

In-House design of the new Double Multilayer Monochromator (DMM) for beamline VMXi

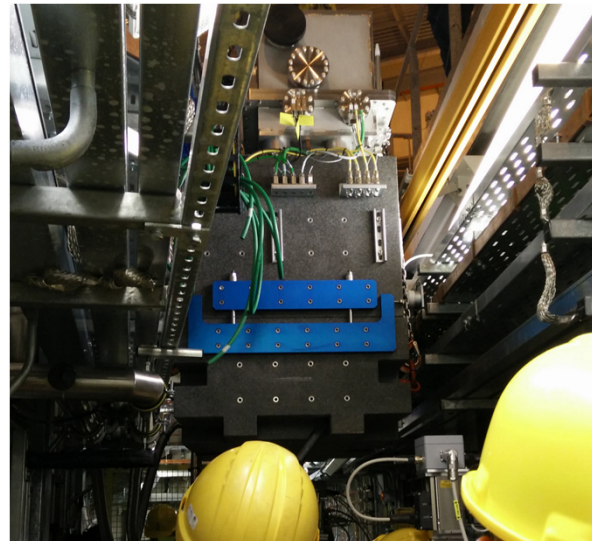
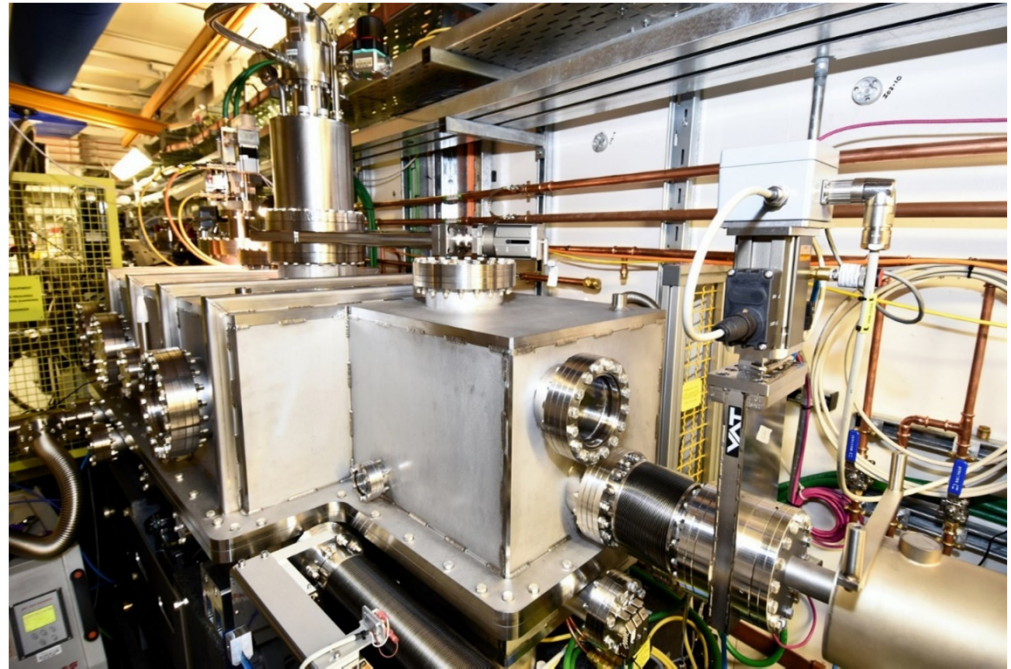
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16/09/16

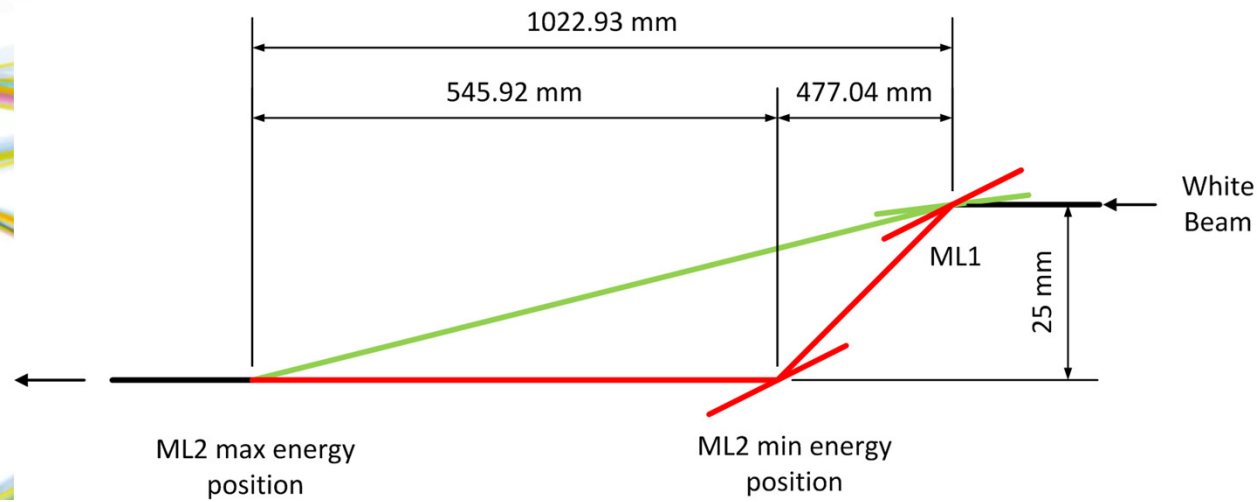
Talk outline

- DMM geometry
- Design specifics
 - Multilayers
 - 2x stripes
 - Pitch axes
 - PiezoMotor 20 mm stroke 1 nm resolution
 - Y and roll axes
 - Ex-vac stages, flexure coupling
 - Z-axis
 - Ex-vac actuator
 - No in-vac rolling hoses / cables
 - Re-entrant vessel
 - X-axis
 - Air bearing for multilayer stripe selection
 - Flexure coupling
- Performance Data
- Beam stability

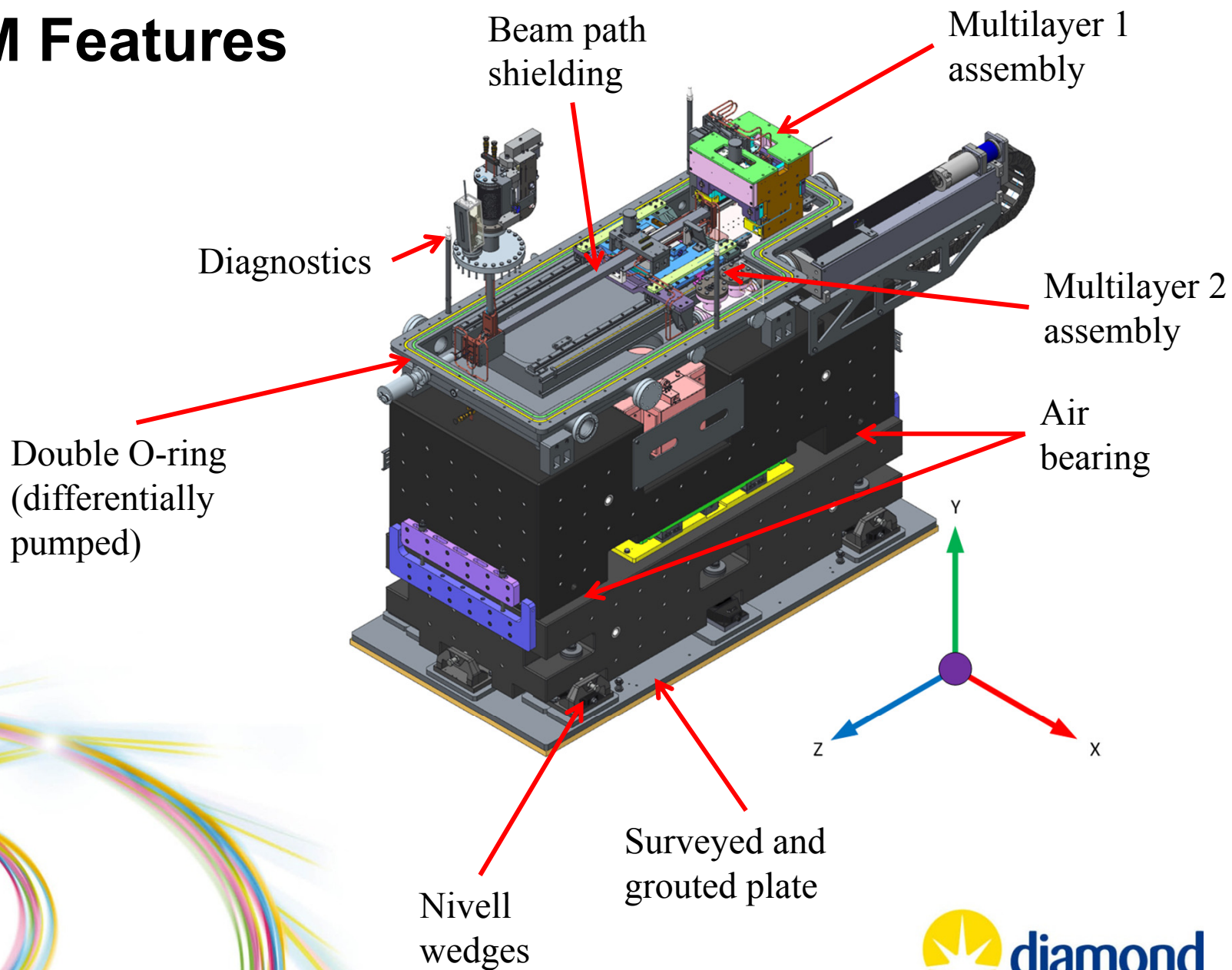


DMM Design

- Installed in Beamline I02 upgrade (VMXi)
- Diffraction occurs at shallow angles (less than 1.5 degrees)
 - Energy range 10 - 25 keV
- 2x man-made multilayer stripes on silicon substrate (2.0 nm and 2.4 nm)
- Broad energy band pass ~60x photos vs DCM
- Requires long travel of 2nd crystal (580 mm) susceptible to parasitic pitch, roll and yaw
- 25mm deflection geometry to maintain compatibility with existing DCM

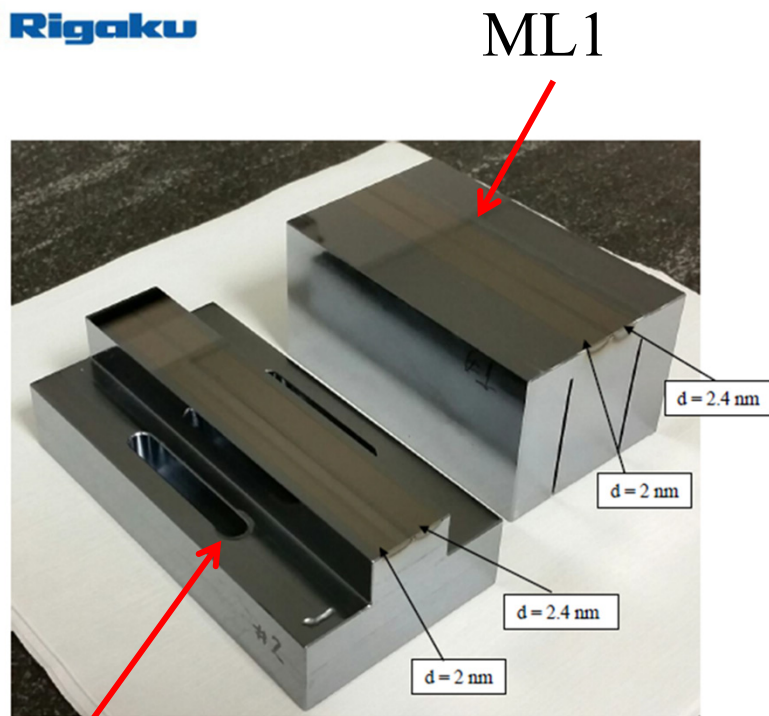


DMM Features



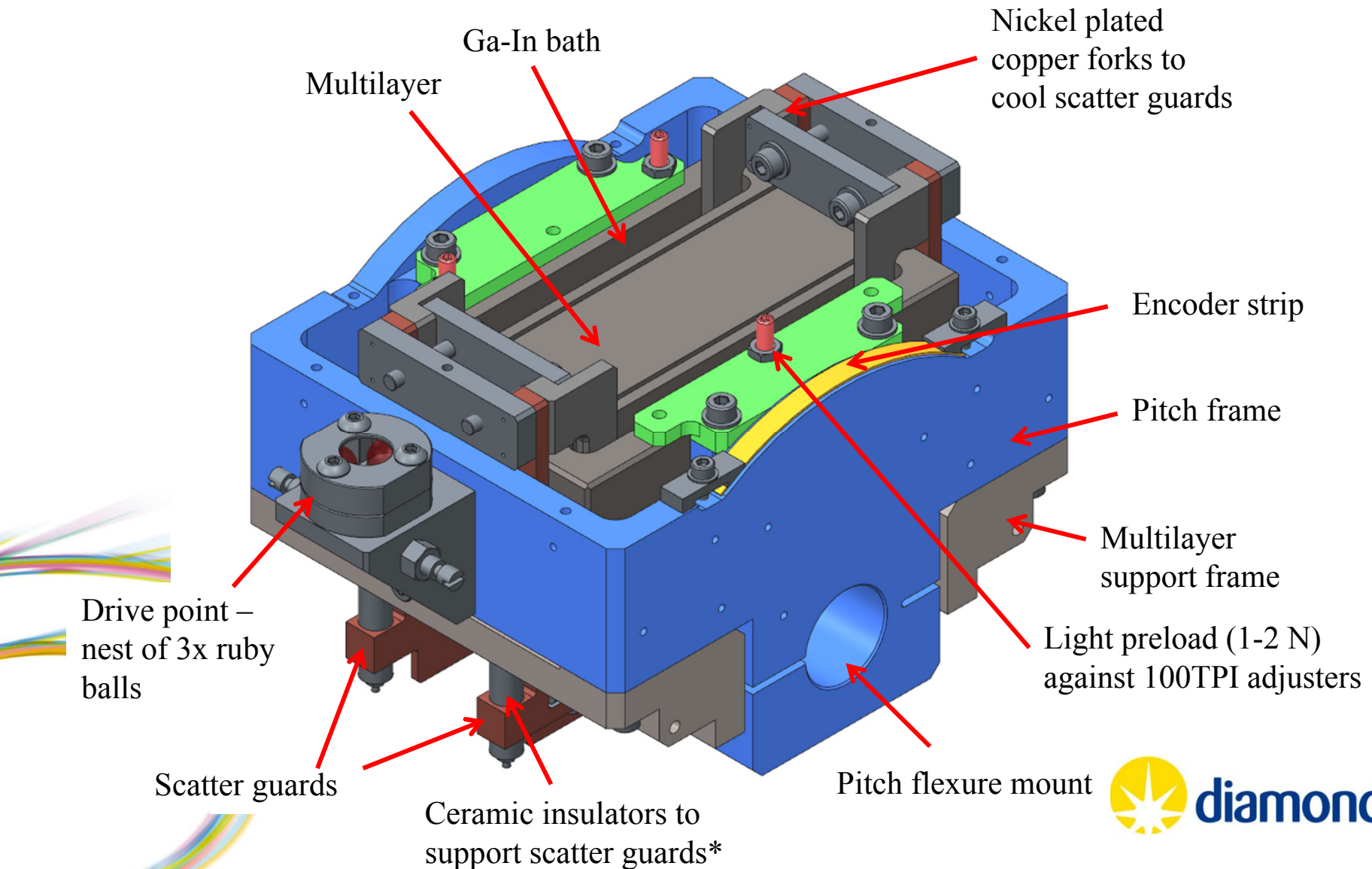
DMM specification and parameters

Incident design power (with CPMU upgrade, ring current @500mA)	~590W
Incident beam size	3.4 x 2.1 mm (max)
Deflection Geometry	25 mm down
Energy Range	10-25 keV
Beam stability (measured 1-350Hz)	34 nrad (RMS)

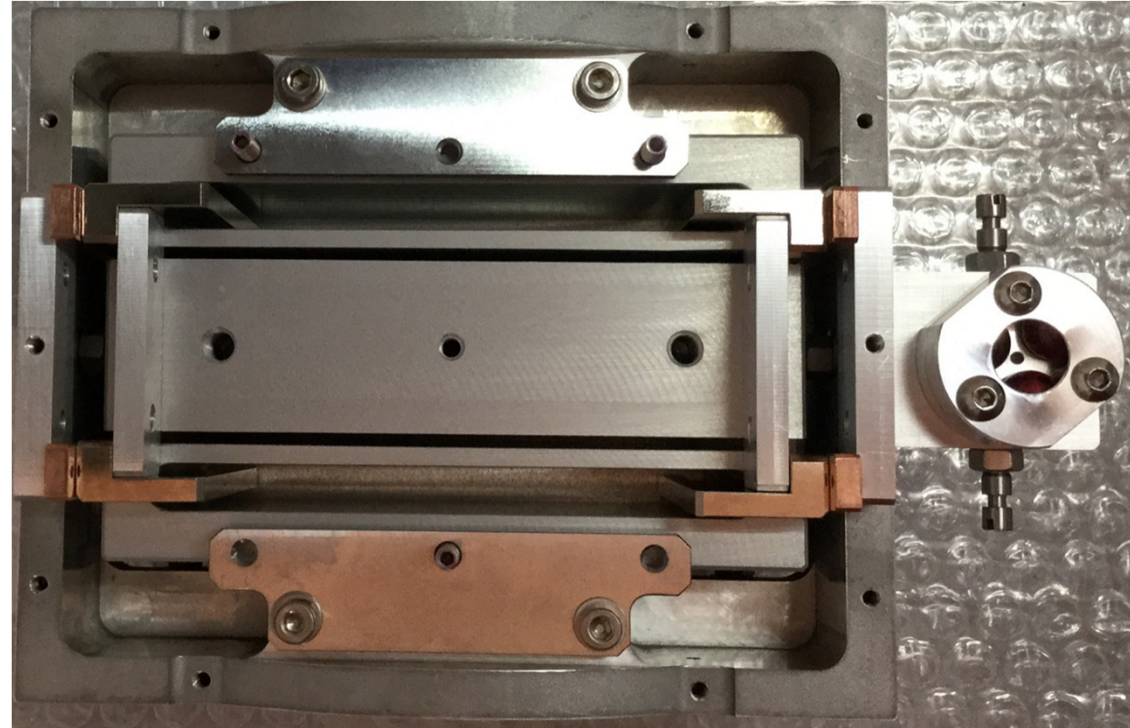
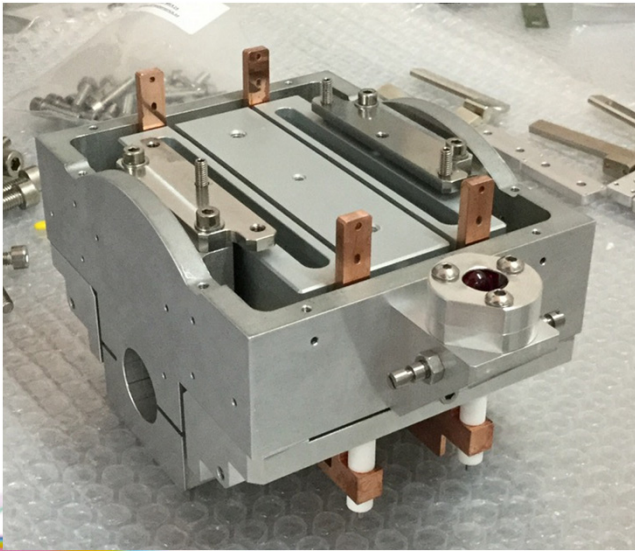


ML2

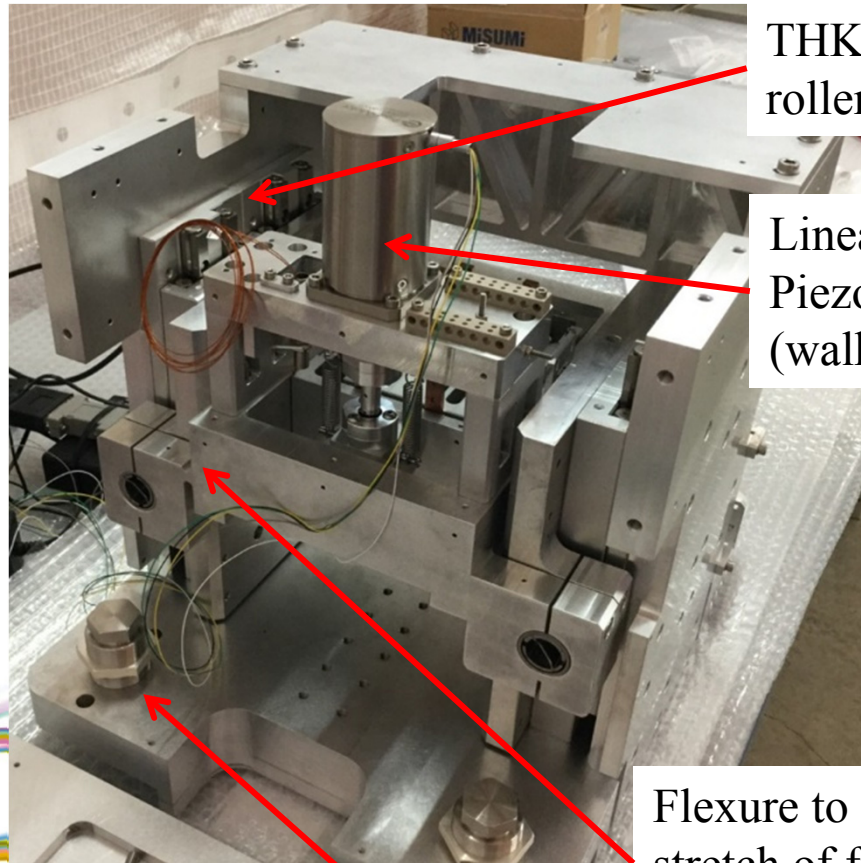
ML1 pitch assembly



ML1 pitch assembly



ML1 subassembly images

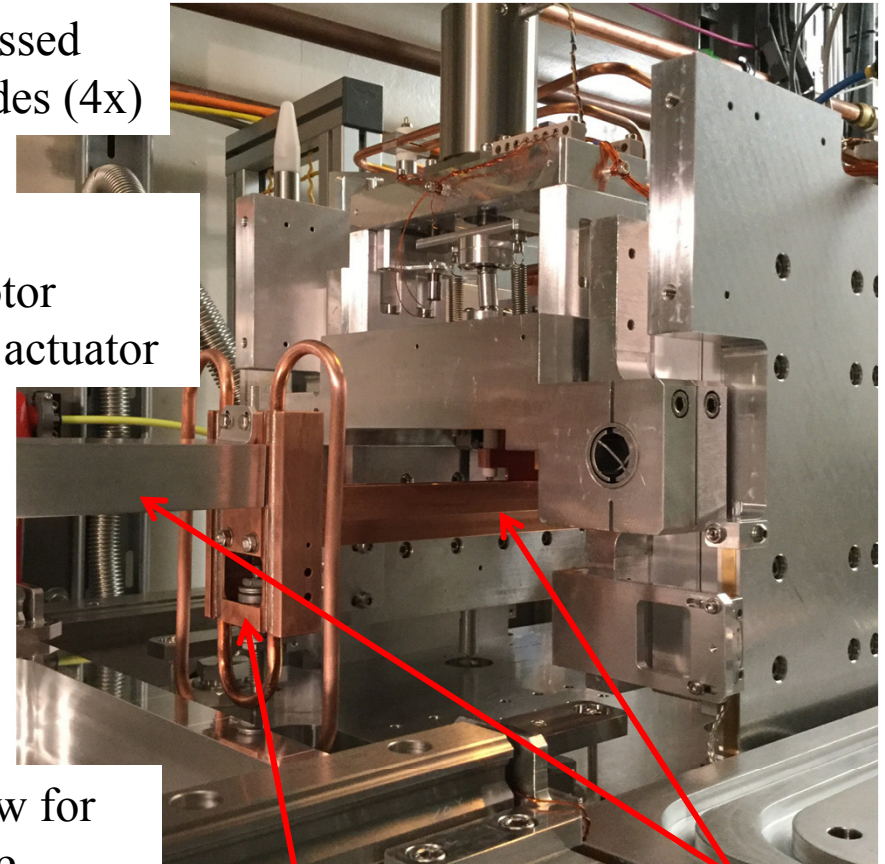


THK crossed
roller slides (4x)

Linear
PiezoMotor
(walker) actuator

Flexure to allow for
stretch of frame
during roll motion

Fine-thread (M32x0.75)
adjusters



Water
cooled mask

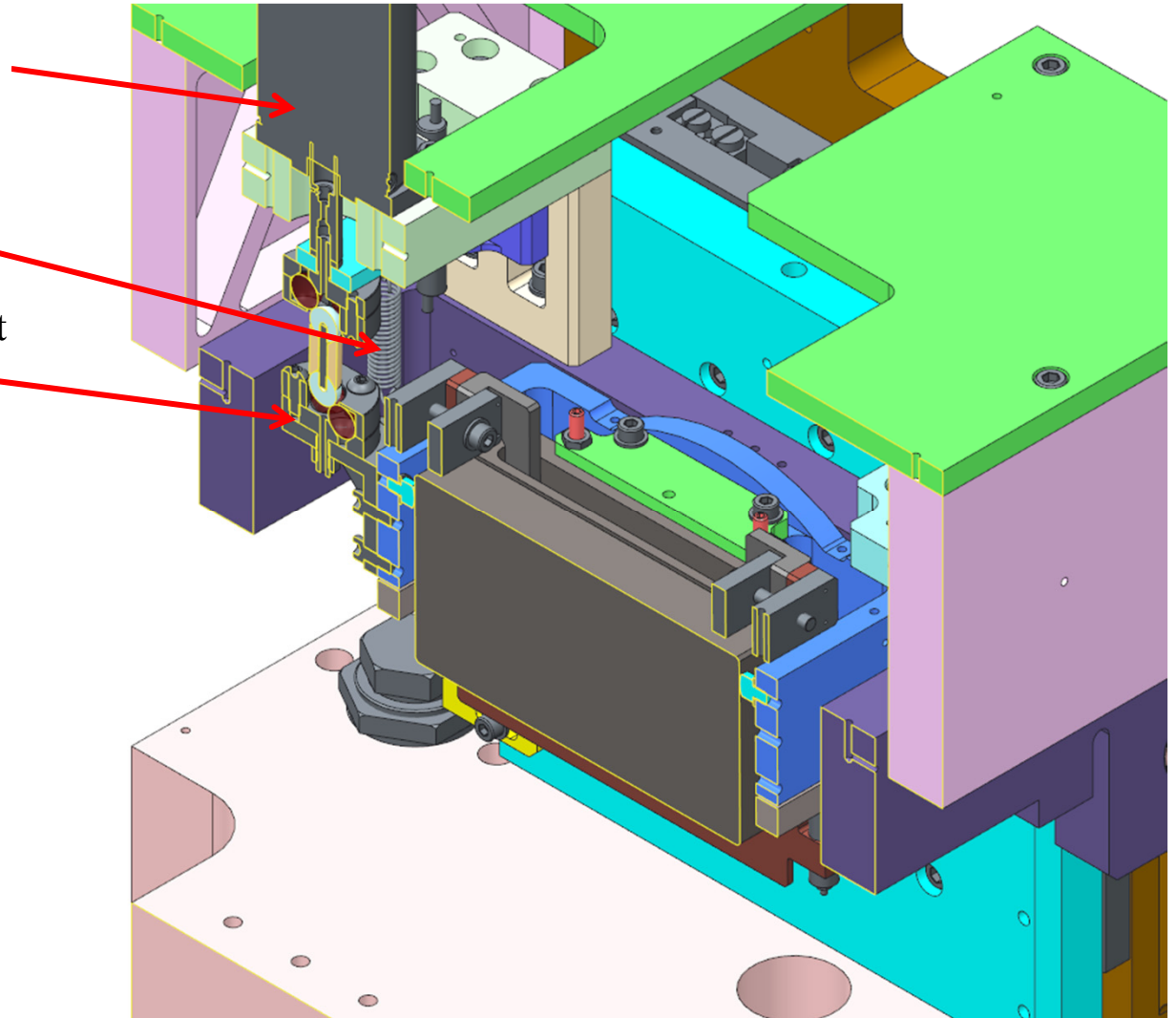
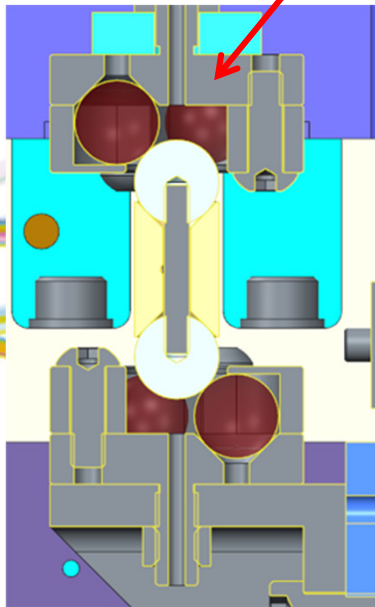
Beam path
shielding

Pitch (Bragg) axes

PiezoLegs 300L actuator (20 mm travel, 3 μm full step, < 1 nm resolution)

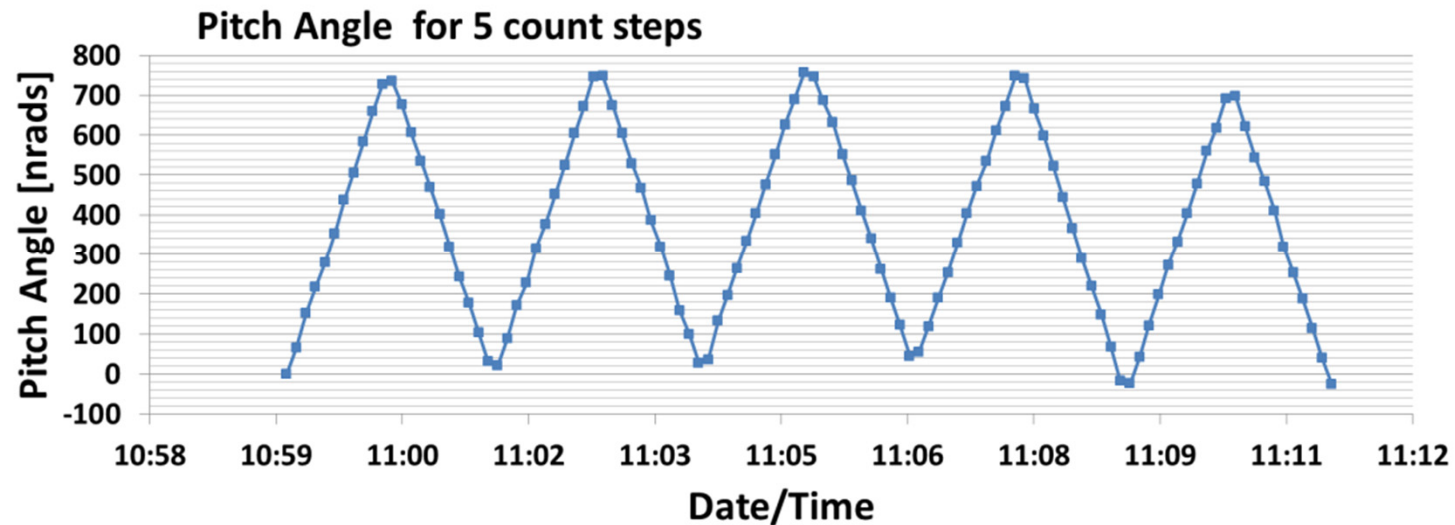
Spring preload

Stainless balls pushing on nest of 3x ruby balls

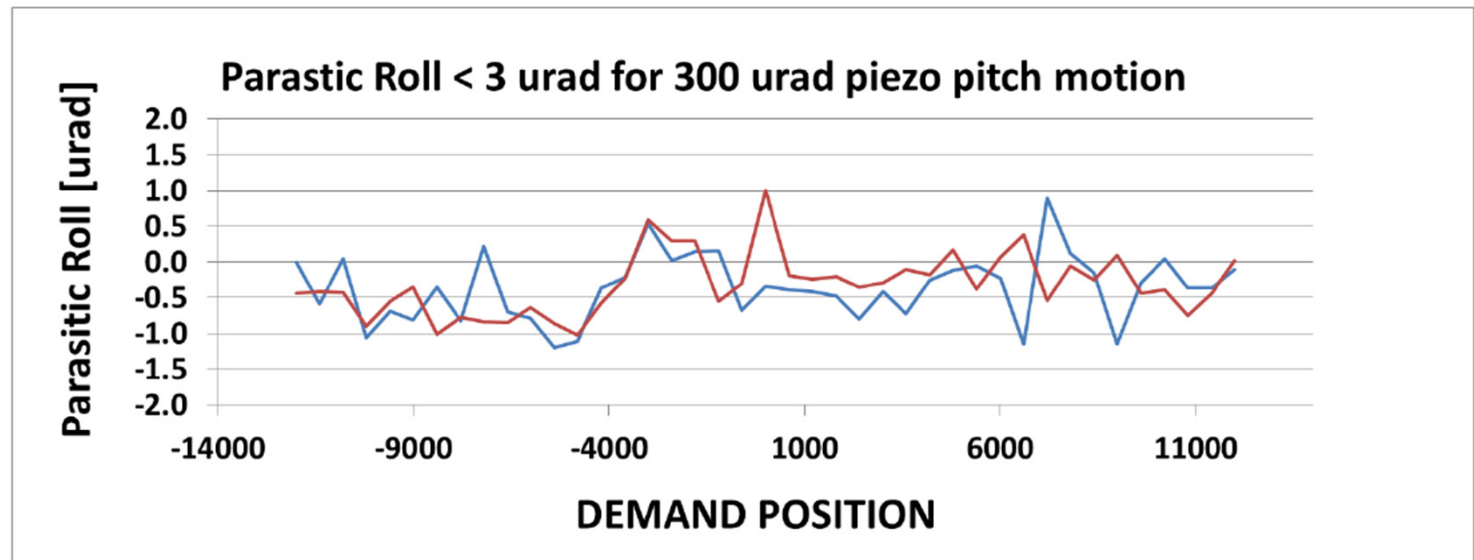
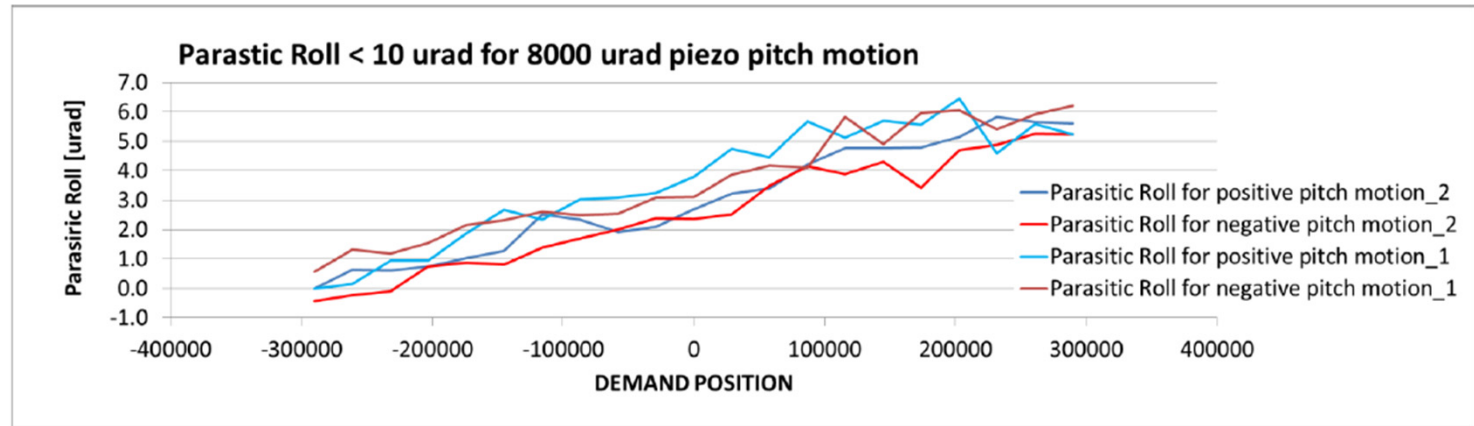


ML1 Pitch performance

Range	-0.5 to +1.5°
Resolution	< 0.1 μ rad
Bidirectional repeatability	< 5 μ rad
Accuracy	< 3 μ rad / 8 mrad

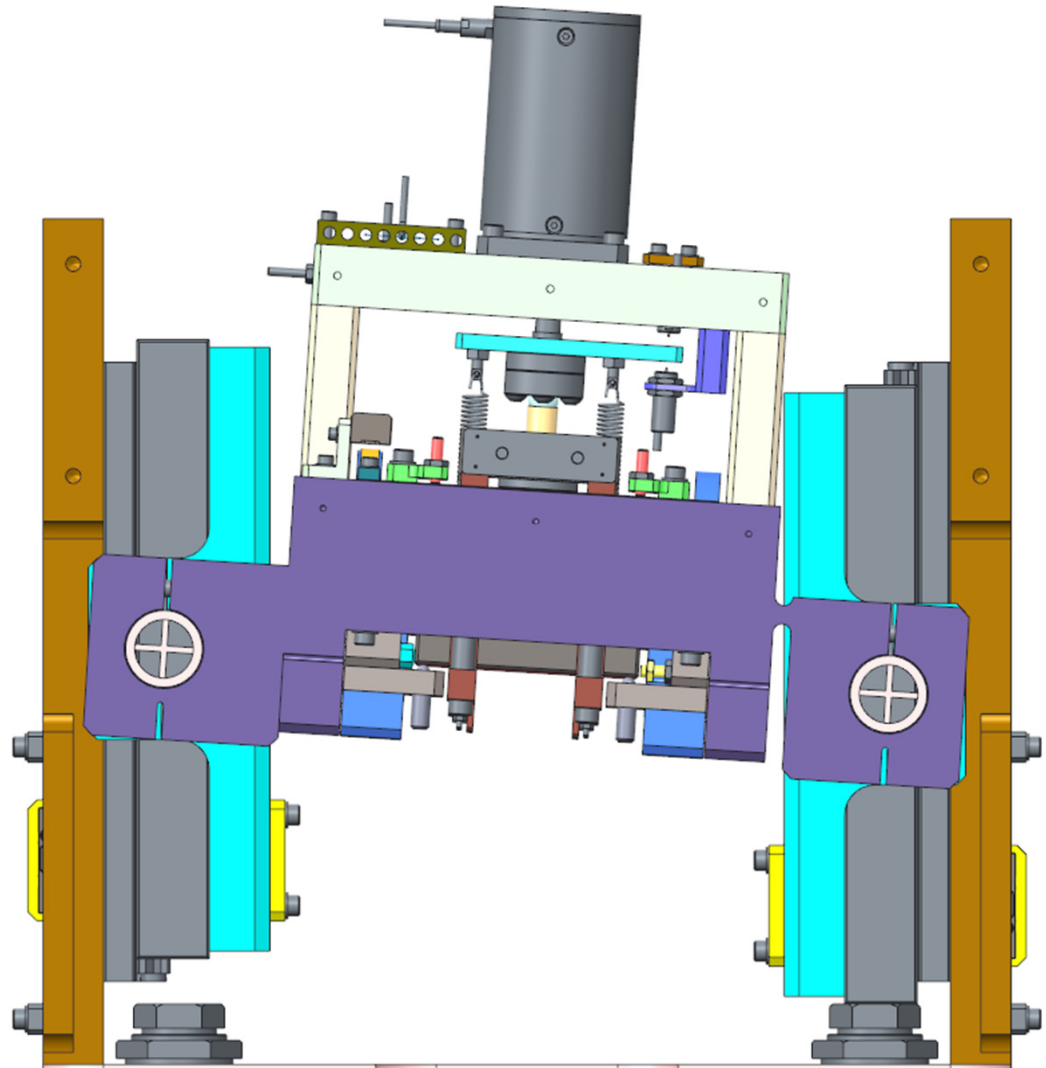


ML1 parasitic roll (A.Bugnar)



ML1 Y and roll

- Huber stages ex-vacuum (15mm stroke)
 - Drive together for height (Y-axis)
 - Drive differentially for roll (about Z-axis)
- Driven through slender flexure rods to minimise coupled moments
- 4x THK VRU4025 Cross roller tables acting in parallel for the slides
 - Parallelism of slides <1um
- Machined flexure in ML1 roll frame to allow for stretch
- Repeatable parasitic roll



ML1 partial cross section

THK crossed
roller tables

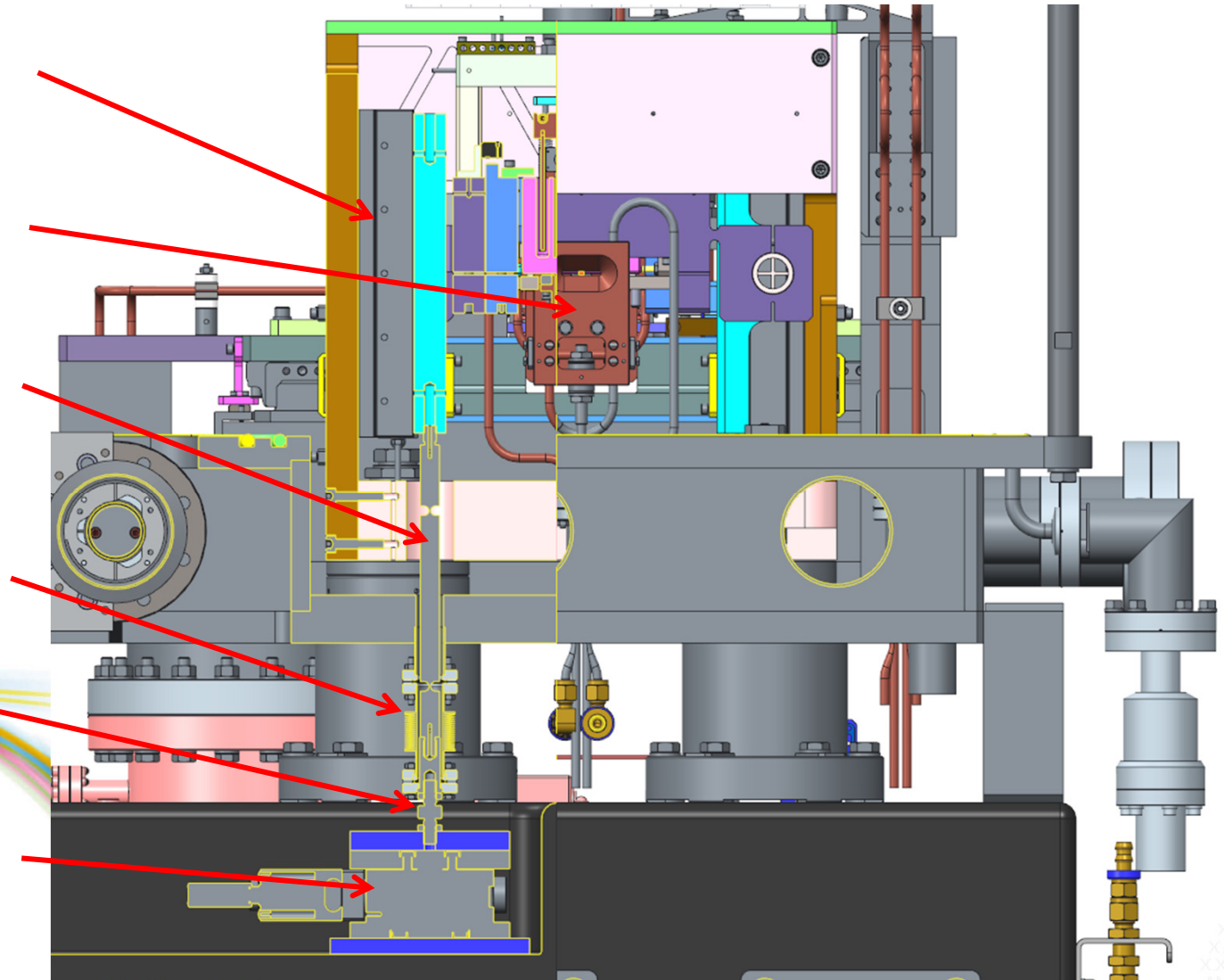
Water-cooled
entry mask

Flexure drive
rod

Edge-welded
Bellows

Turnbuckle

Huber
5103.A10-X1
stage



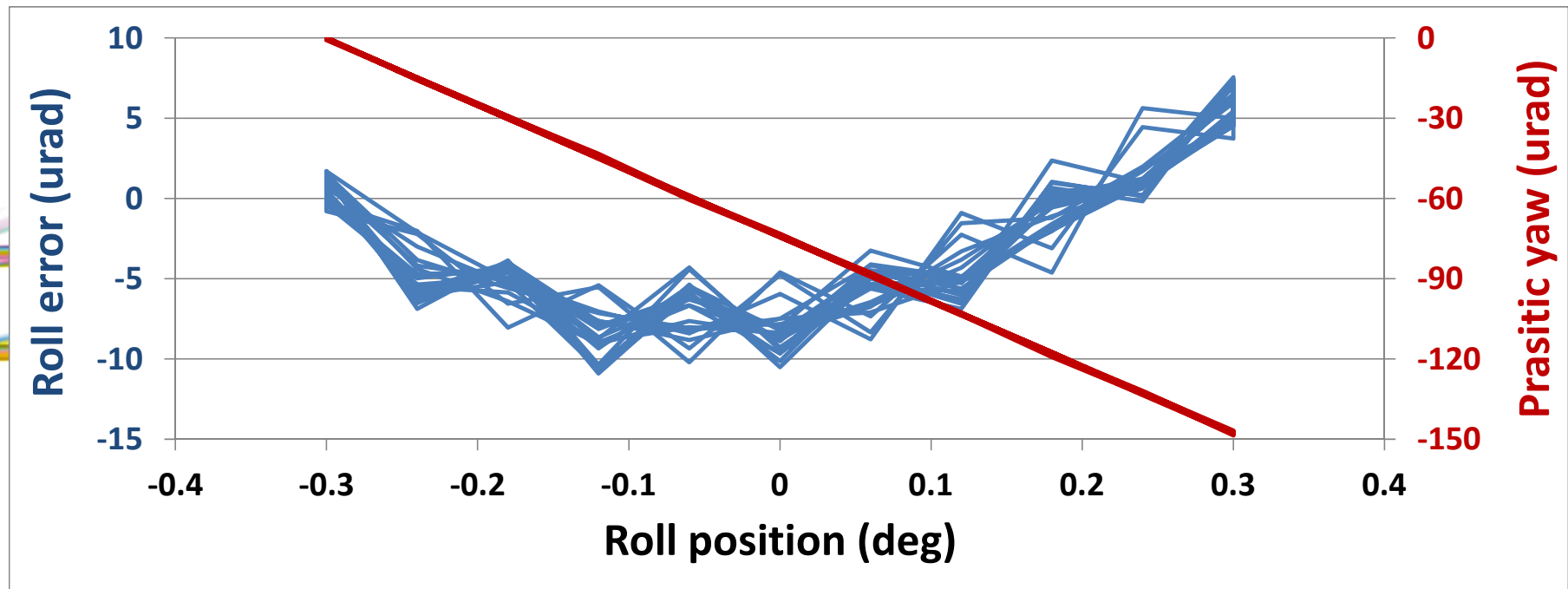
ML1 Y-axis and roll-axis performance (A.Bugnar)

ML1 Y-axis performance

Range	+5 mm – 7 mm
Resolution	0.25 μm
Bidirectional repeatability	1 μm / 0.7 mm
Parasitic pitch	50 μm / 0.7 mm

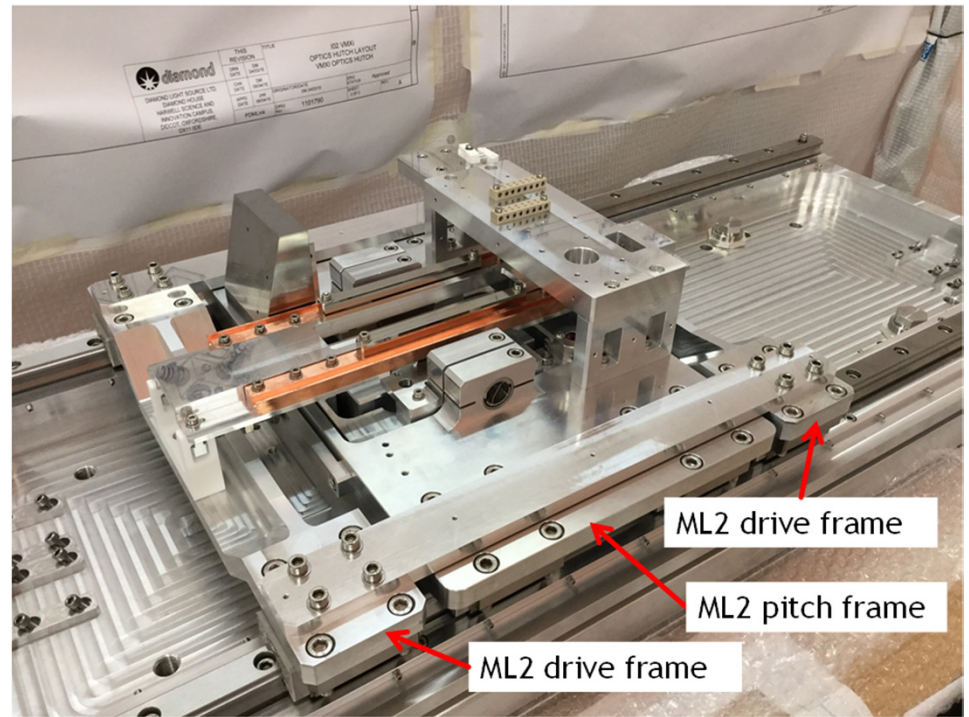
Roll-axis performance

Range	$\pm 0.5^\circ$
Resolution	1 μrad
Bidirectional repeatability	5.7 μrad
Parasitic pitch	175 / over 2°
Parasitic yaw	150 / over 2°



ML2 assembly

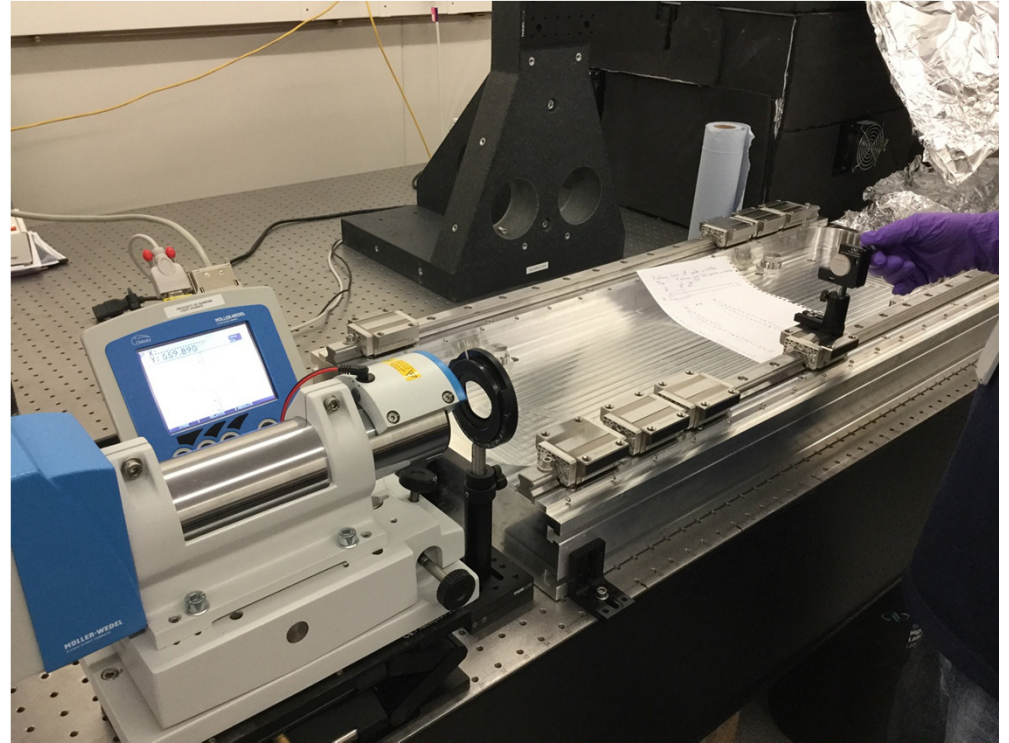
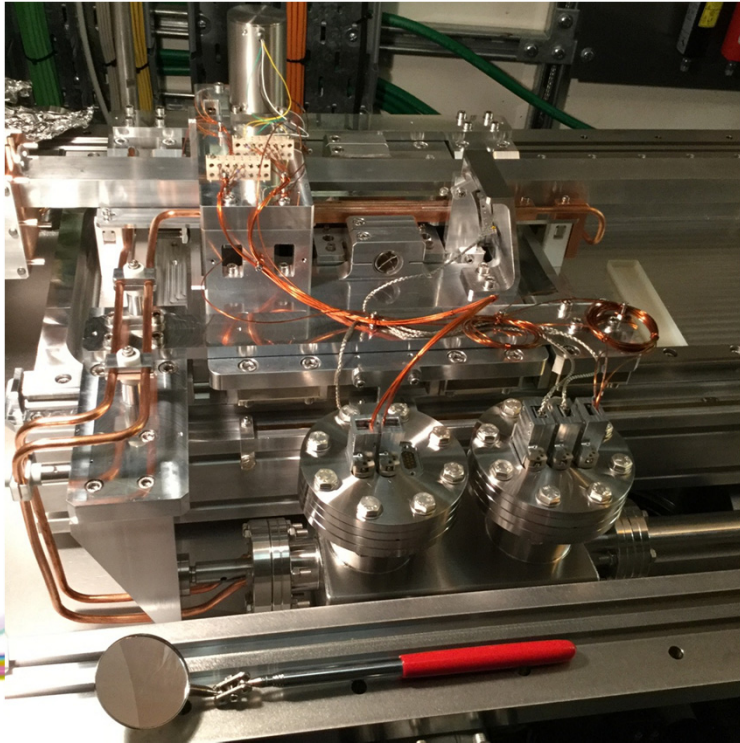
- Driven via external actuator (UHV design linear shift)
 - No internal rolling cables
 - Force reactions outside of ML2 assembly
- Rails aligned using autocollimator to better than $30\ \mu\text{rad}$
- Drive frame driven off-axis
- Pitch frame driven on-axis via balls on flats



ML2 Z-axis performance

Range	580 mm
Resolution	$2\ \mu\text{m}$
Bidirectional repeatability	$64.8\ \mu\text{m}$ (no vacuum loads)
Parasitic pitch	$110\ \mu\text{rad}$
Parasitic yaw	$20\ \mu\text{rad}$
Speed	100 mm/s

ML2 assembly



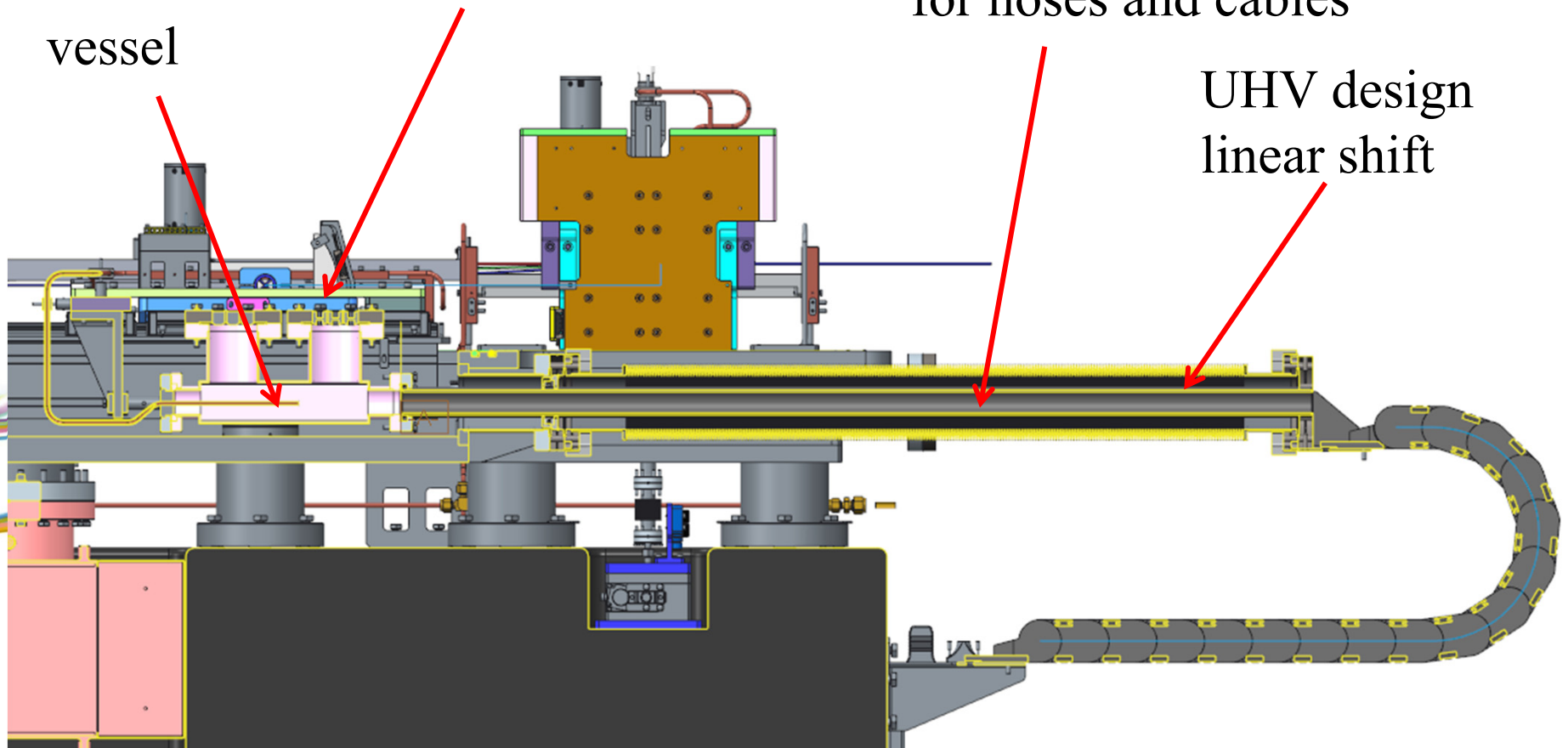
ML2 Drive cross section

Re-entrant
vessel

No rolling cables or
hoses in vacuum

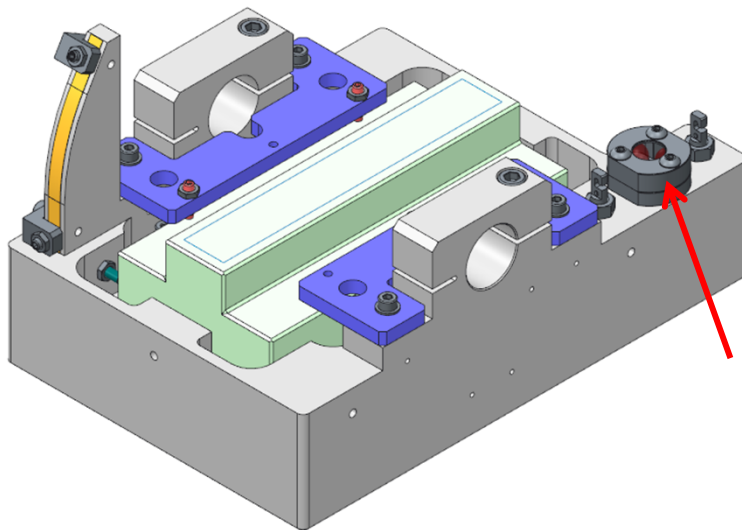
Air path into vessel
for hoses and cables

UHV design
linear shift



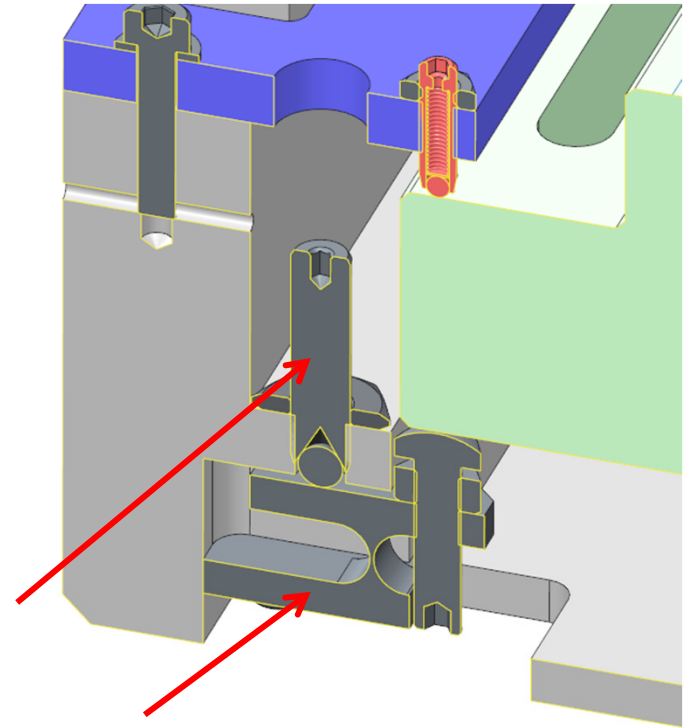
ML2 Pitch Frame

- Access underneath not practical
- Flexure mechanism to adjust roll and height from above
- Drive point asymmetry required to avoid beam



Nest of 3x
ruby balls

100 TPI
adjuster



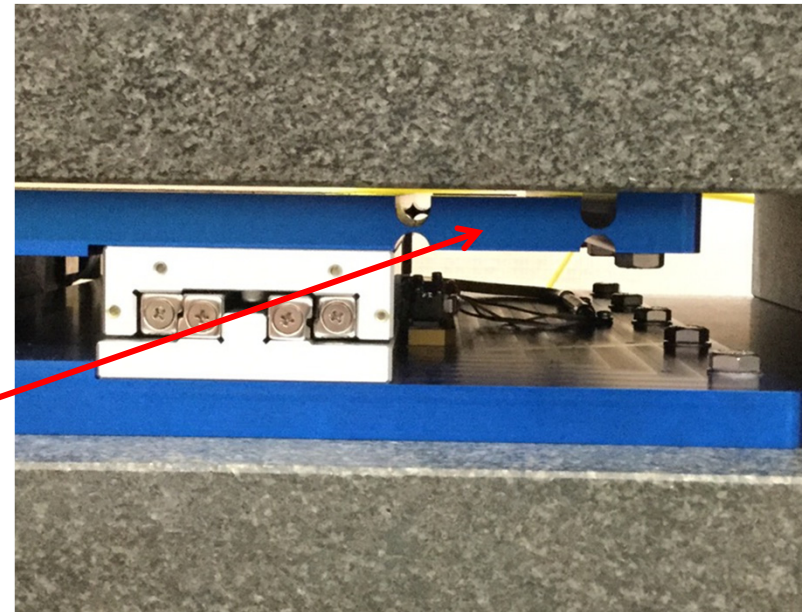
Flexure for
multilayer height
adjustment

X-Axis

- Select stripes of multilayers
- Air bearing (FFD design) for main vertical loads
 - When air removed solid granite-on-granite
- In-house designed actuator
 - 4x large, short-stroke THK cross roller slides
 - THK KR unit provides drive
 - Over constrained but precision machining / careful assembly
- Flexure to allow air bearing lift ($\sim 25\text{ }\mu\text{m}$) but good yaw and pitch resistance

X-axis performance

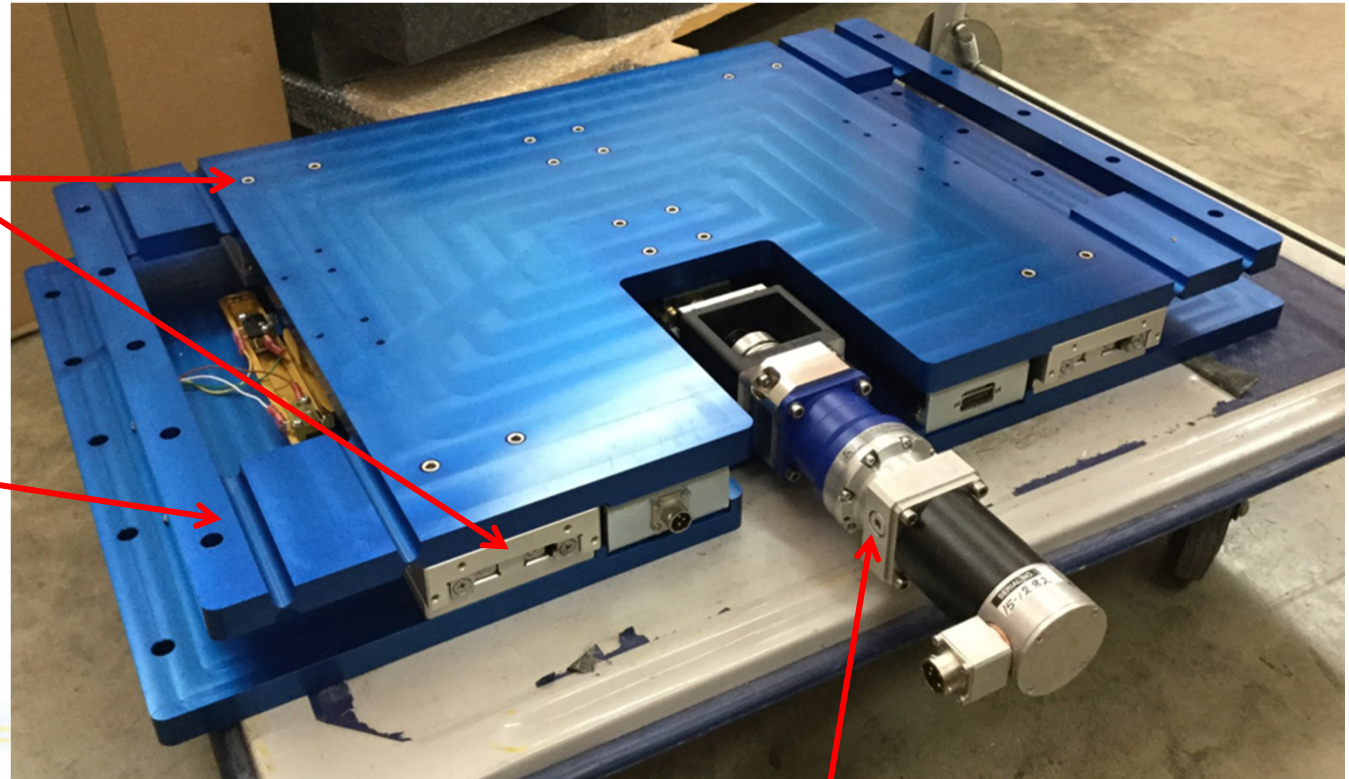
Range	$\pm 15\text{ mm}$
Bidirectional repeatability	$4.5\text{ }\mu\text{m}$
Parasitic pitch	$5\text{ }\mu\text{rad}$
Parasitic roll	$8\text{ }\mu\text{rad}$
Parasitic yaw	$30\text{ }\mu\text{rad}$



X-Axis

THK Crossed
roller tables
(VRU 6110)

Flexure to allow air
bearing lift



THK KR actuator
Wittenstein low backlash gearbox
Stepper motor
5 mm/s

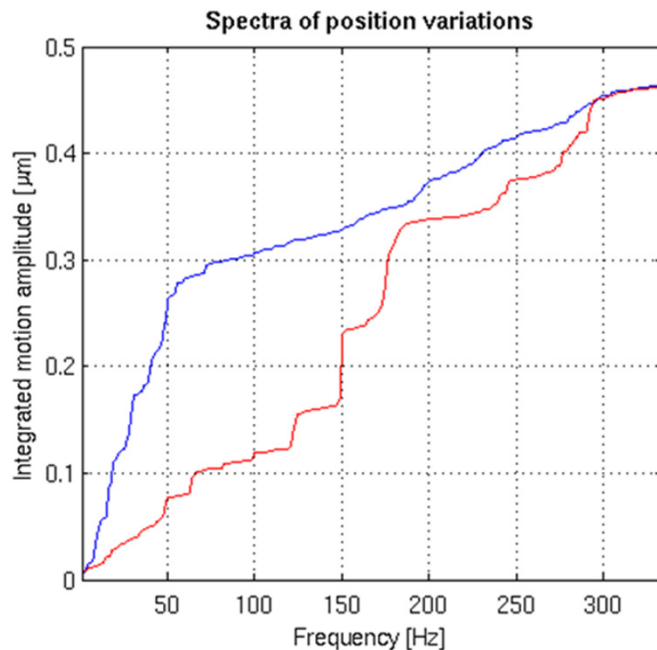
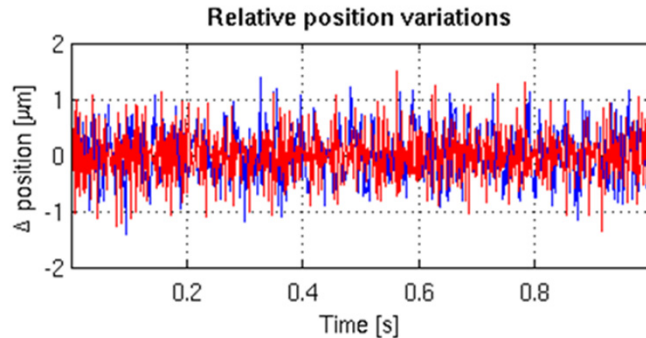


DMM axes performance figures

Parameter	Specification	Measured	Comments
Repeatability of ML1 Y	1 μm over 0.7 mm	0.2 μm	
Parasitic pitch of ML1 Y	50 μrad over 0.7 mm	4 μrad	
Repeatability of ML1 roll	5 μrad over 6 deg	5.7 μrad	Outside specs but still ok
Parasitic yaw of ML1 roll	Not given	150 μrad	
Parasitic pitch of ML1 roll	175 μrad over 2 deg	140 μrad	
Parasitic pitch of ML2 Z	100 μrad over 550 mm	110 μrad	Outside specs but still ok
Parasitic yaw of ML2 Z	200 μrad over 550 mm	20 μrad	
Repeatability of ML2 Z	20 μm over 550 mm	64.8 μm	No vacuum loads
Repeatability of X	100 μm over 30 mm	4.5 μm	
Parasitic pitch of X	100 μrad over 30 mm	5 μrad	
Parasitic yaw of X	Not given	30 μrad	
Parasitic roll of X	100 μrad over 30 mm	8 μrad	

Beam stability 13.5 m from ML1

— Horiz.
— Vert.



Captured on 700Hz fast X-ray camera

← ~0.46 μm

$$\frac{0.46 \mu m}{13.5 m} = 34 \text{ nrad RMS}$$

Beam stability 34 nrad 1-350Hz

Thank you for your time

- Questions?

Acknowledgements to the team

- Dr Jon Kelly (senior mechanical project engineer)
- Dr Alex Bugnar (Diamond precision metrology lab)
- David Butler, Mark Lunnon, Adam Prescott (technicians)
- Brian Nutter, Trevor Bates (controls engineers)