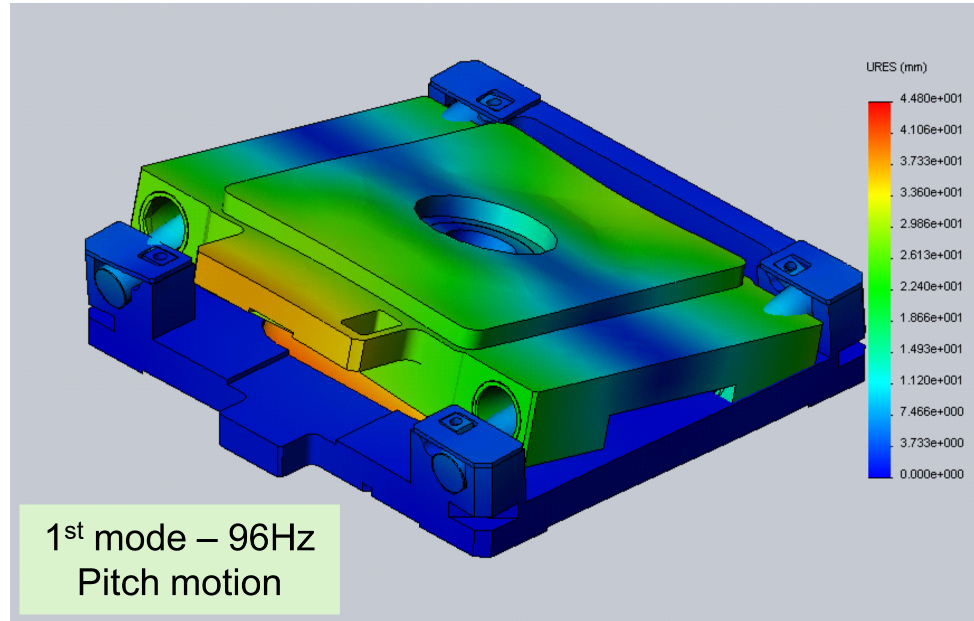
Frame components
Material C45E – Criteria: low ratio α/κ (α:11.10^{-6}K^{-1} κ:50 W/m.K) and high stiffness (E: 200 Gpa)
Thermal stabilisation before final machining

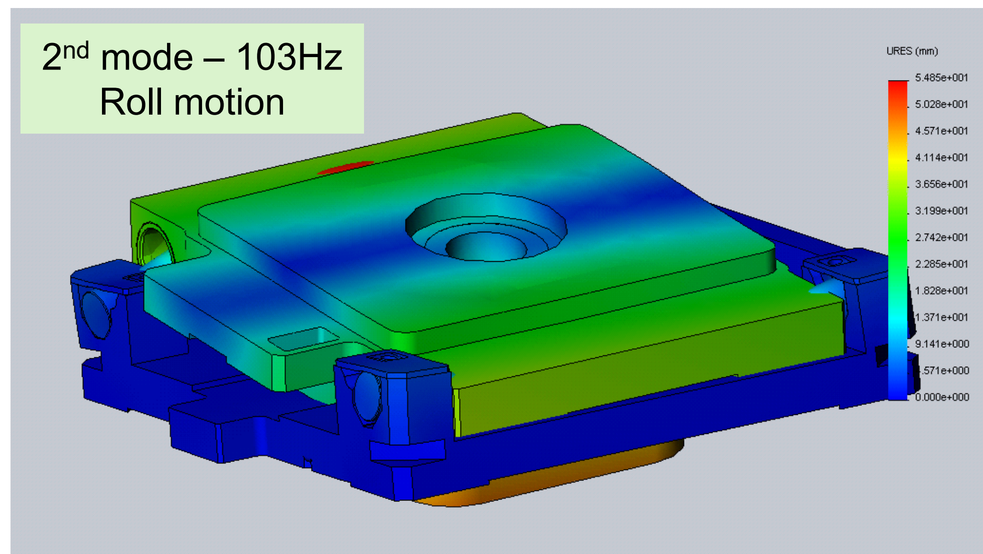


Ball-bush guidings (Mahr)
- •Factory preload 2-3 µm
- •Specific selection of components (Mahr) for linearity and coaxiality between rolling areas
- •The 4 bushes are glued in the carrier in order to minimize the parasitic constraints after the assembly
- •The // (<2µm) between shafts is finely adjusted with the use of slip gages and iterative measurements on a CMM
- • Optimised preloading of the shaft locking for low deformation

IV. DTy Linear stage – FEA calculations of Eigen frequencies

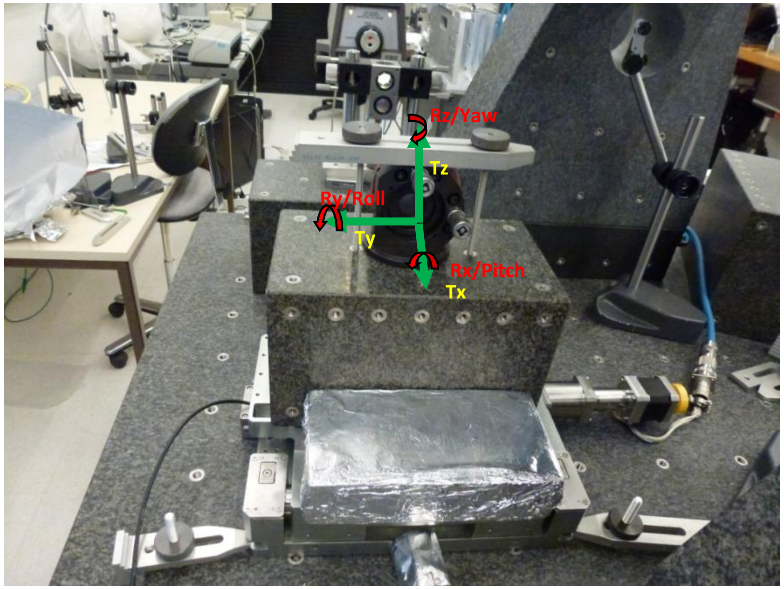




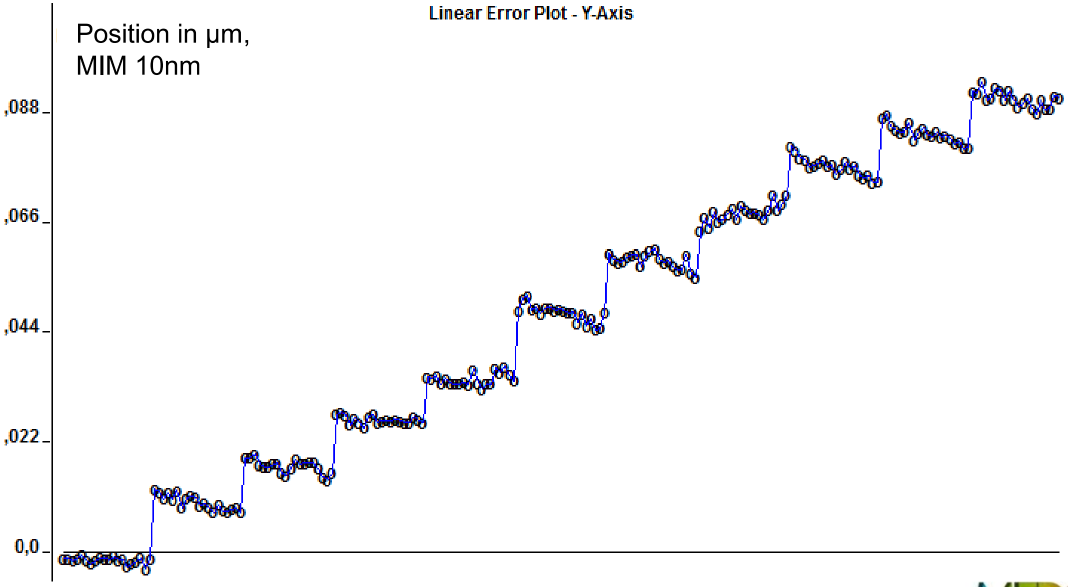


IV. DTy Linear stage – Metrology characterisation

DTy stage	PEL meas.	SPECS
Accuracy & repeat. full stroke	263 nm / R 50nm	3µm R4
Accuracy & repeat. stroke 100µm	66 nm / R 27nm	3µm R10nm
MIM positive or negative	6 nm	10 nm
Straightness **horiz.**. full stroke	37 nm / R 33nm	10 µm R1
Straightness **horiz.** stroke 100µm	22 nm /R 20nm	/
Straightness **vertic.** full stroke	212 nm / R 115 nm	10µm R1
Straightness **vertic.** Stroke 100µm	27 nm / R 27nm	/
Pitch error **Ryx** full stroke	2.9 µrad / R 0.39 µrad	5µrad R0.5
Yaw error **Ryz** full stroke	4.5 µrad / R 0.33 µrad	/
Roll error **Ryy** full stroke	1.23 µrad / R 0.93 µrad	/
Accuracy & repeat full stroke @ Height 50mm and without load	*47 nm / R 23nm*	/



Measurement near the POI H = 200 mm



V. CONCLUSION AND PERSPECTIVES

✓ An electrical slip-ring can pass sensitive signals

✓ The concept of integration used with the high precision rotary stage has no significant effect on the error motions

✓ A specific but simple linear stage can achieve a very high precision without any complex control systems

✓The RT150up stage can achieve very low motion errors

X The thermal drifts of the rotary stage are not only along the linear axes

X Improvements are possible :

- reduction of heat sources
- improvement of air-supplying distribution
- thermal control of the RT150up frame
- active compensation of error motions

END

Thank you for your attention

Any questions ?

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