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

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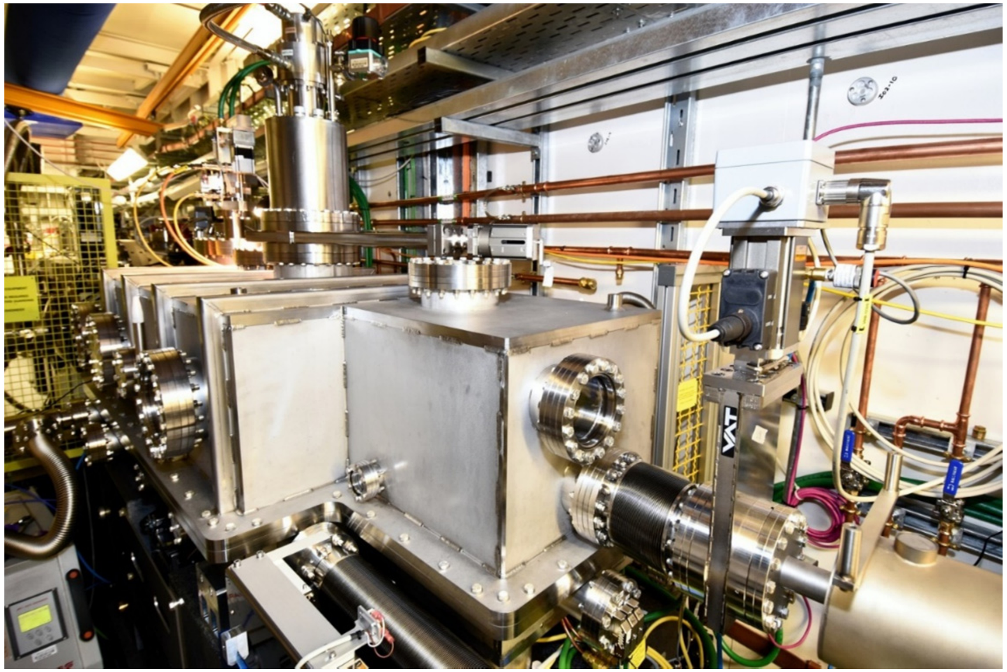
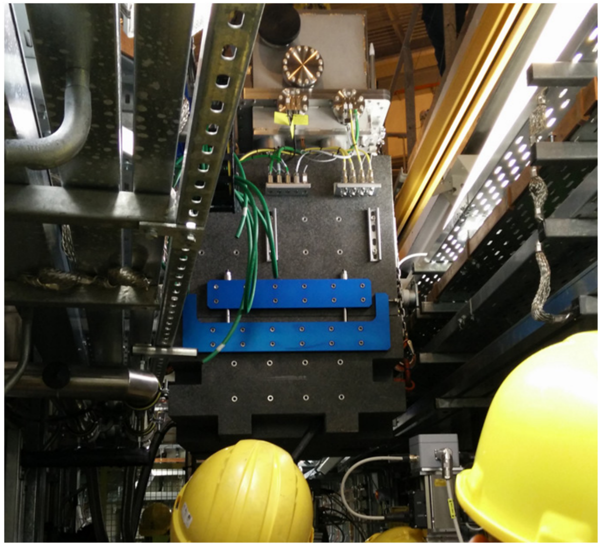
16/09/16

Talk outline

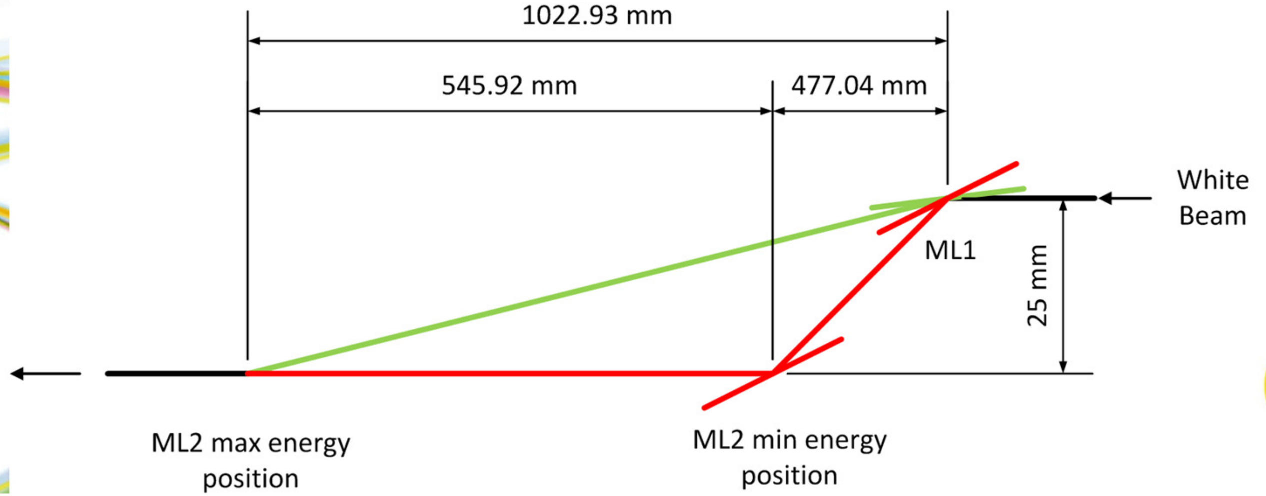
- DMM geometry
- Design specifics
  - Multilayers
    - 2x stripes
  - Pitch axes
    - PiezoMotor 20 mm stroke 1 nm resolution
  - Y and roll axes
    - Ex-vac stages, flexure coupling
  - Z-axis
    - Ex-vac actuator
    - No in-vac rolling hoses / cables
    - Re-entrant vessel
  - X-axis
    - Air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



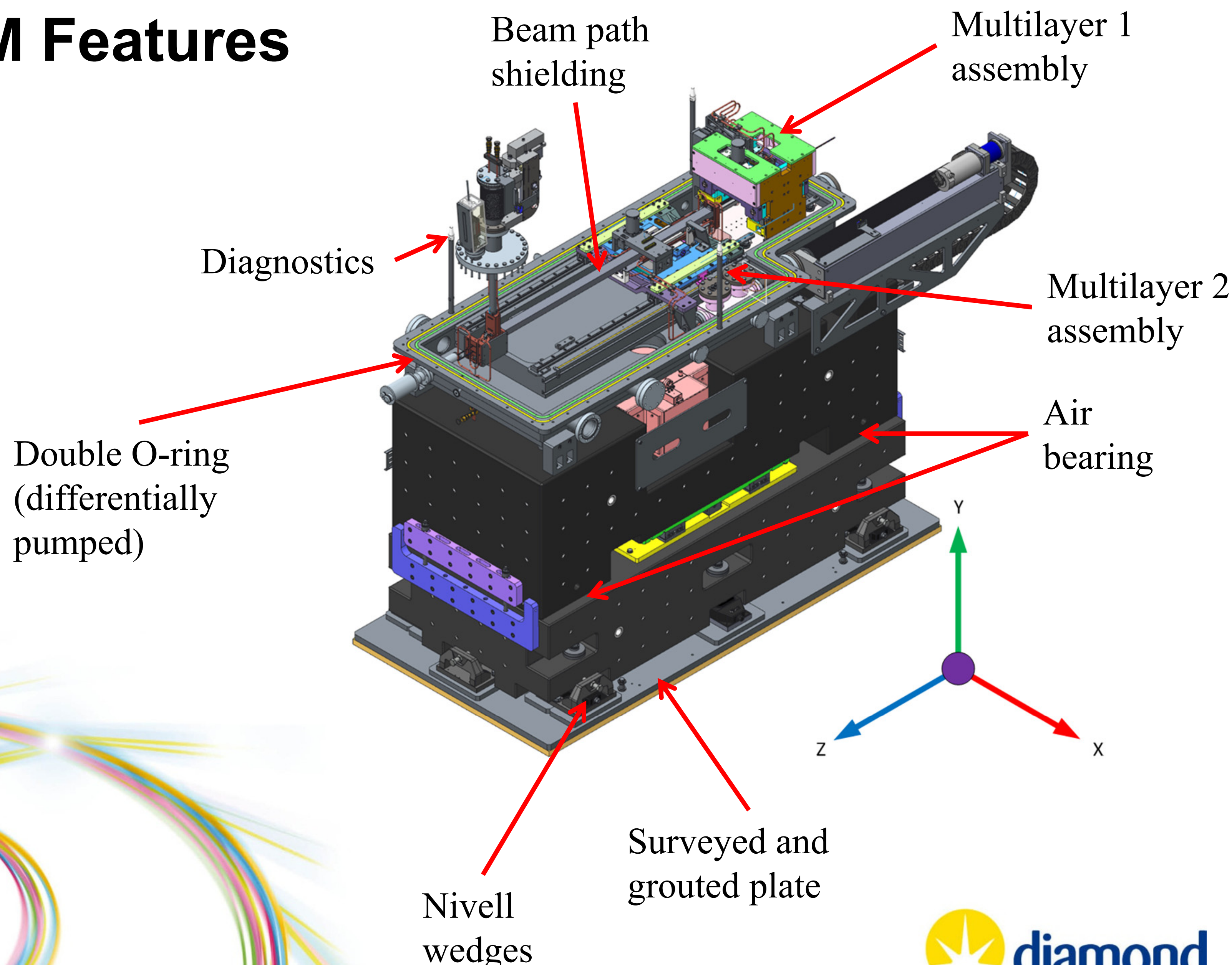


DMM Design

- 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



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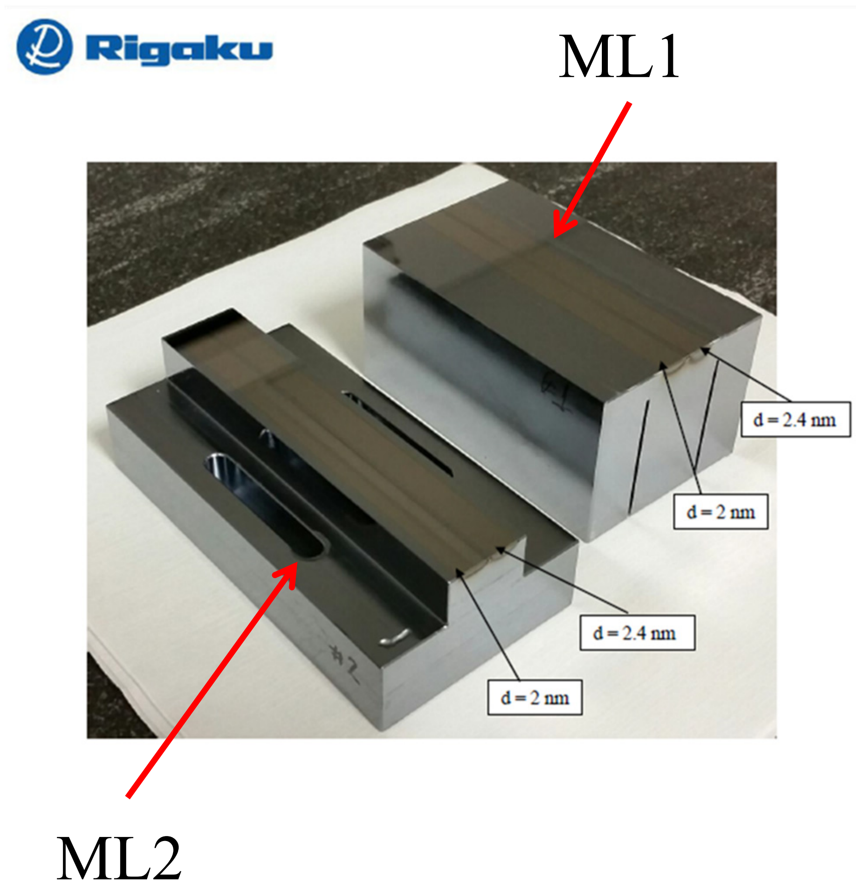
DMM specification and parameters

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)



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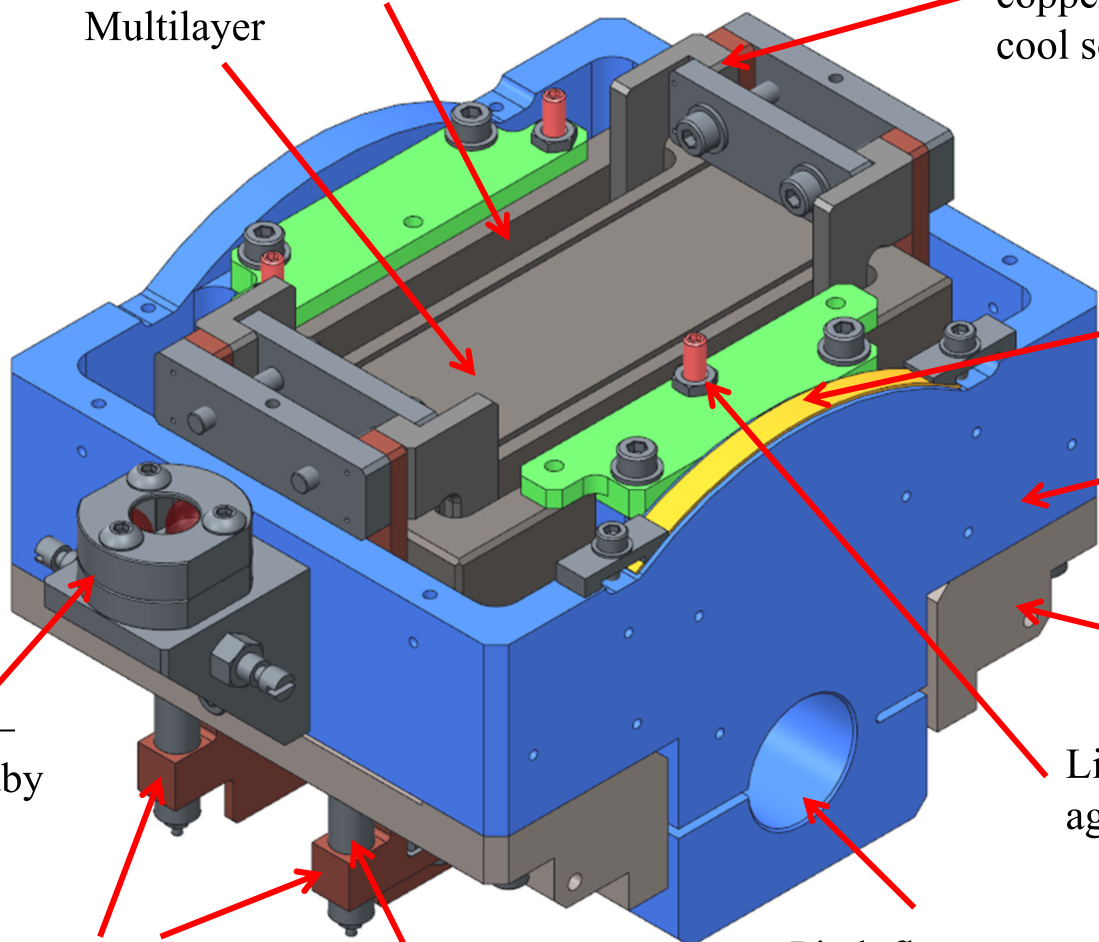
ML1 pitch assembly



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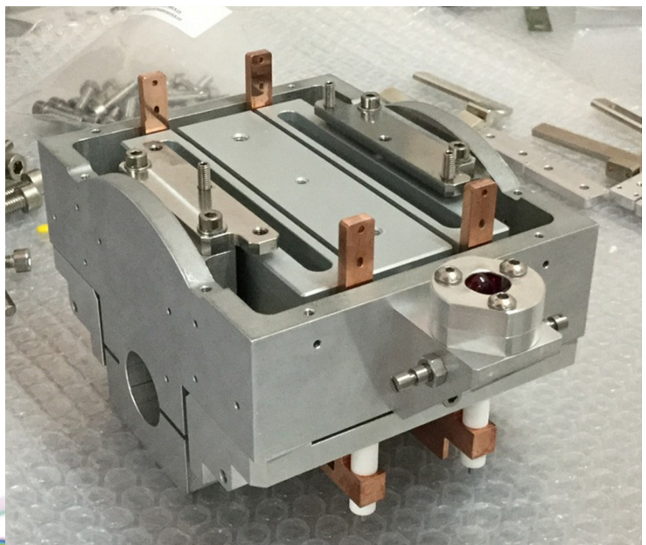
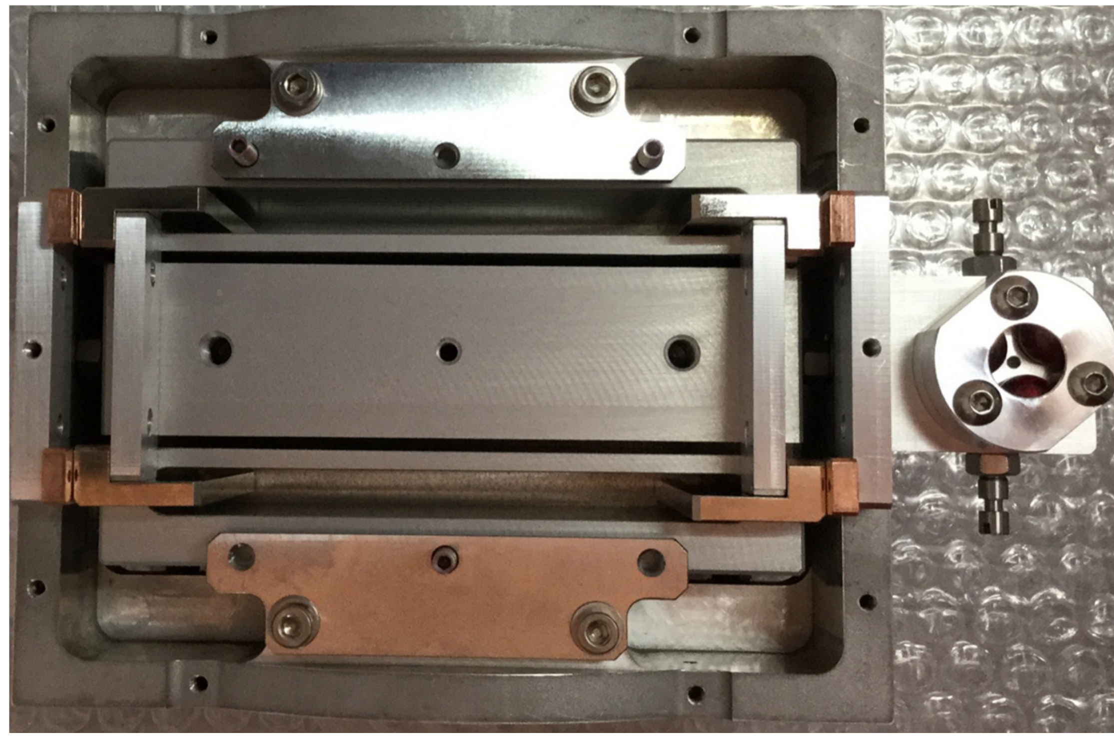
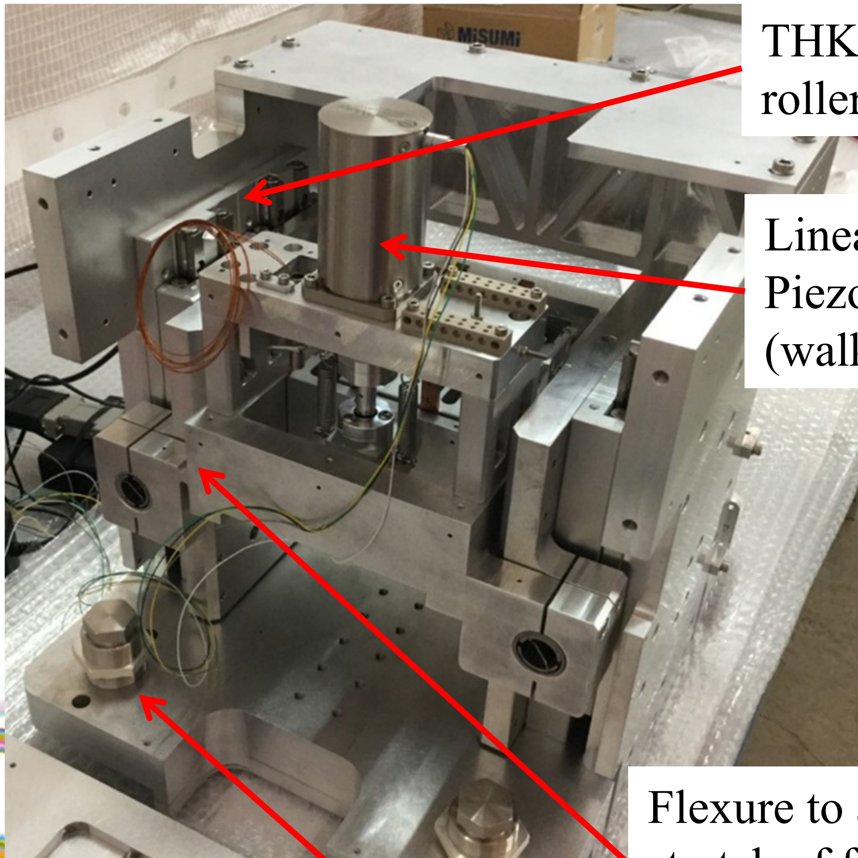
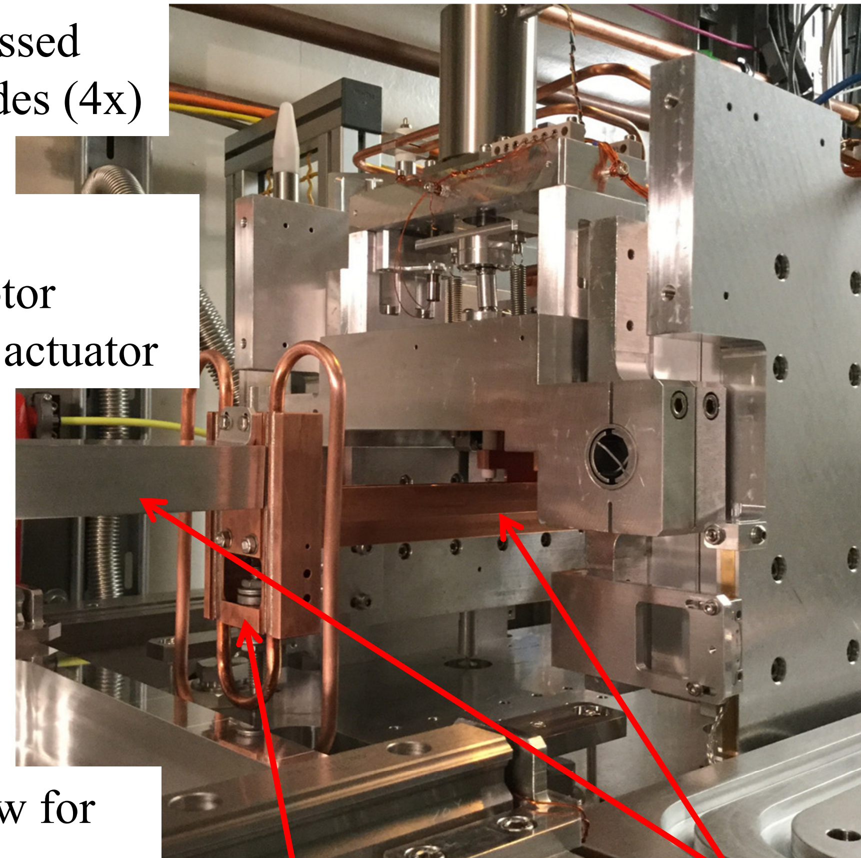
ML1 pitch assembly





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

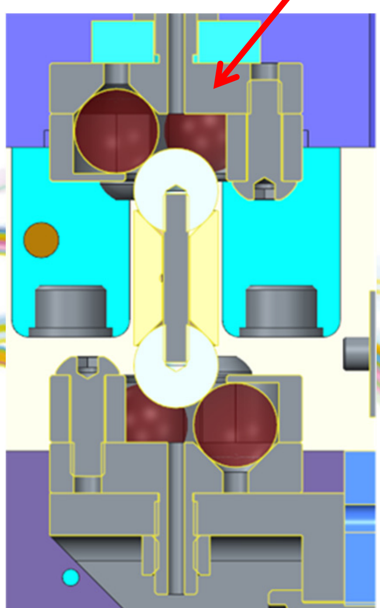
Beam path shielding

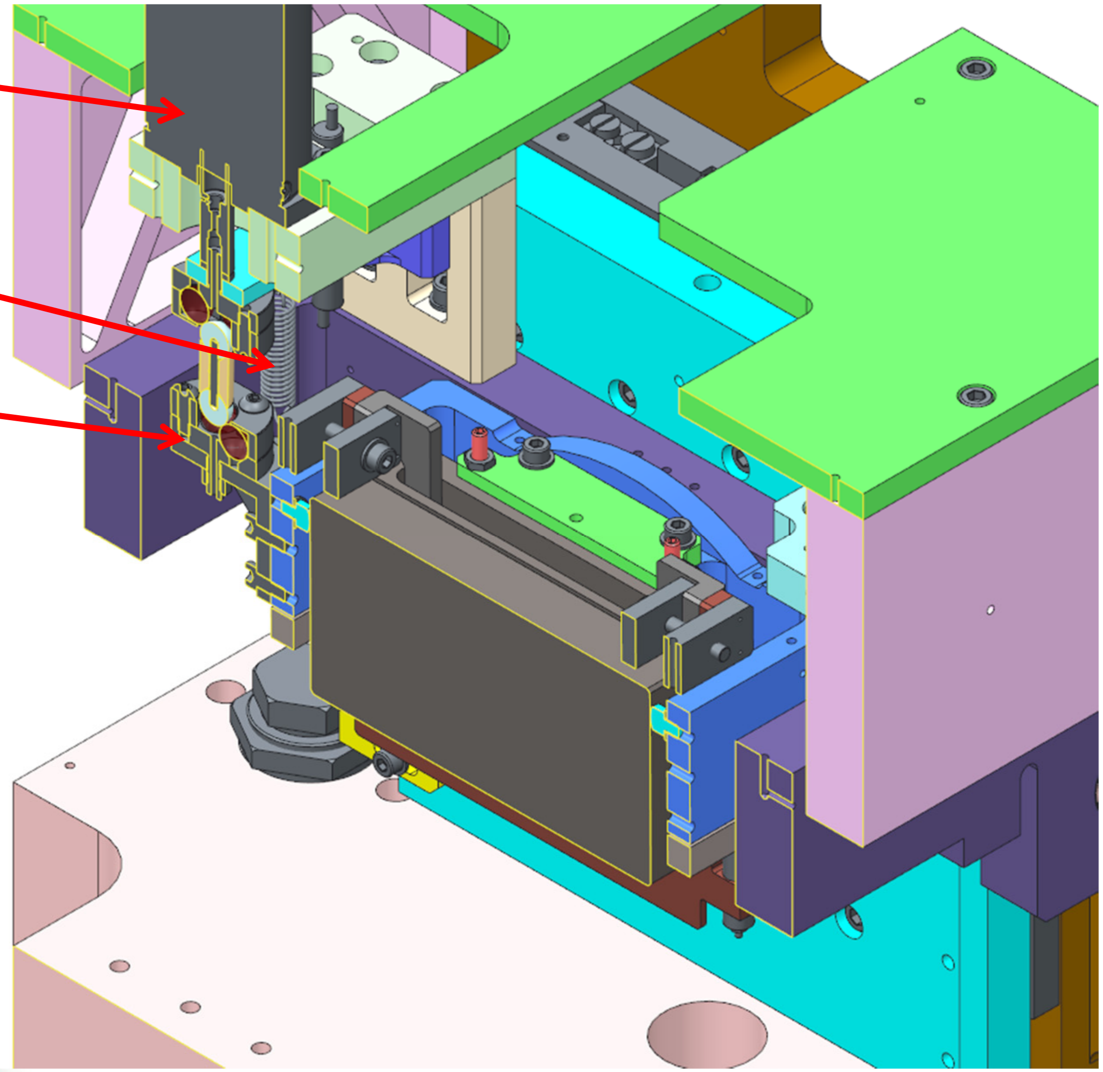
Pitch (Bragg) axes

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

Spring preload

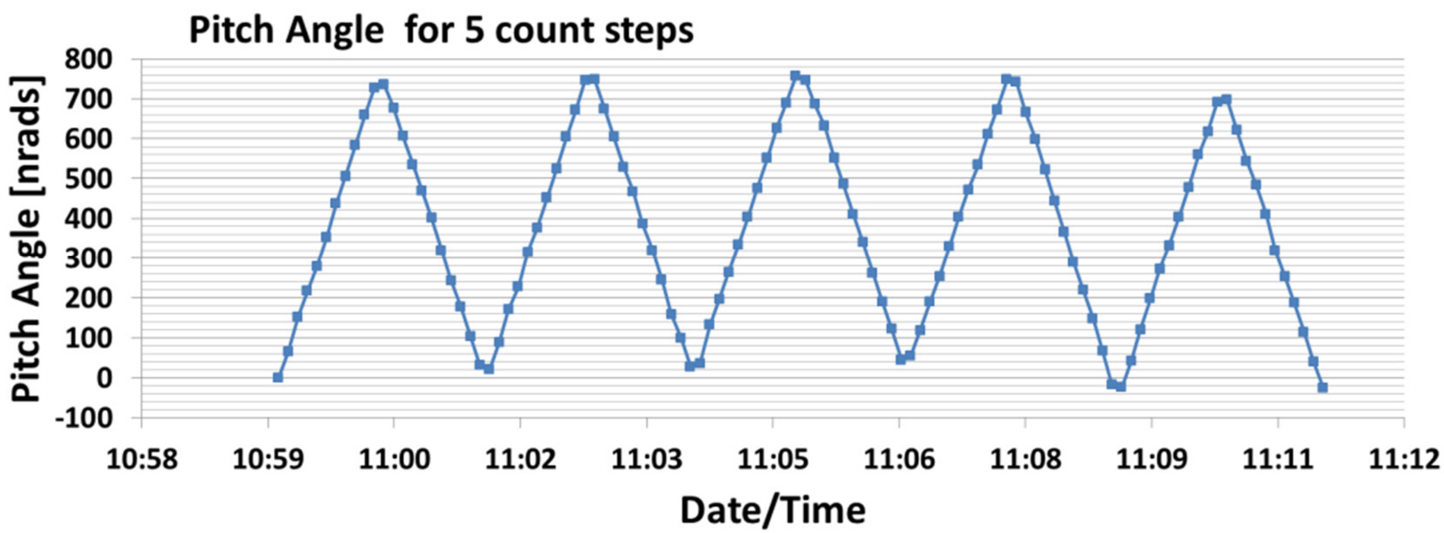
Stainless balls pushing on nest of 3x ruby balls



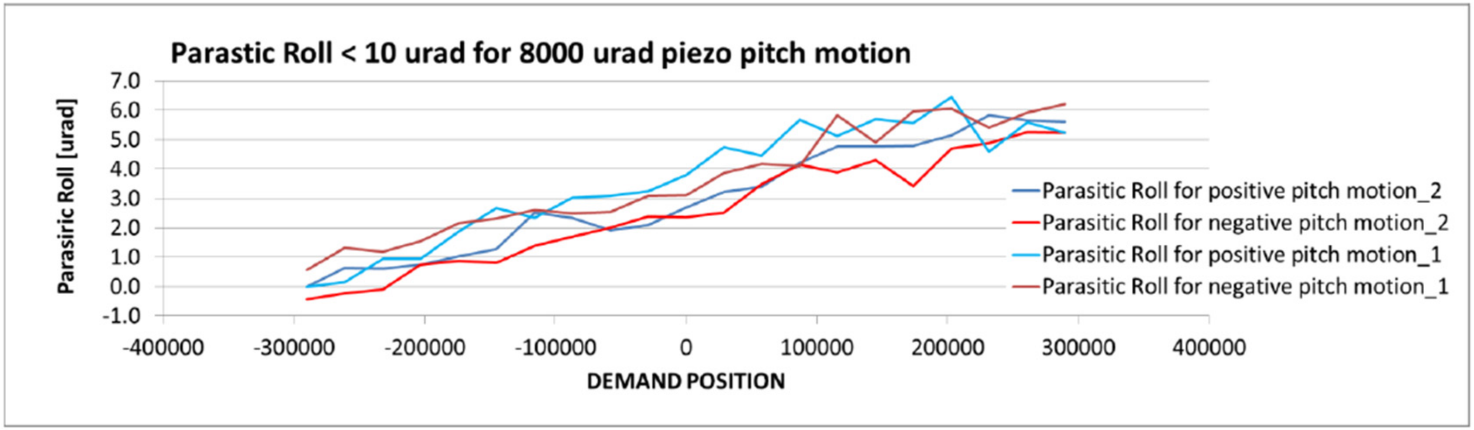


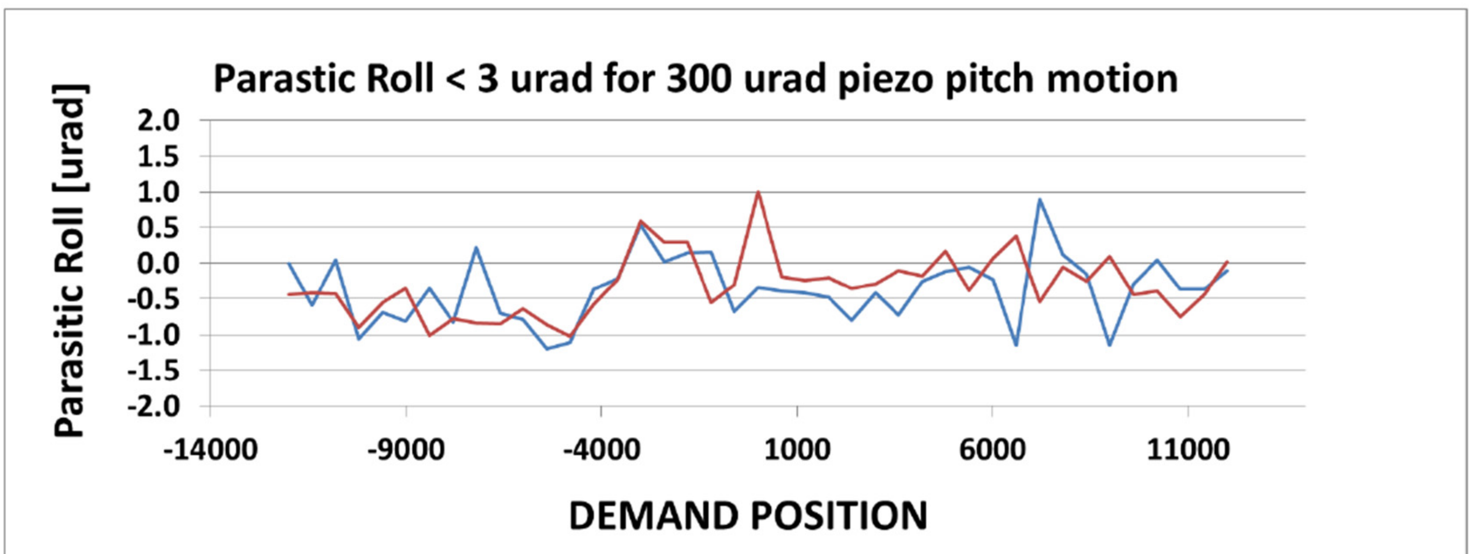
ML1 Pitch performance

Range	-0.5 to +1.5º
Resolution	< 0.1 μrad
Bidirectional repeatability	< 5 μrad
Accuracy	< 3 μrad / 8 mrad



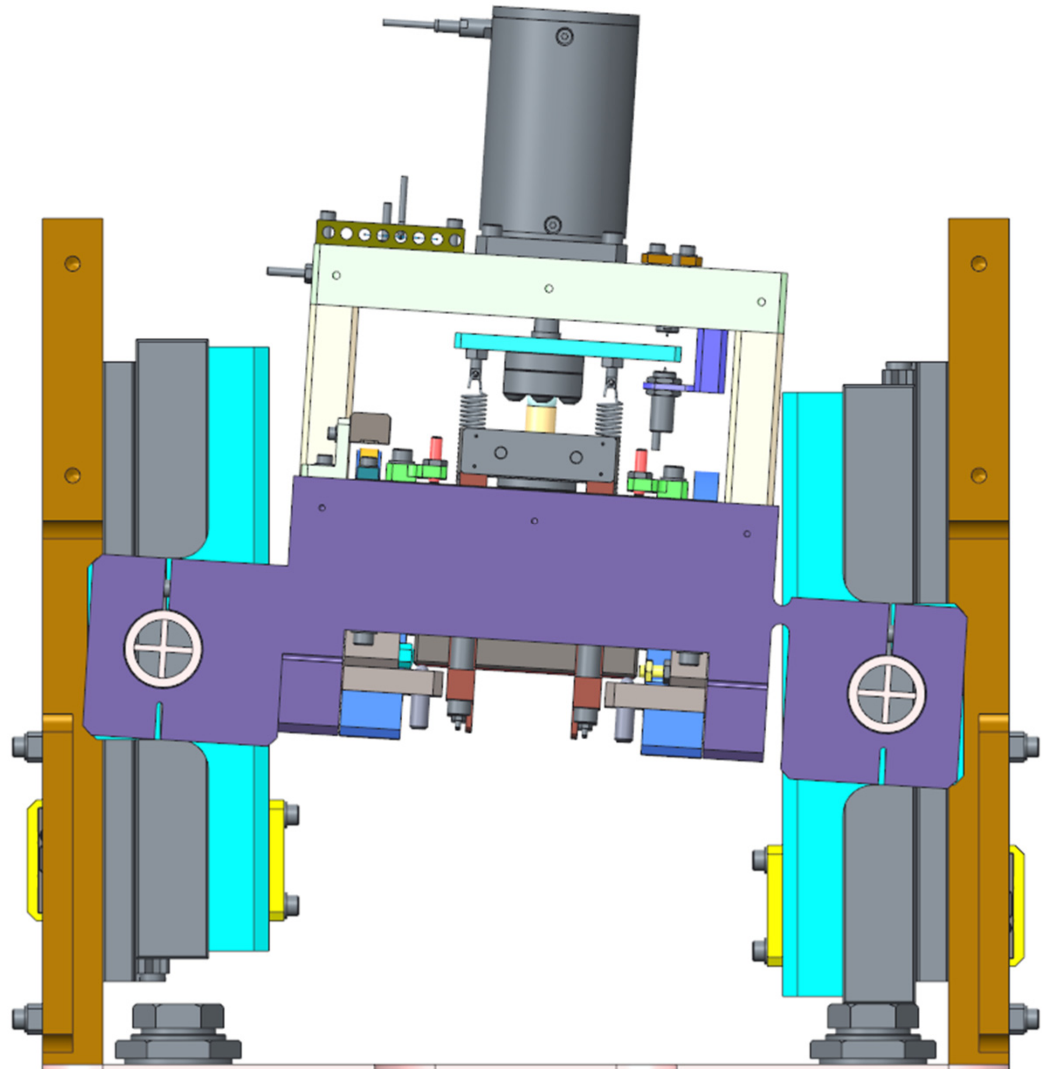
ML1 parasitic roll (A.Bugnar)





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

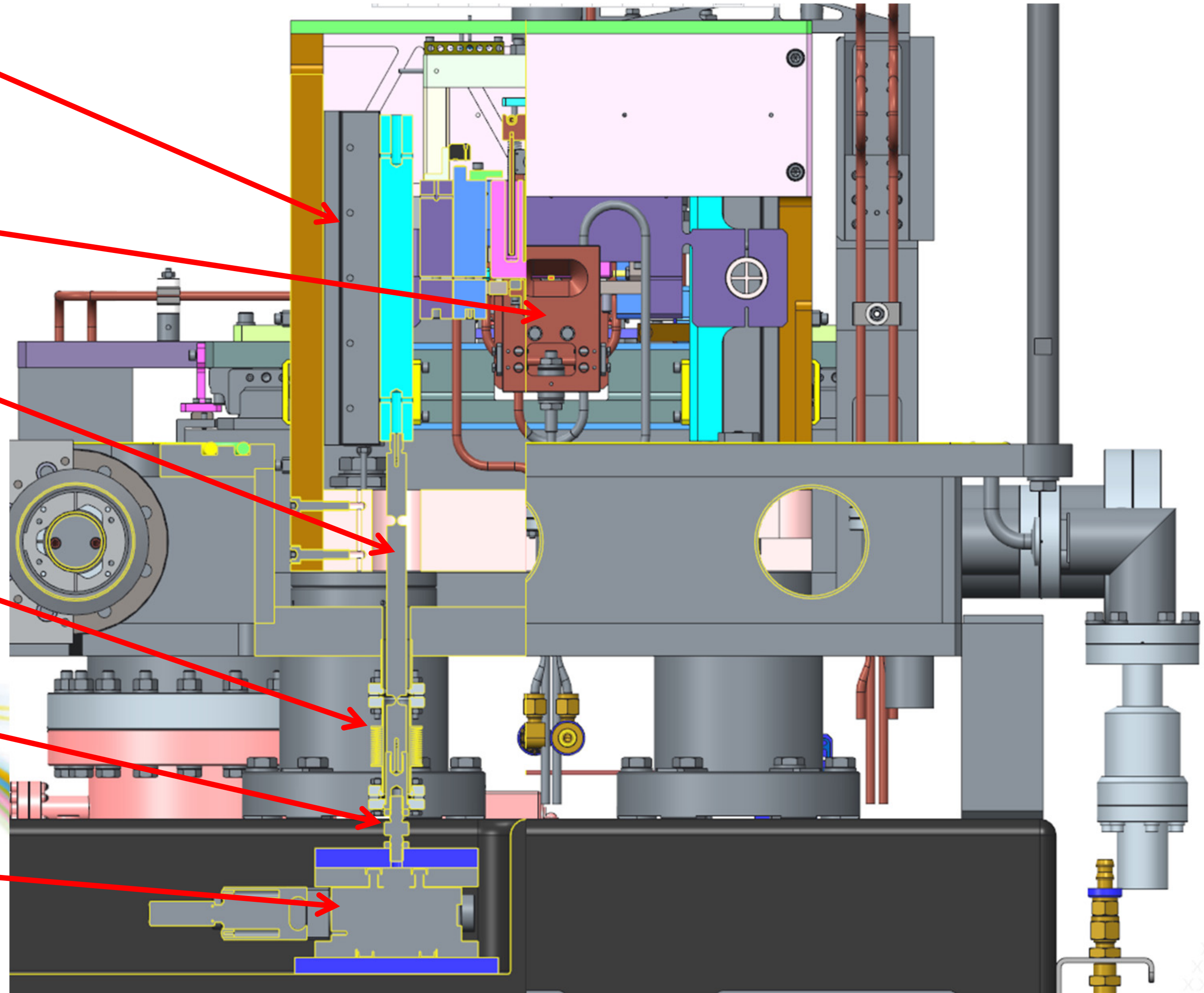
Water-cooled entry mask

Flexure drive rod

Edge-welded Bellows

Turnbuckle

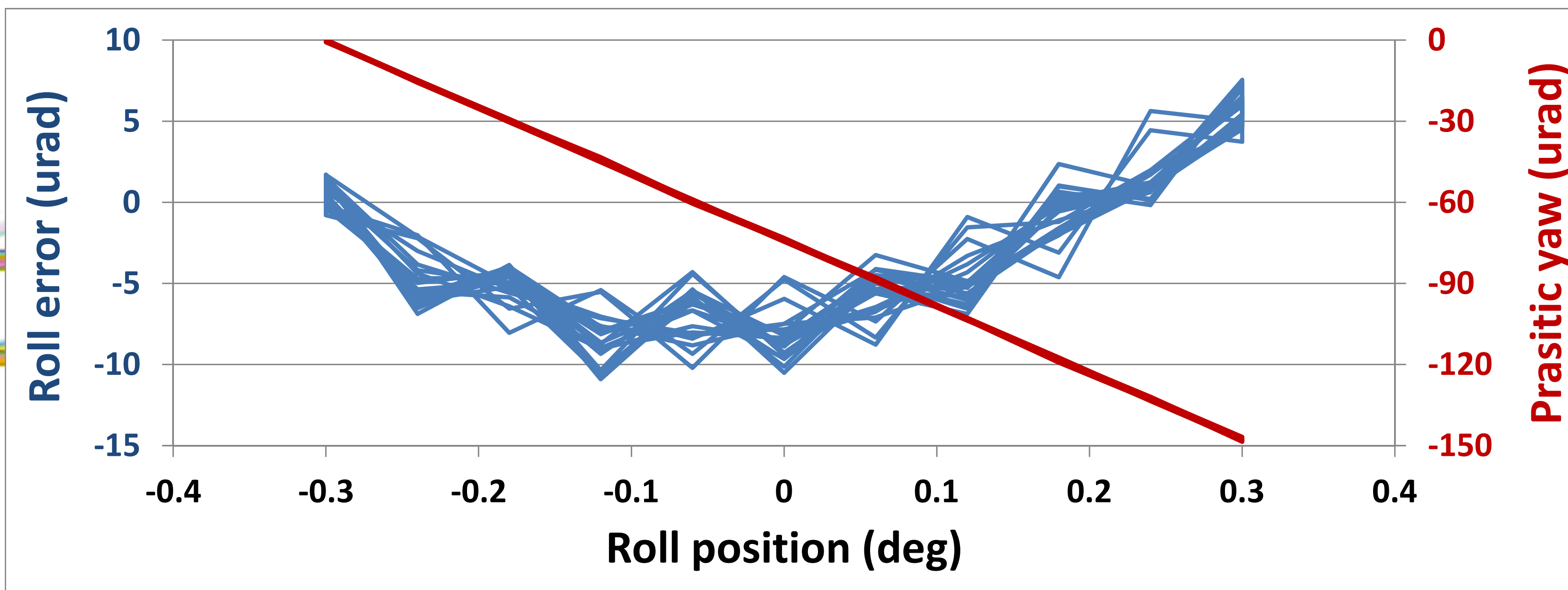
Huber 5103.A10-X1 stage



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

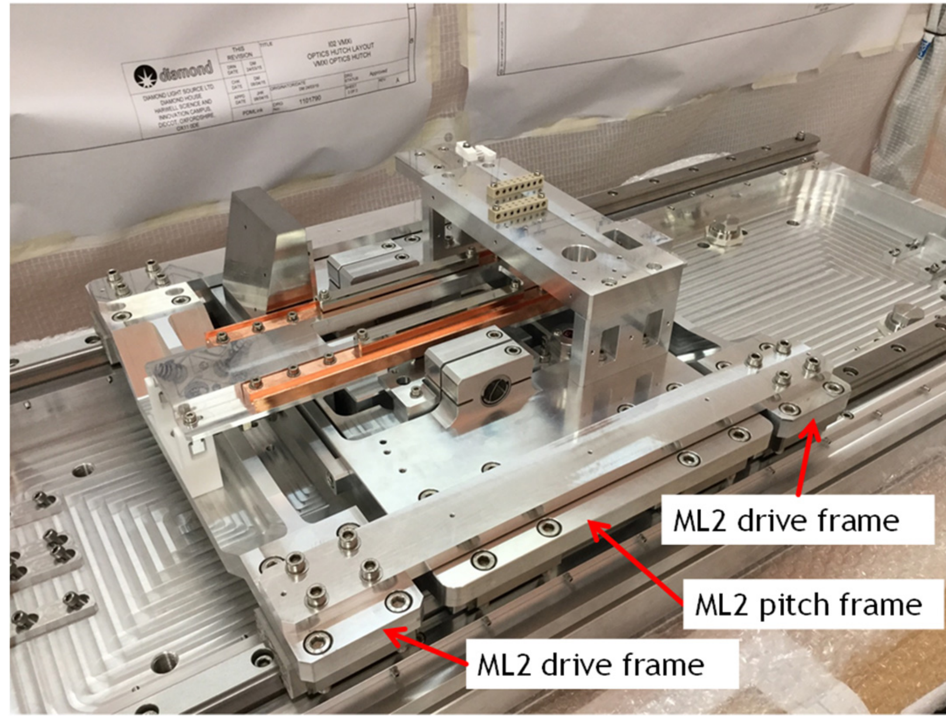
ML1 Y-axis performance	
Range	+5 mm – 7 mm
Resolution	0.25 µm
Bidirectional repeatability	1 µm / 0.7 mm
Parasitic pitch	50 µm / 0.7 mm

Roll-axis performance	
Range	± 0.5º
Resolution	1 µrad
Bidirectional repeatability	5.7 µrad
Parasitic pitch	175 / over 2º
Parasitic yaw	150 / over 2º



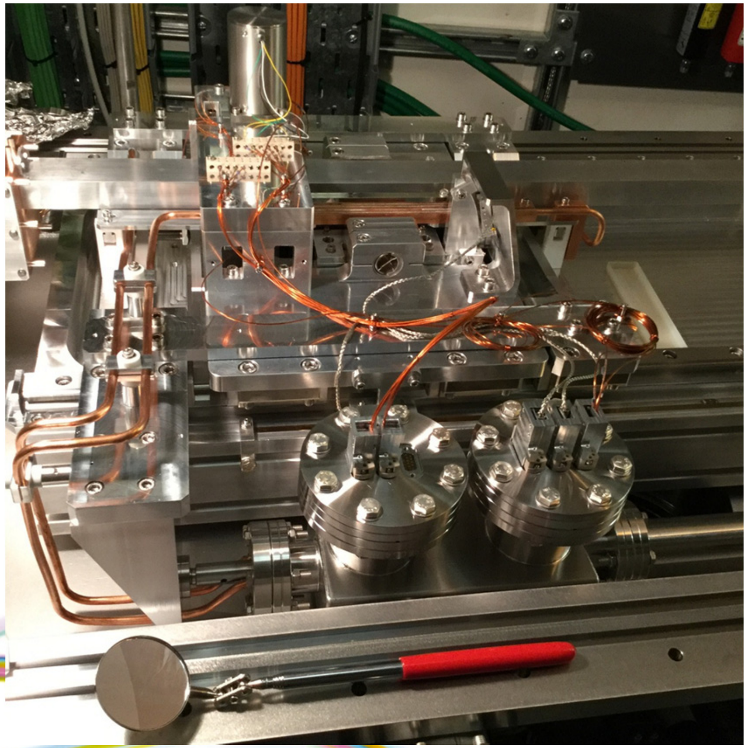
ML2 assembly

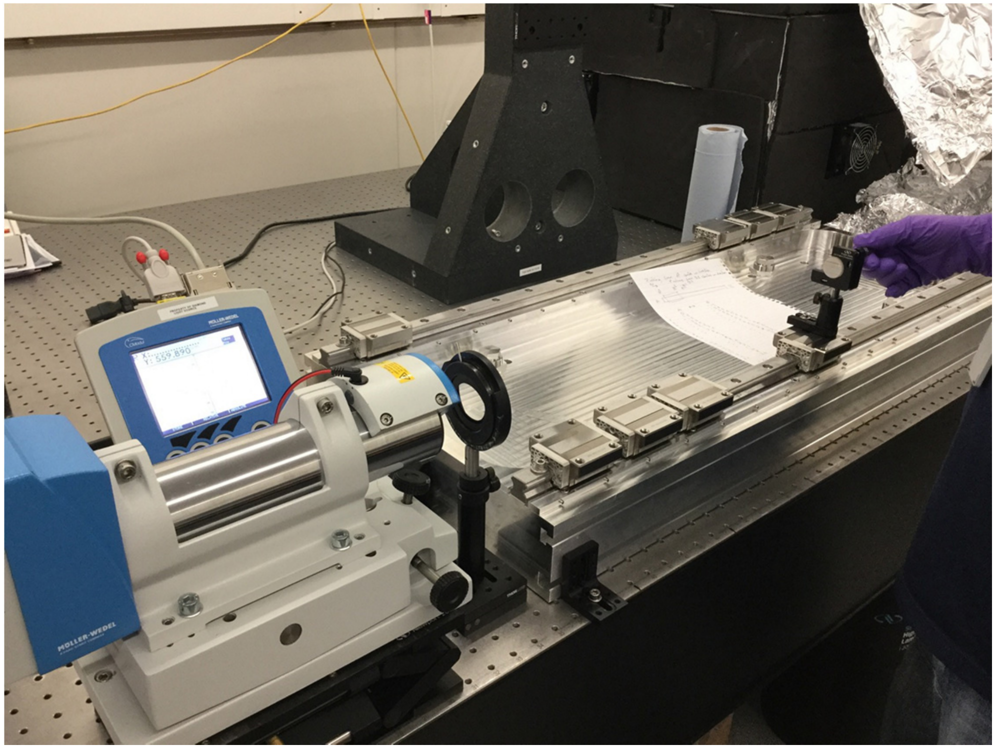
- Driven via external actuator (UHV design linear shift)
  - No internal rolling cables
  - Force reactions outside of ML2 assembly
- Rails aligned using autocollimator to better than 30 µrad
- Drive frame driven off-axis
- Pitch frame driven on-axis via balls on flats



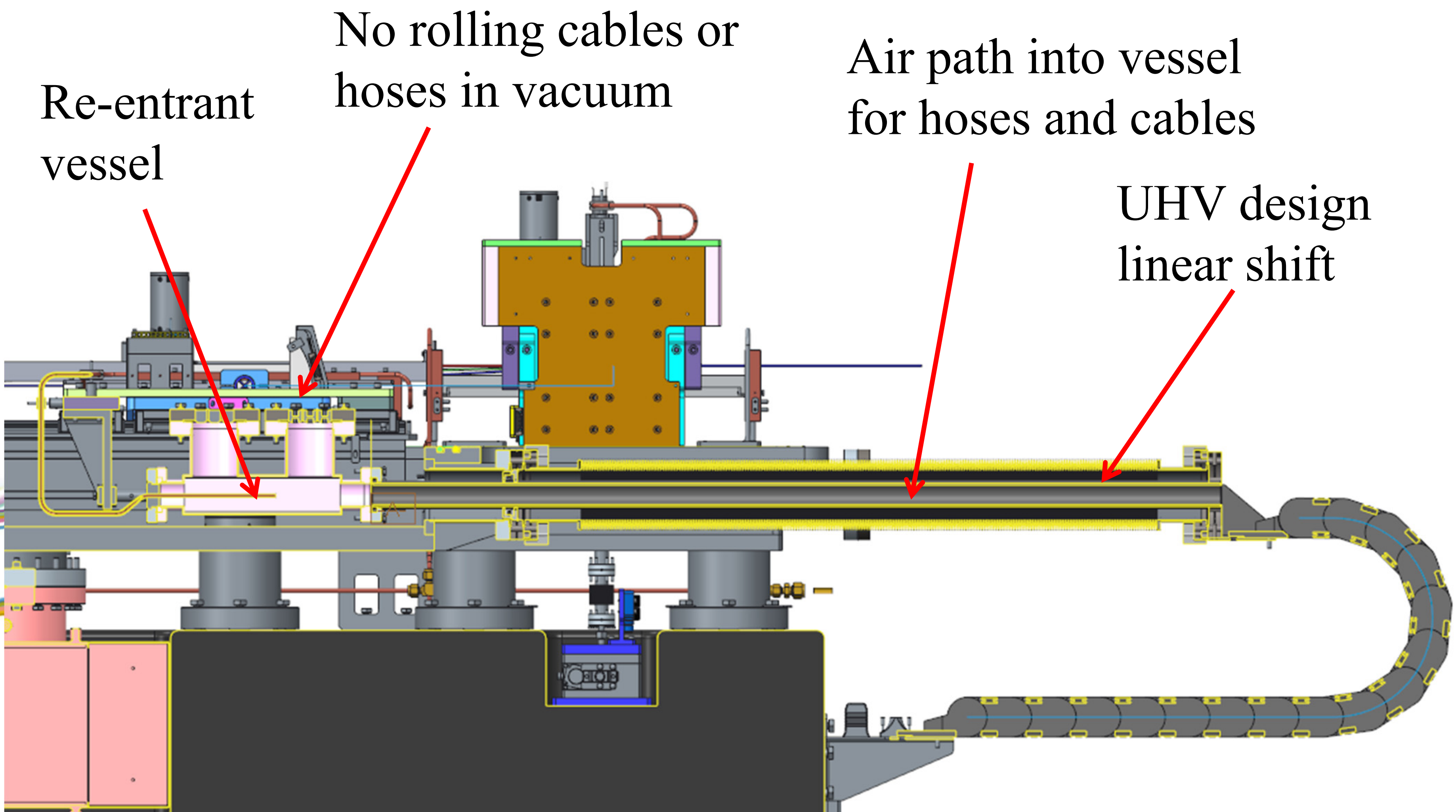
ML2 Z-axis performance	
Range	580 mm
Resolution	2 µm
Bidirectional repeatability	64.8 µm (no vacuum loads)
Parasitic pitch	110 µrad
Parasitic yaw	20 µrad
Speed	100 mm/s

ML2 assembly



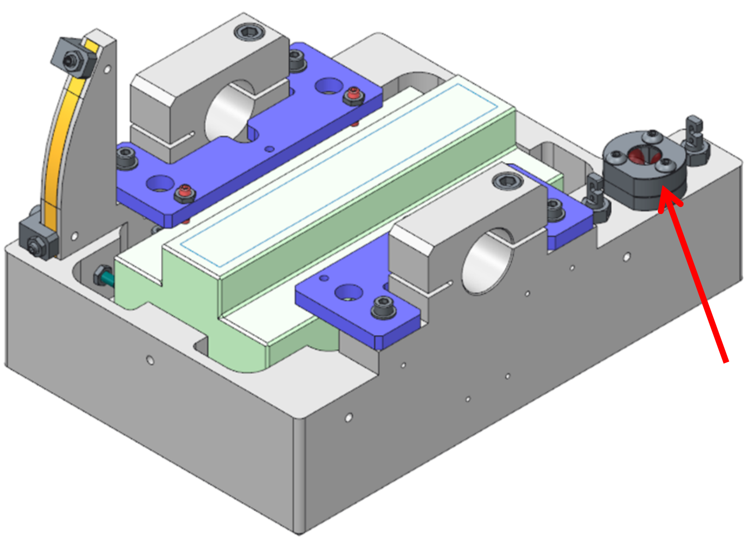


ML2 Drive cross section

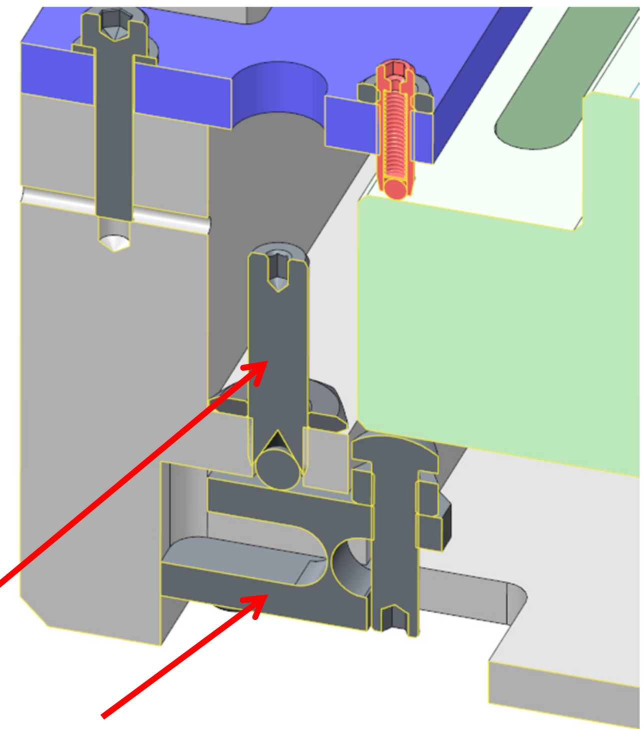


ML2 Pitch Frame

- 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

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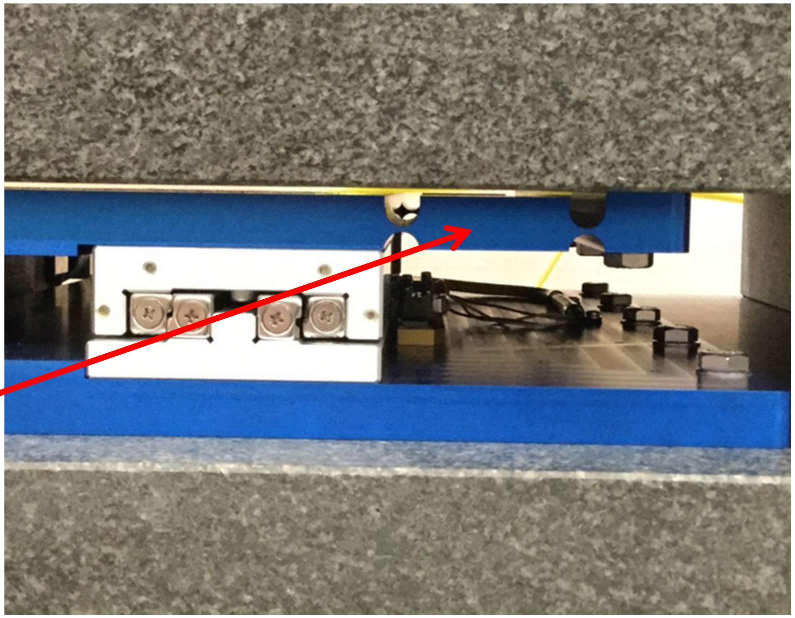
X-Axis

- 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 (~25 µm) but good yaw and pitch resistance

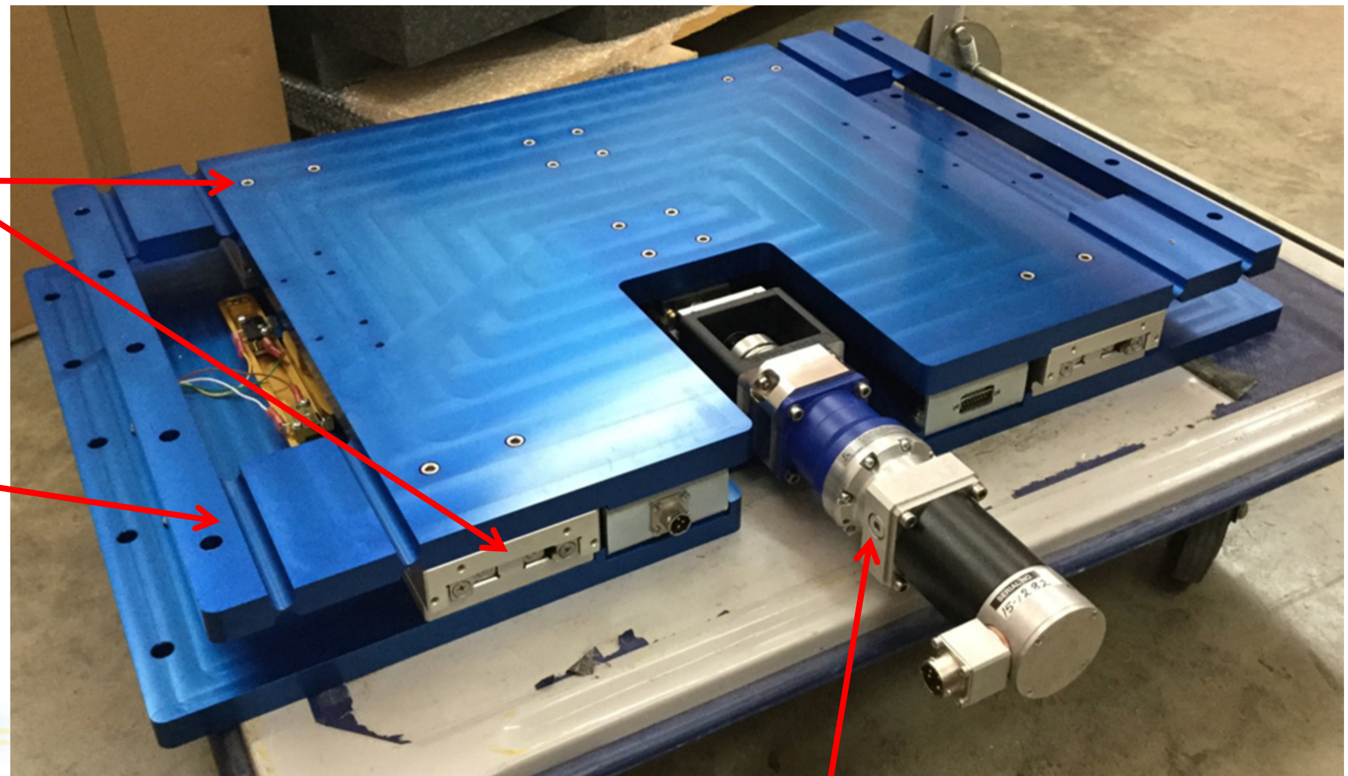
X-axis performance	
Range	±15 mm
Bidirectional repeatability	4.5 µm
Parasitic pitch	5 µrad
Parasitic roll	8 µrad
Parasitic yaw	30 µrad



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

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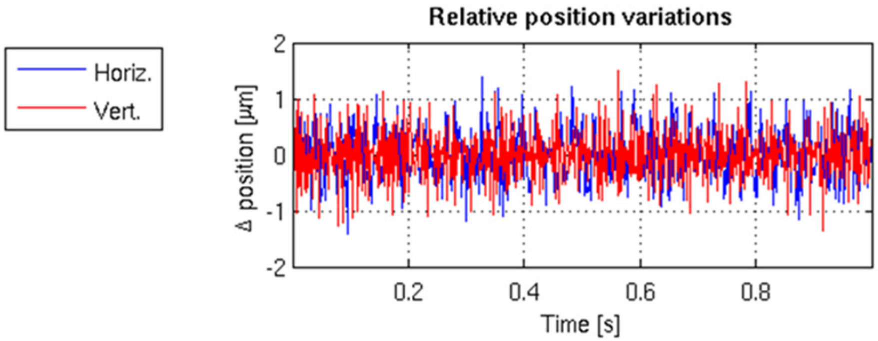
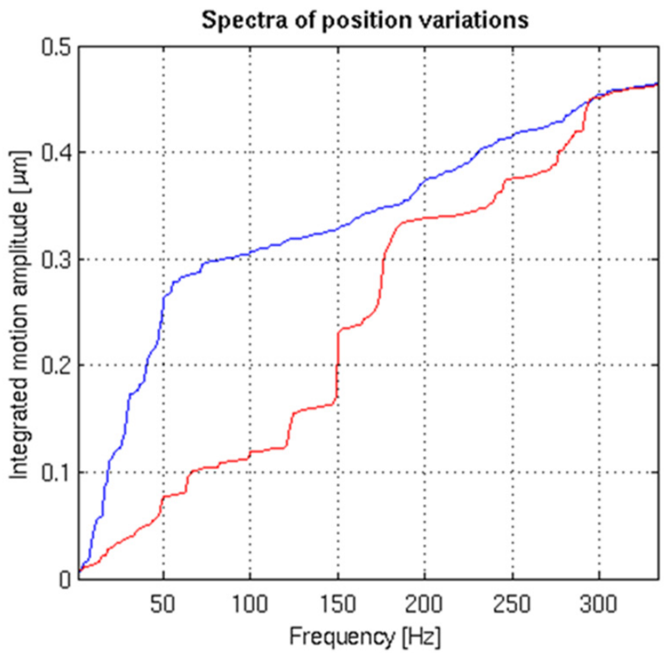
DMM axes performance figures

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





Captured on 700Hz fast X-ray camera

← ~0.46 μm

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

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)