Sub-system mechanical design for an eLISA optical bench

LISA Symposium X

Gainesville, Florida – 20th May 2014

Michael Perreur-Lloyd

Football$_E$ = Soccer $_{AE}$

Thanks for staying!

You can be my Tartan Army…

But it's really more like Europe versus USA…

But it's really more like Europe versus USA…

…as this is presented on behalf of:

University of Glasgow - Christian Killow, David Robertson, Harry Ward

Airbus DS - Ewan Fitzsimons, Dennis Weise

AEI Hannover - Michael Tröbs, Maike Lieser, Sönke Schuster, Jan-Simon Hennig, Gerhard Heinzel & Karsten Danzmann

Kick-off
What?
Spec's
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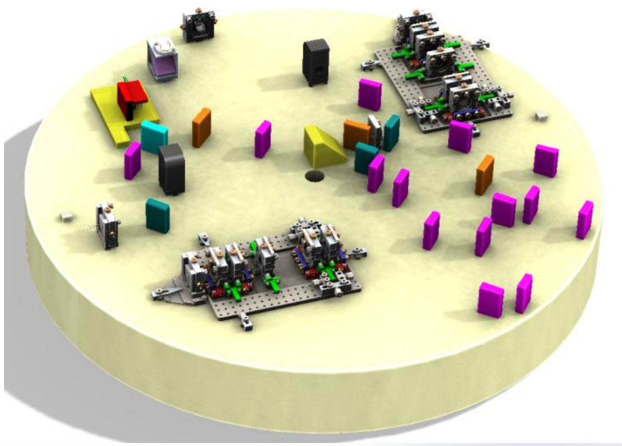
Testing
Conclusions
And finally…

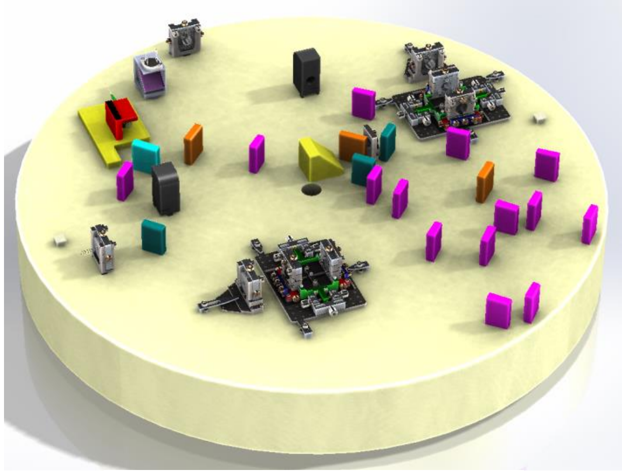
What are we going to build?

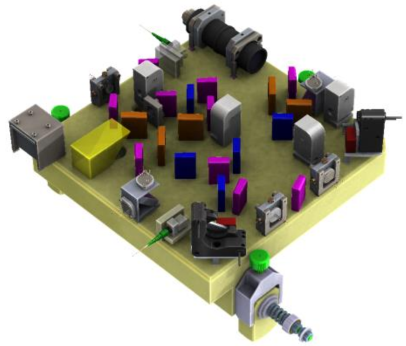
- A test bed to investigate tilt-to-piston coupling in the context of eLISA
- Which includes:
  - An Optical Bench with space for an interchangeable imaging system and a Tx Beam
  - A Telescope Simulator, generating a representative (tilt-able) flat top Rx beam, a local oscillator, and featuring a reference interferometer combining both these beams

See poster by Maike Lieser of AEI Hannover

- This talk is focussed on the Imaging System mechanical design…







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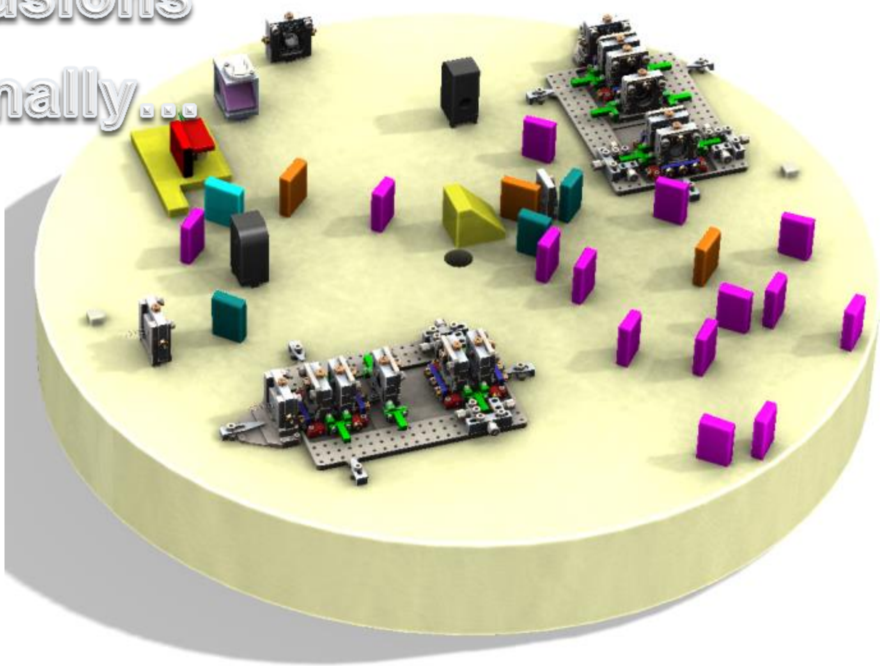
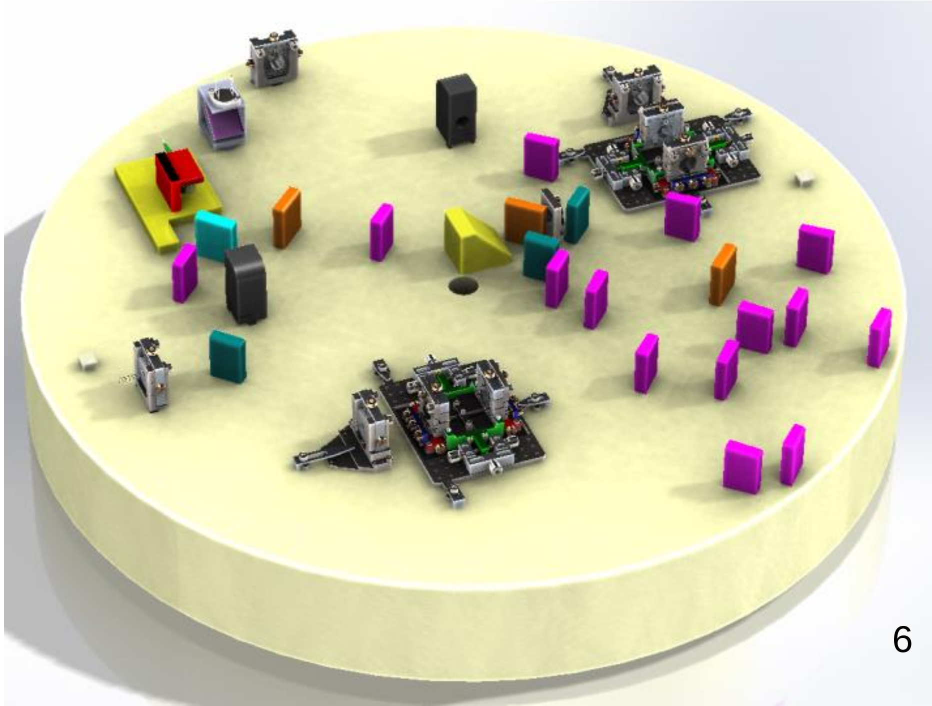
What do the imaging system mechanics need to do?

- Allow for precision alignment of the lenses & photodiode

But, also:

- be precision adjustable, to allow for characterisation of the designs
- be removable so as to be replaced by the alternative design

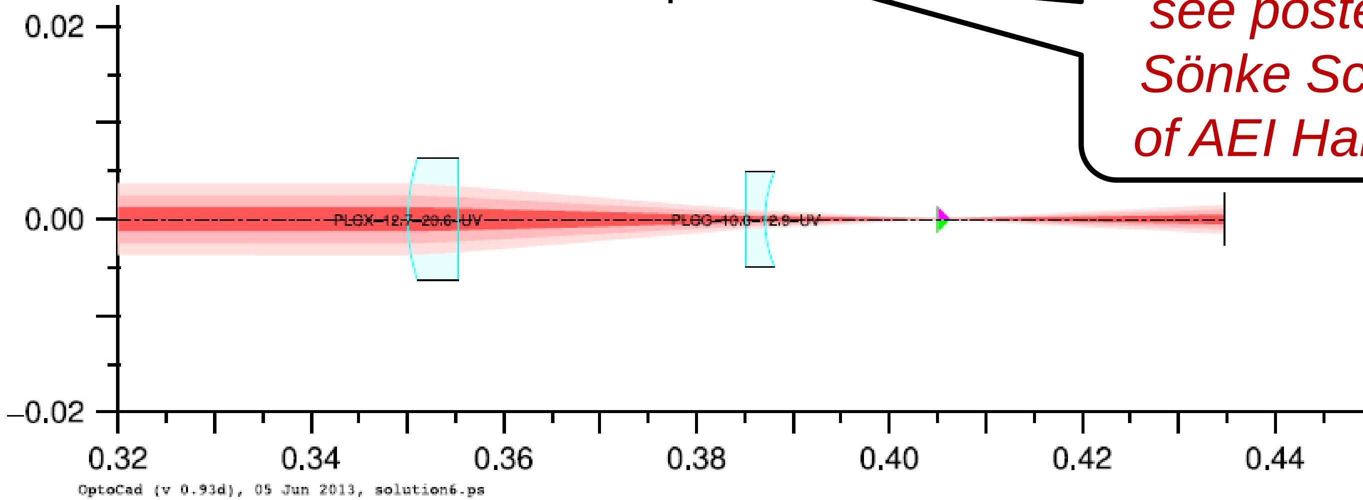




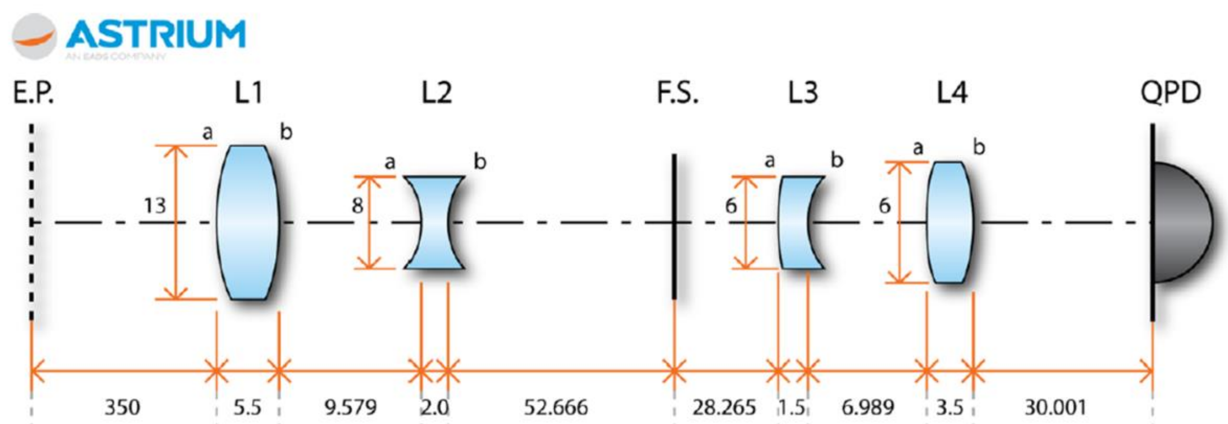
What are the imaging system optical designs like?

- Two designs to test and compare different optical design approaches
  - Two lens, non-classical optics

see poster by Sönke Schuster of AEI Hannover



  - Four lens, classical optics



Alignment

- Typical alignment specifications for an lens
  - Decentre, X, Y: +/- 20um
  - Distance tolerance Z to next lens: +/- 50um
  - Lens centring: +/- 3' (or ~1 mrad)
  - Lens tilt (pitch): +/- 3' (or ~1 mrad)

Characterisation

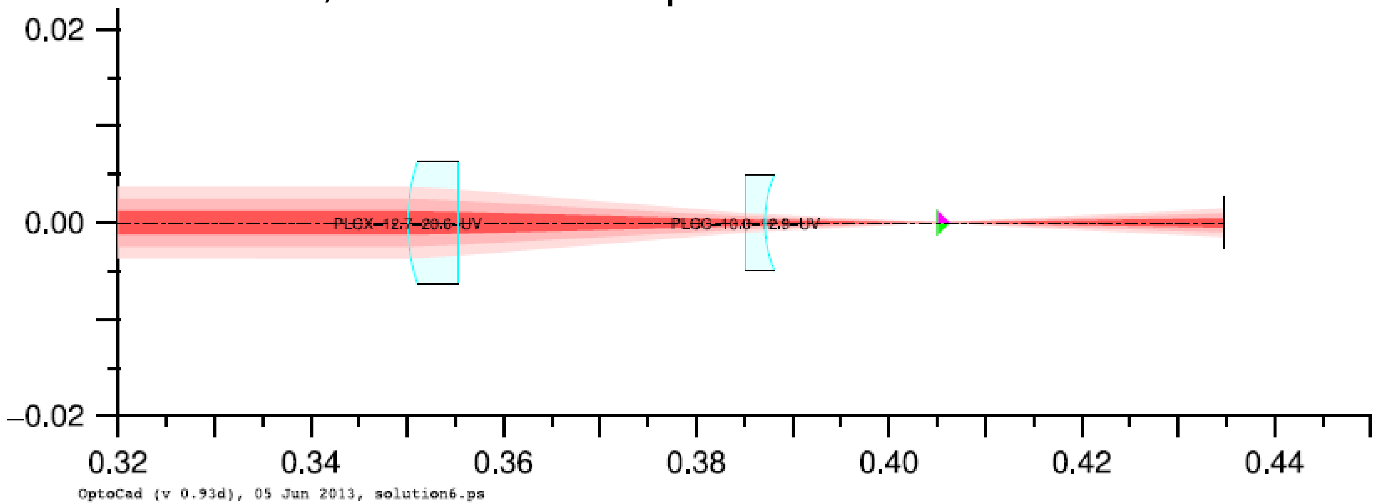
- Maximum required range:
  - Decentre X, Y: +/- 60um
  - Distance tolerance Z to next lens: +/- 200um
  - Lens pitch/yaw: +/- 10'
- Resolution of movement:
  - Micron
  - Sub arc-minute (~100s of urad)

Design Details

- To allow for alignment and characterisation of the imaging system
  - Adjustment mechanisms of individual mounts require:
    - Lateral, X and Y
    - Longitudinal, Z
    - In-plane rotation (yaw)
    - Out-of-plane rotation (pitch)
  - Adjustment of lens pair assemblies is required in
    - Lateral, X and Y
    - Longitudinal, Z
    - Yaw
    - Pitch

Imaging system optical designs

- Two designs to test and compare different optical design approaches
  - Two lens, non-classical optics



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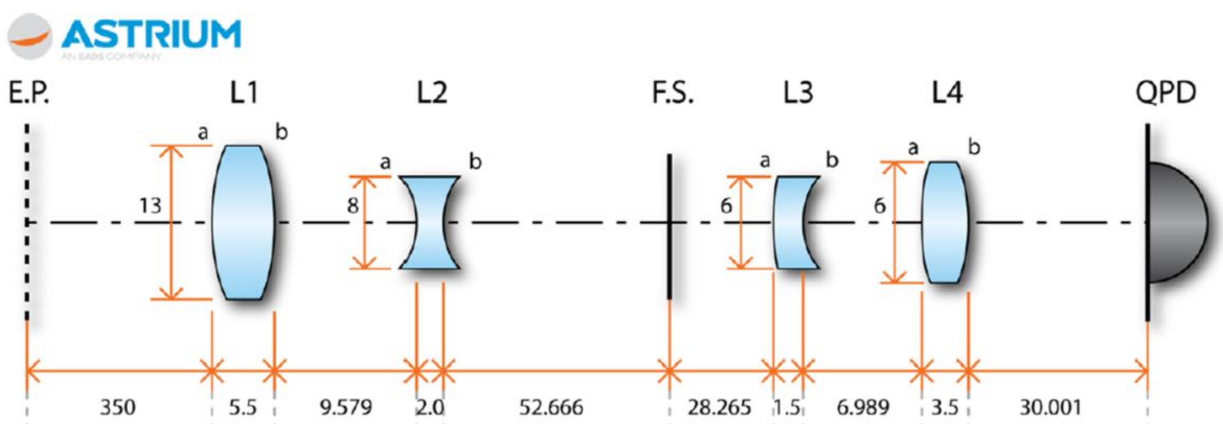

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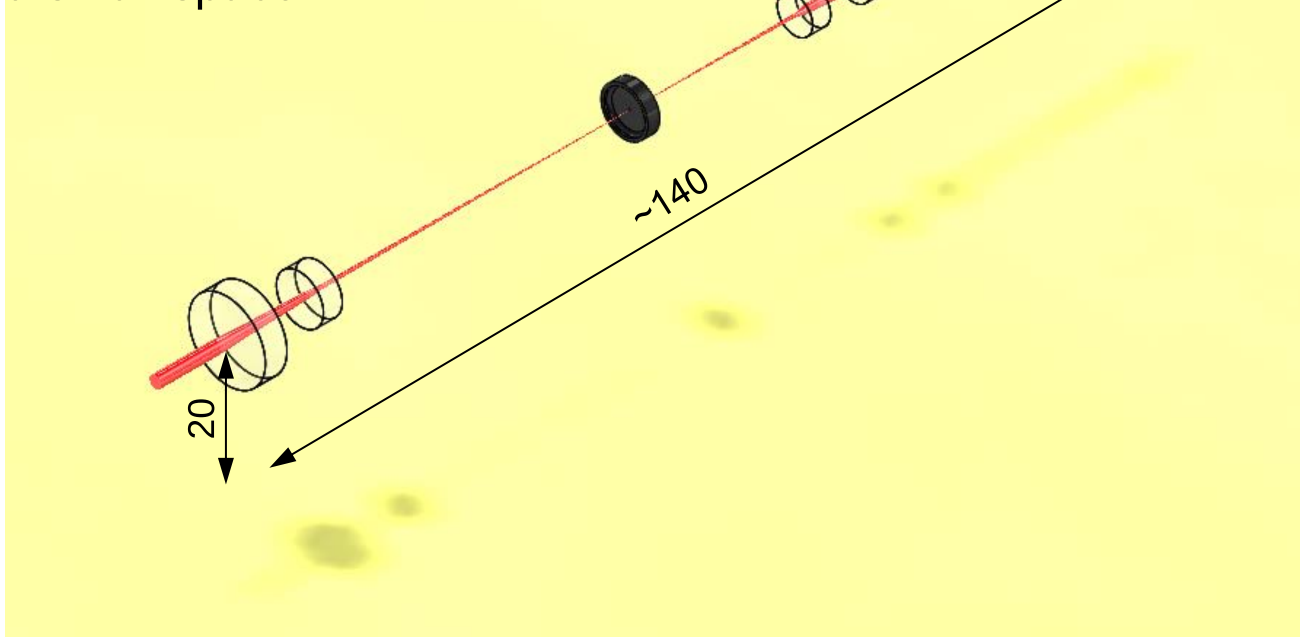
Design features

Four lens design

- Beam height of 20mm above the Zerodur baseplate
- A lot of adjustment mechanisms to fit in a small space!



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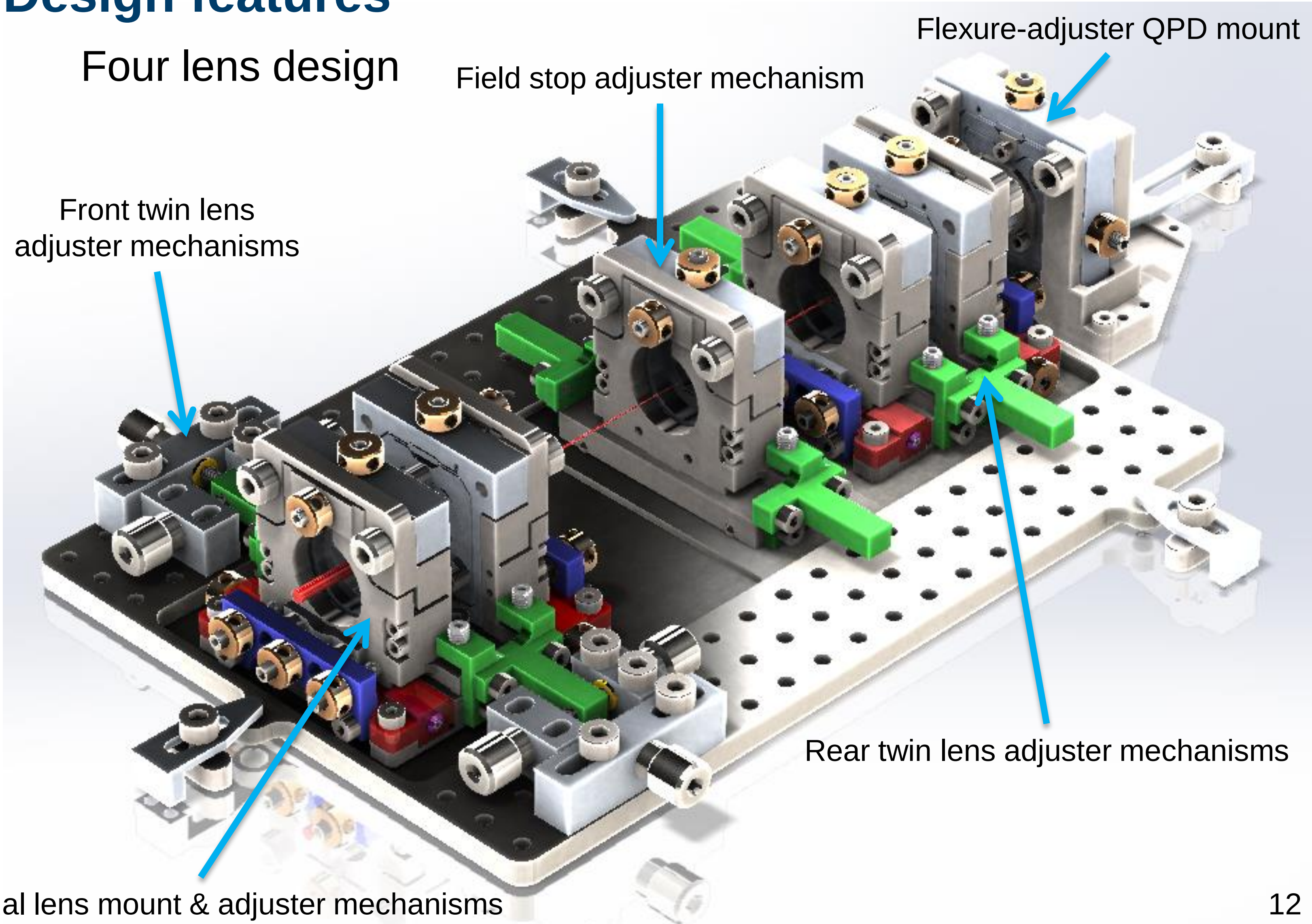
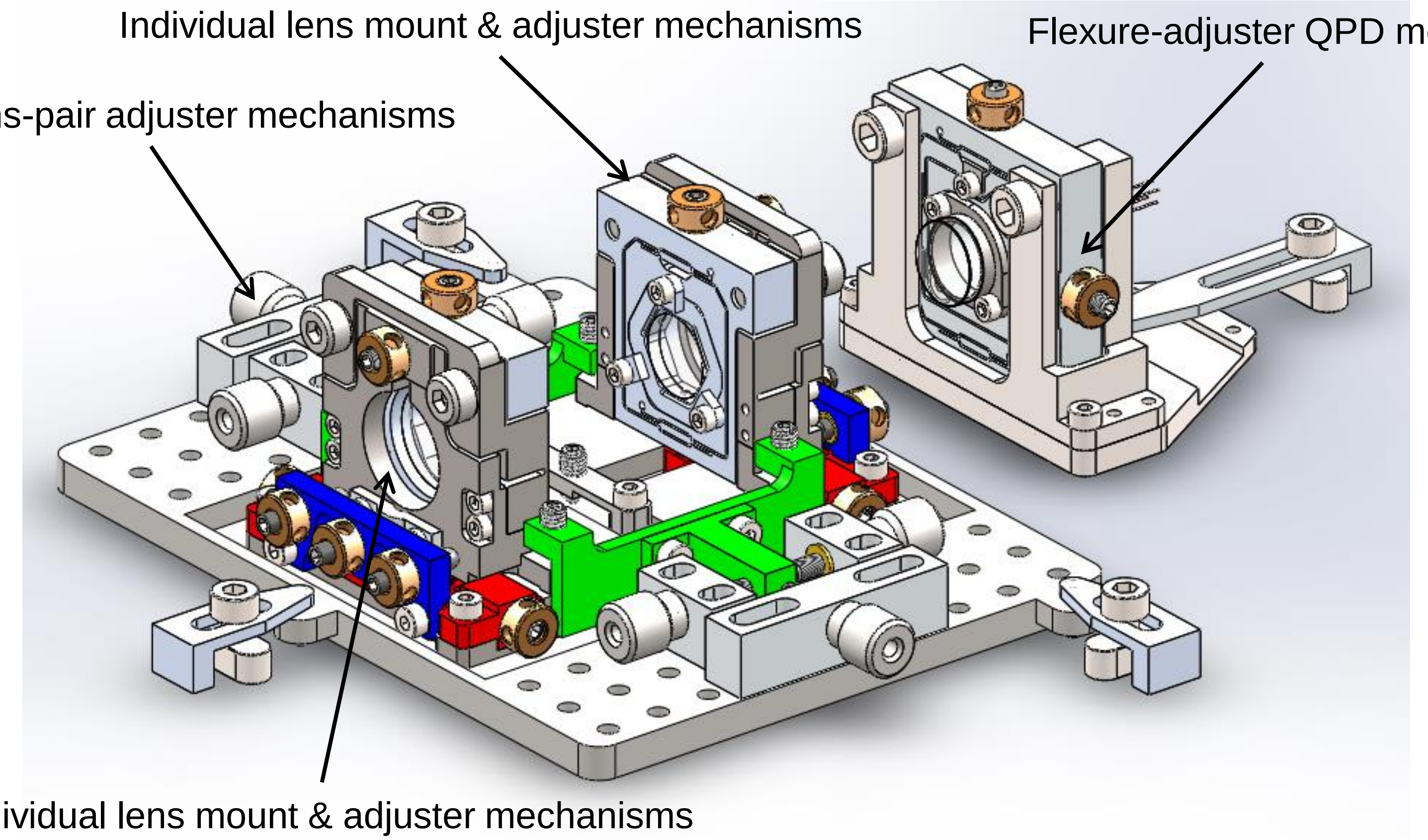
Four lens design



Design features

Two lens design



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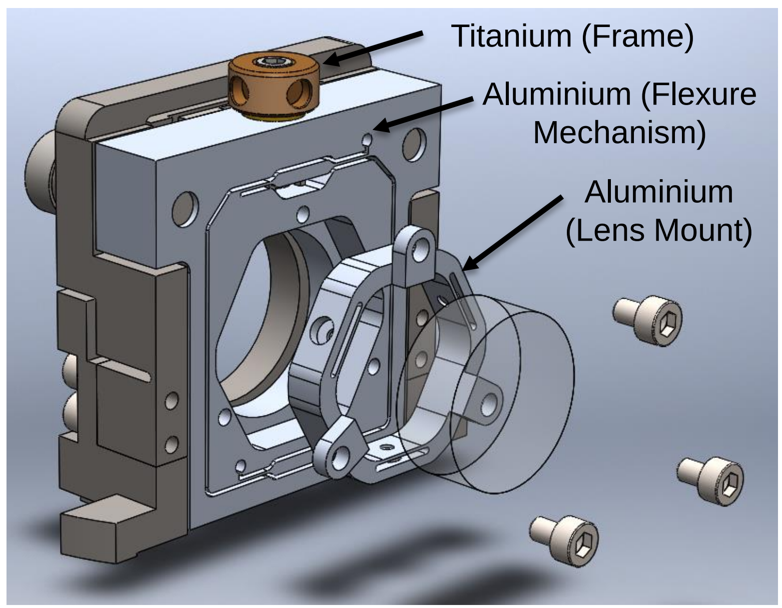
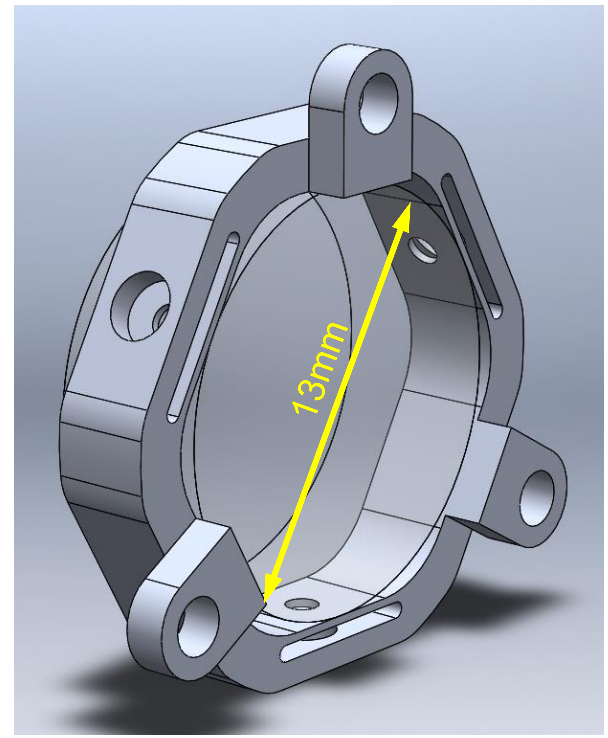
Design features

Individual lens holders (1)

- Overall design is thermally-stable in the vertical direction
  - Through a combined titanium & aluminium architecture
- Customised for different lens diameters
  - 6, 8, 10, 12.7 & 13mm



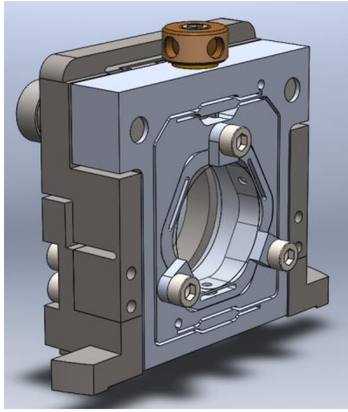


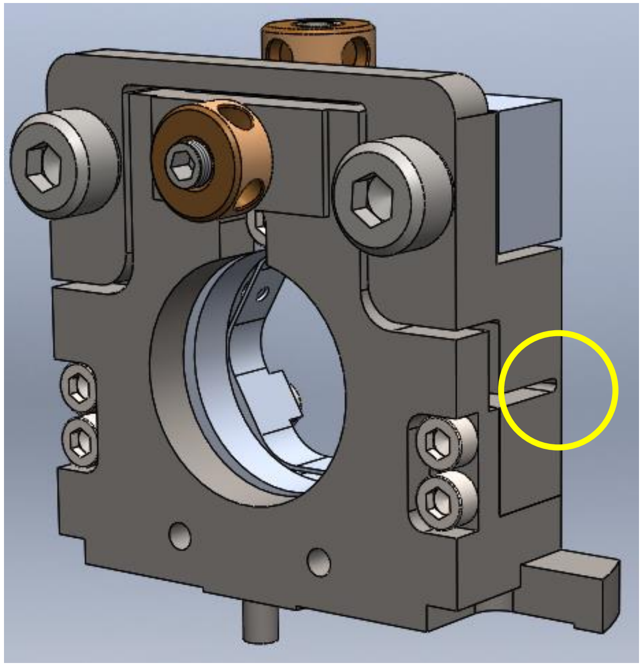
Thanks to Harald Kögel (Airbus DS) who designed and successfully tested a 25mm version of this optical mount

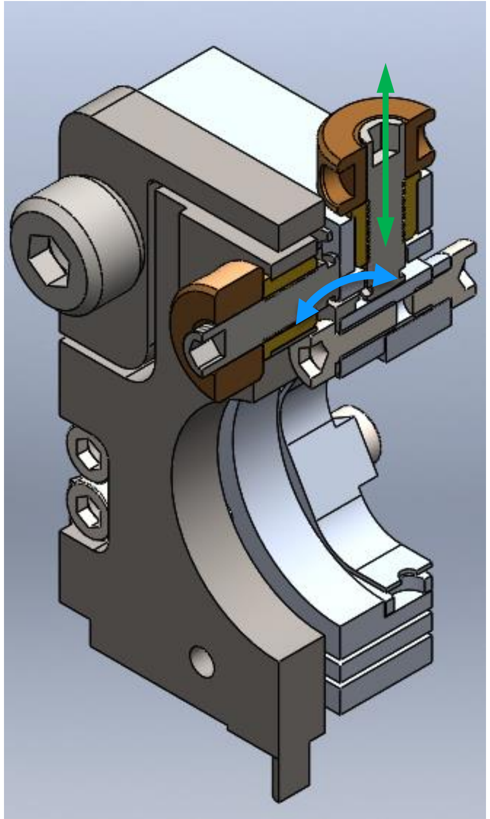
Design features

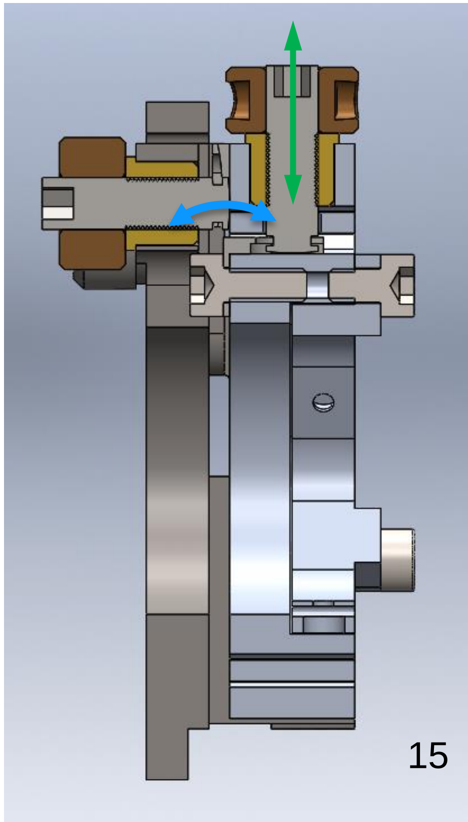
Individual lens holders (2)

- Vertical and pitch adjuster mechanisms
- Ultra-fine pitch screws, M2.5 x 0.20
- Flexure pivot





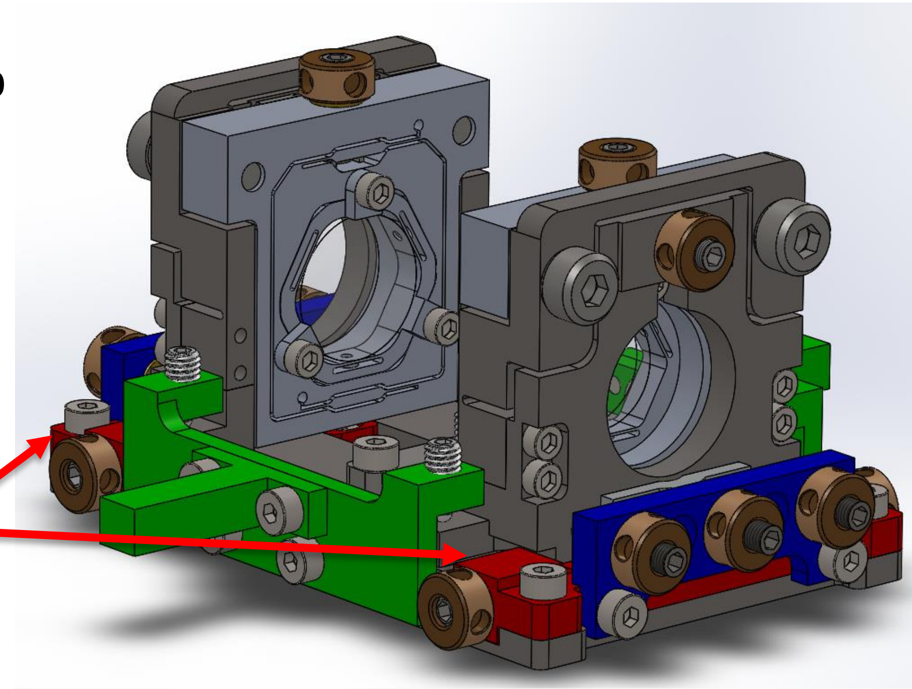


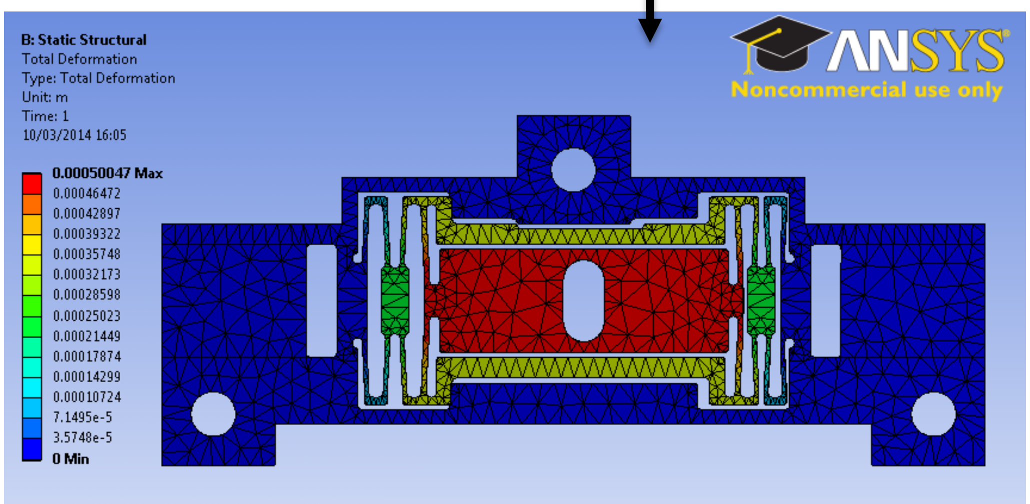


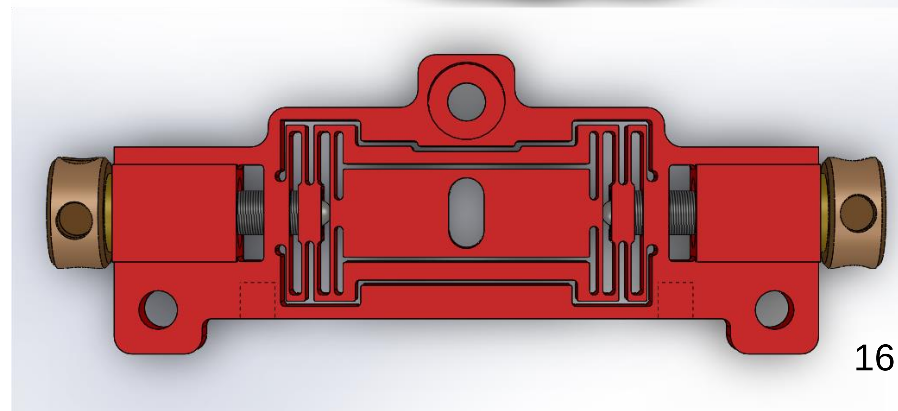
Design features

Individual lens holder (3)

- Lateral adjuster allows up to +/-0.3mm of movement range
- FE analysis of flexure mechanisms
  - Lateral-adjustment flexure mechanism



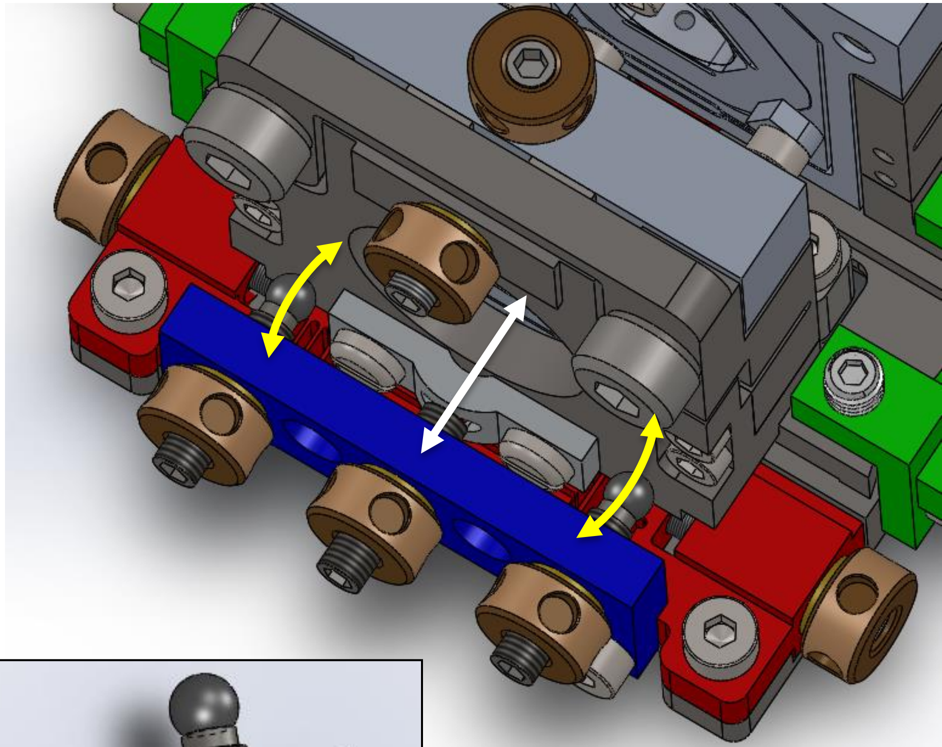


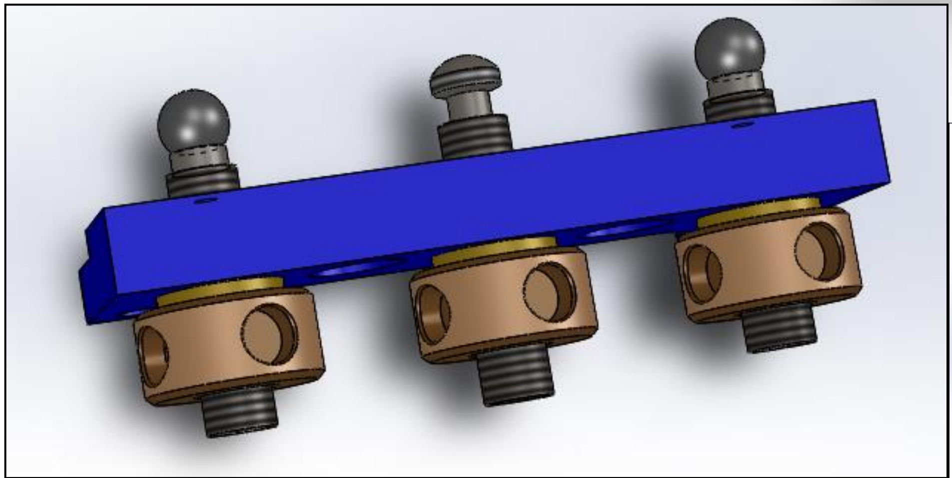


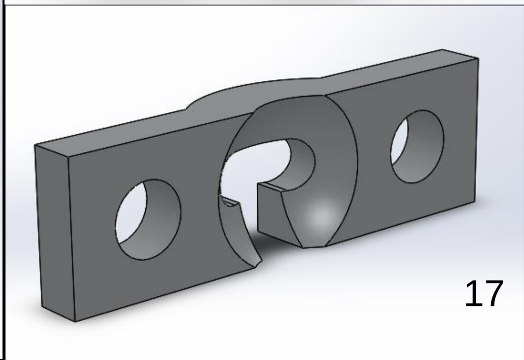
Design features

Individual lens holder (4)

- Longitudinal & Yaw adjusters
- Central screw pushes and pulls, and acts against a spherical bearing surface to allow pivoting
- Side screws push to pivot the lens mount

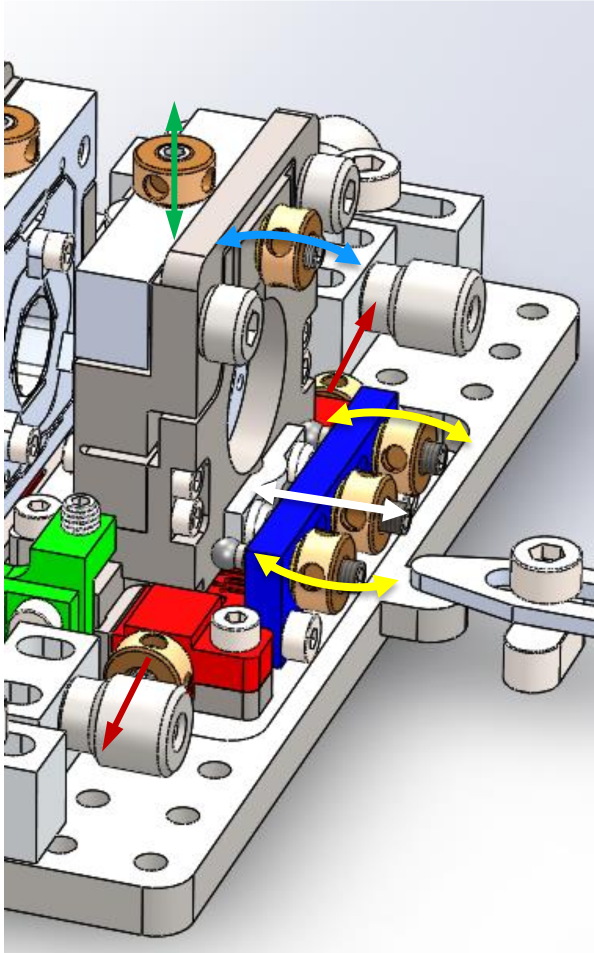






Design feature summary

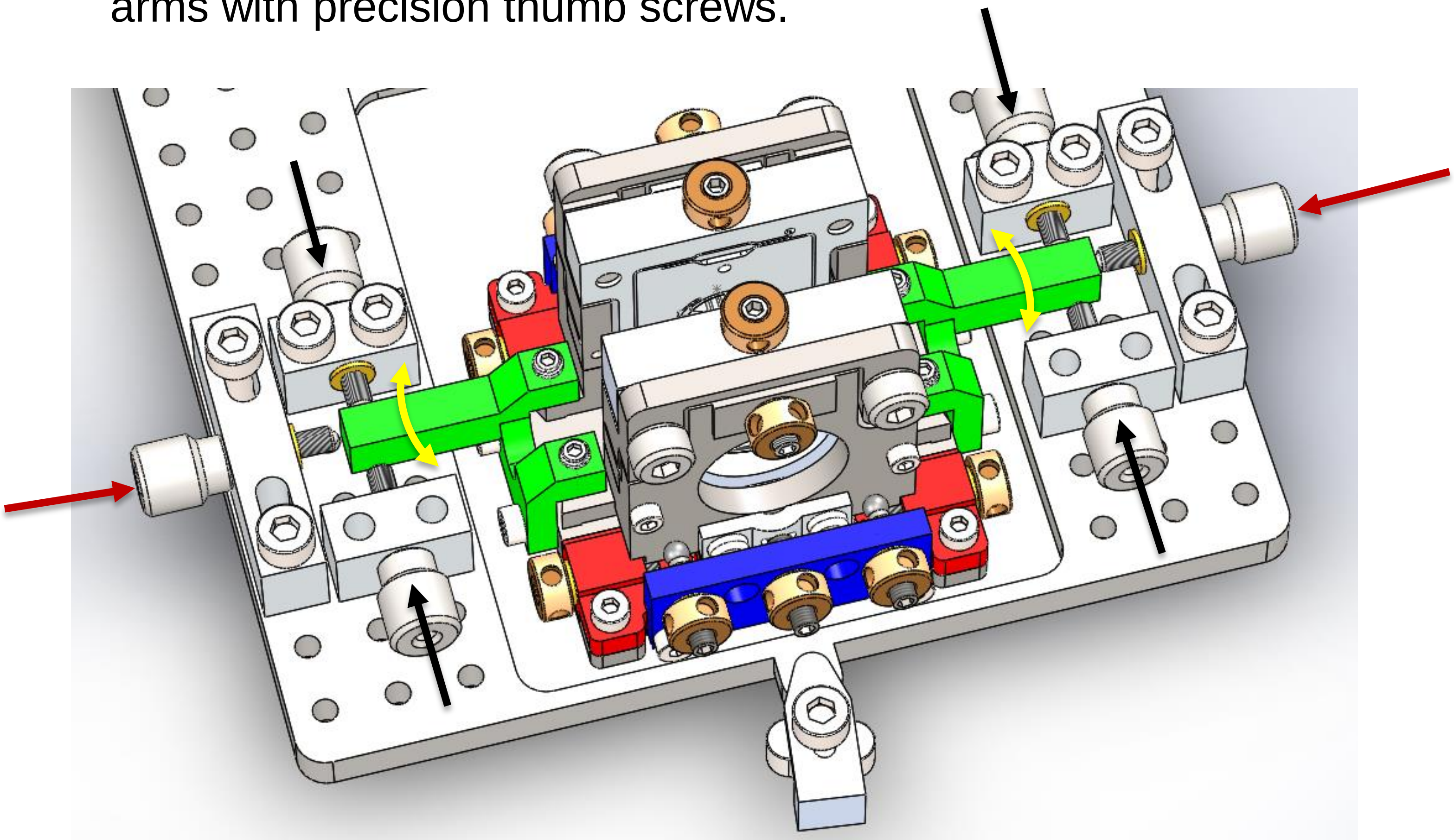
- Individual lens holders have 5 DoF adjustment
- Fine adjustment (~few micron accuracy)
  - Vertical
  - Longitudinal
  - Lateral
  - Pitch
  - Yaw
- Individual lens holders are mounted in a two lens holder sub-assembly



Design features

Lens pair assembly (1)

- The lens pair sub-assembly may also be moved longitudinally and laterally and rotationally (in yaw) by pushing on the green adjustment arms with precision thumb screws.



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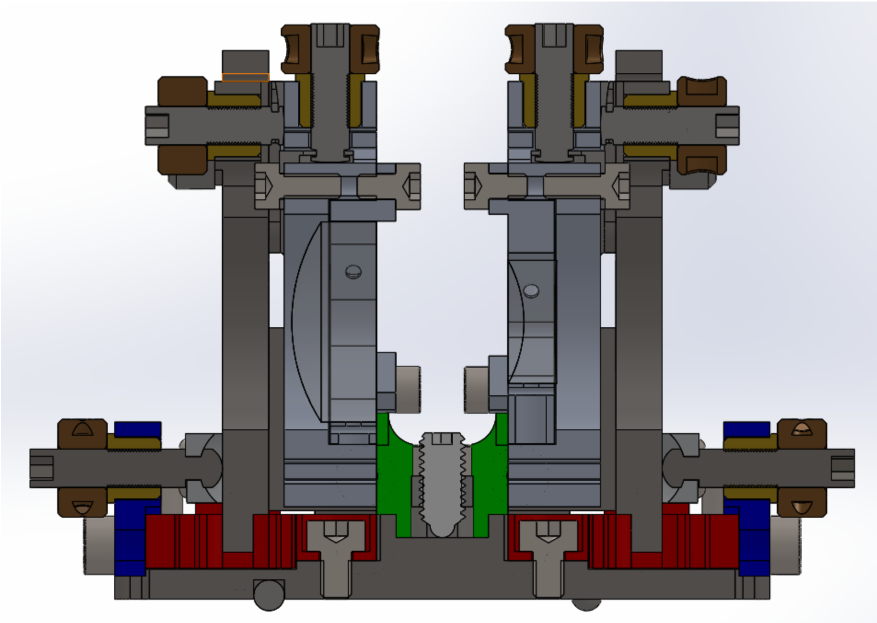
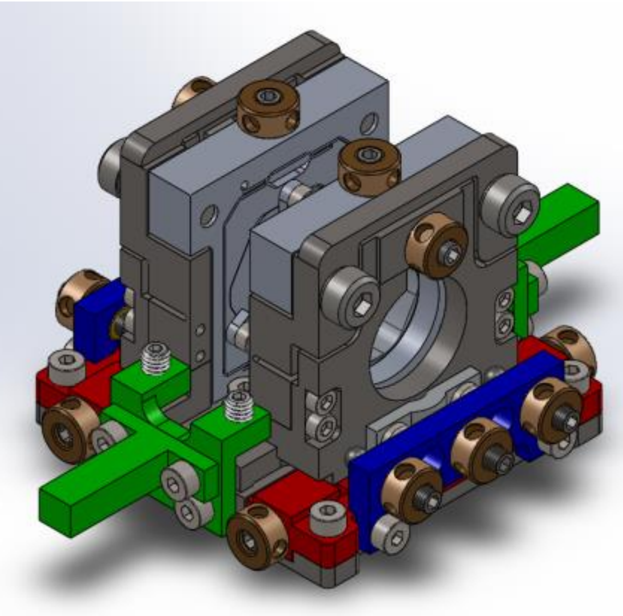
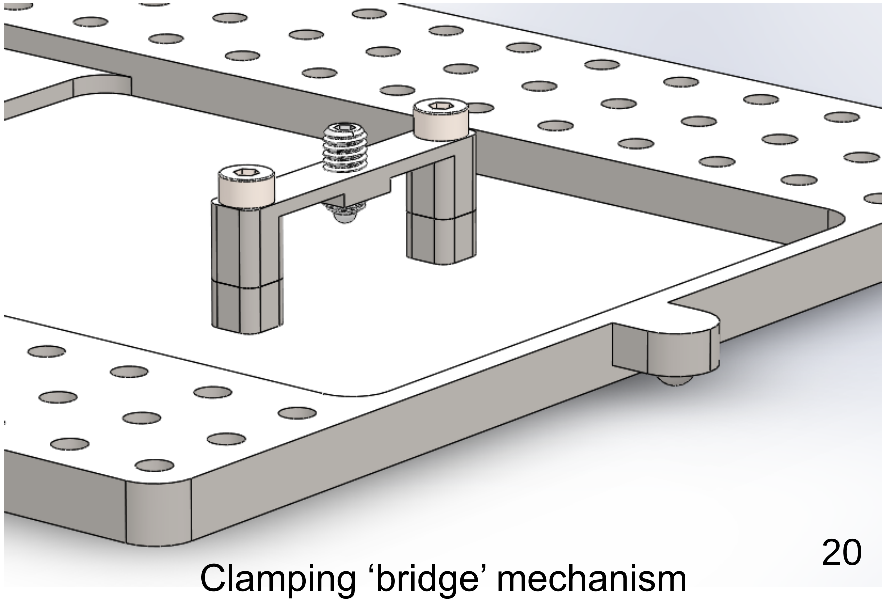
Lens pair assembly (2)

- Clamping to titanium baseplate is made using an aluminium ‘bridge’ with a central spring plunger screw to provide the downward force



Cross-section view of the lens pair assembly

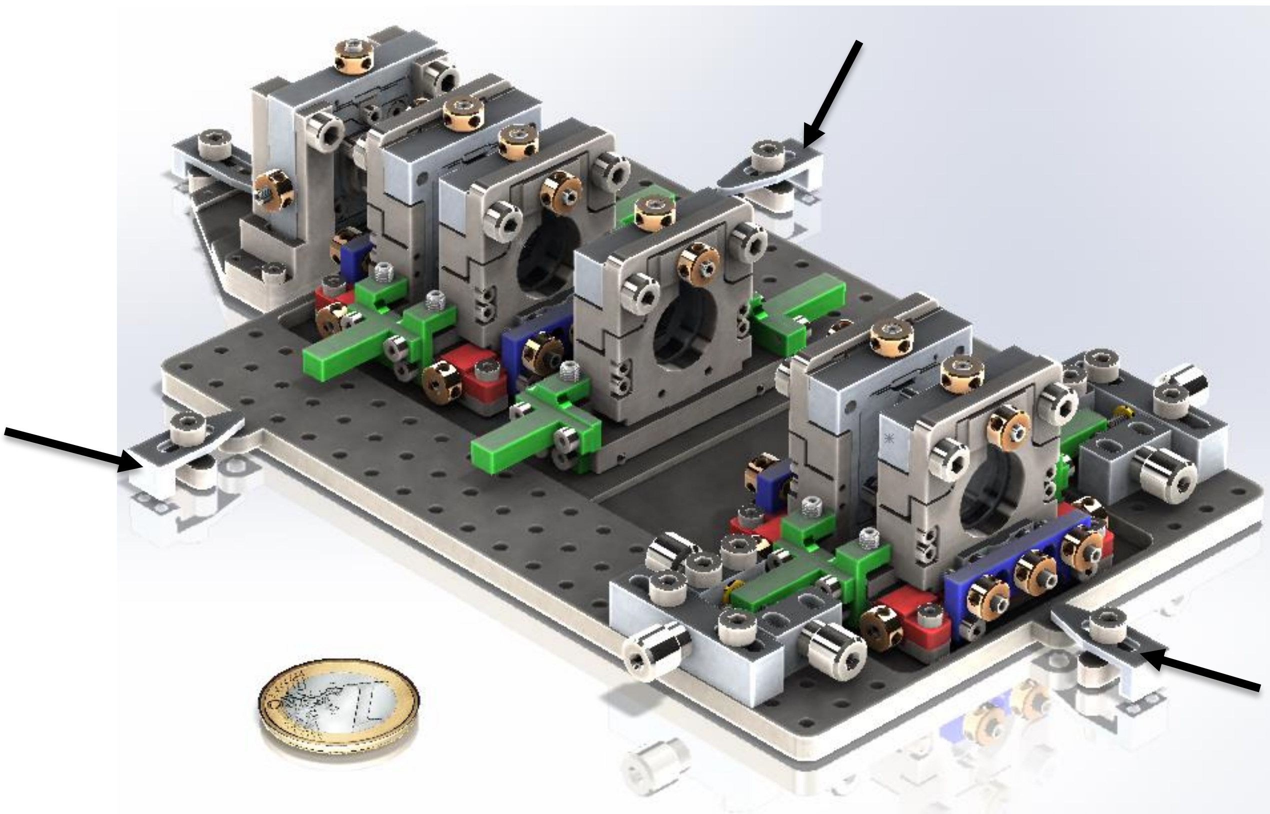




Clamping ‘bridge’ mechanism

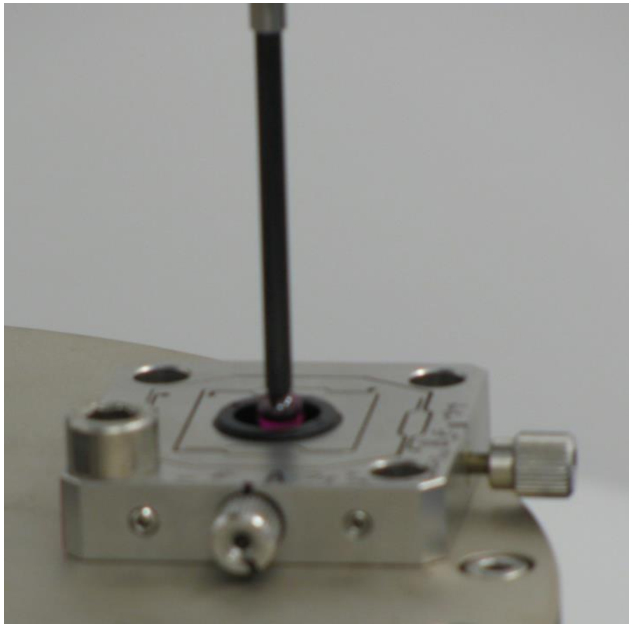
The fully assembled imaging system

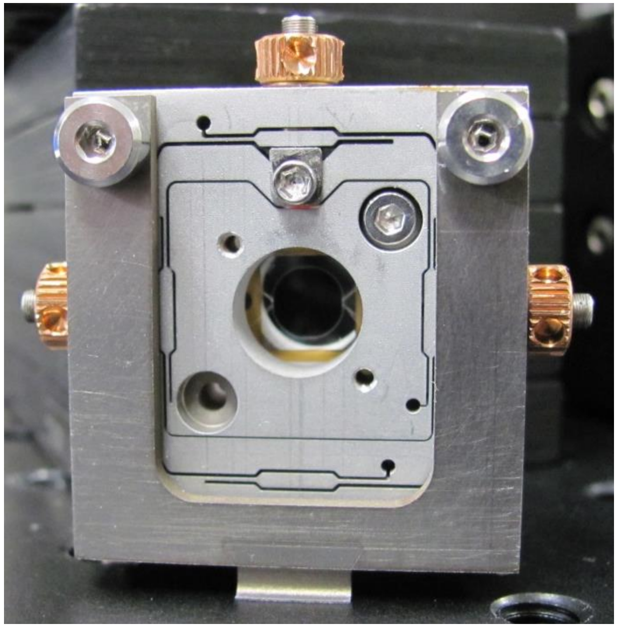
- Overall assembly on its titanium super-baseplate may be moved into position with micron hammers, and precision thumb screws (temporarily mounted on the OB).
- The super-baseplate, sits on its three ball-bearings, is locked in position via three lever-clamps.



Do we know it is all going to work?

- Our flexure-adjuster PD mount design derives from a COTS flexure mount which was tested in conjunction with the CMM.
- Micron-level adjustments were possible.
  - The COTS design although bigger had identical ultra-fine pitch screws.

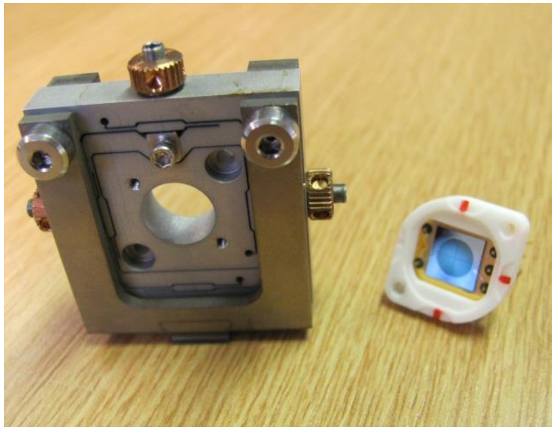


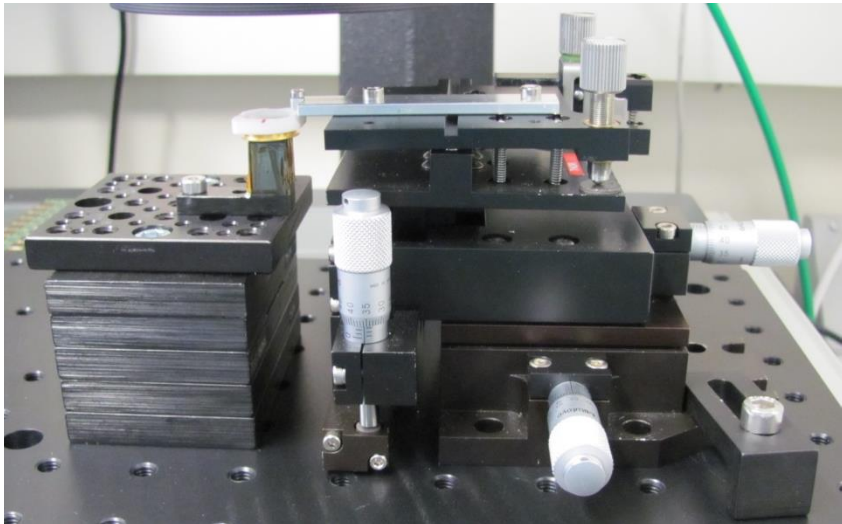


Left: COTS flexure mount; Right: Assembled prototype

Do we know it is all going to work?

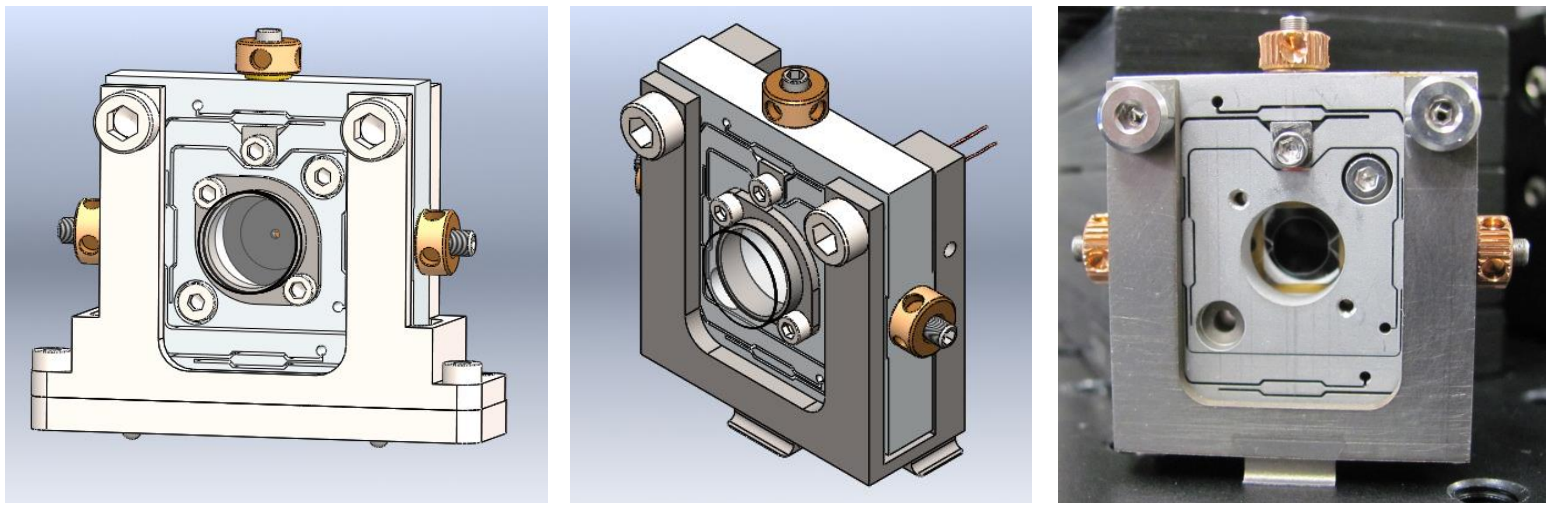
- Mounting the QPD into a MACOR interface collar using a 5 DoF translation stage and an optical CMM
- First try we have achieved so far only partially successful
  - sub-100micron precision of alignment
- Improvements to the technique, interface collar design and a little more care to get to the sub-10micron alignment required





Do we know it is all going to work?

- Additionally we have now tested a prototype of the flexure-adjuster PD mount
  - albeit a different design that has flexure feet to allow permanent glue attachment to a Zerodur baseplate
- Design was then built in to a fibre injector stability experiment



Left: PD Mount design for interchangeable imaging systems experiment;
Centre: Prototype PD Mount design;
Right: Assembled prototype

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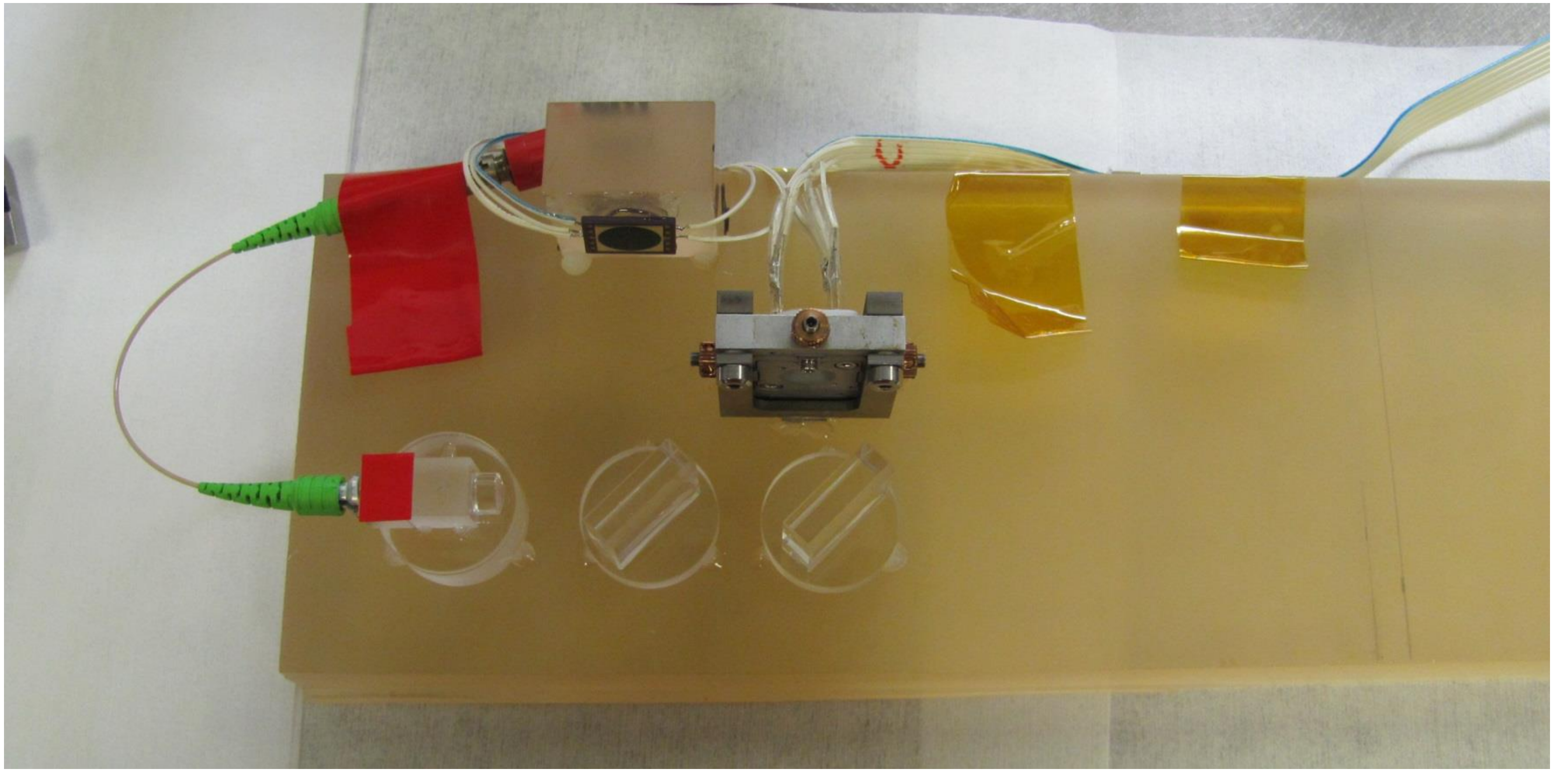
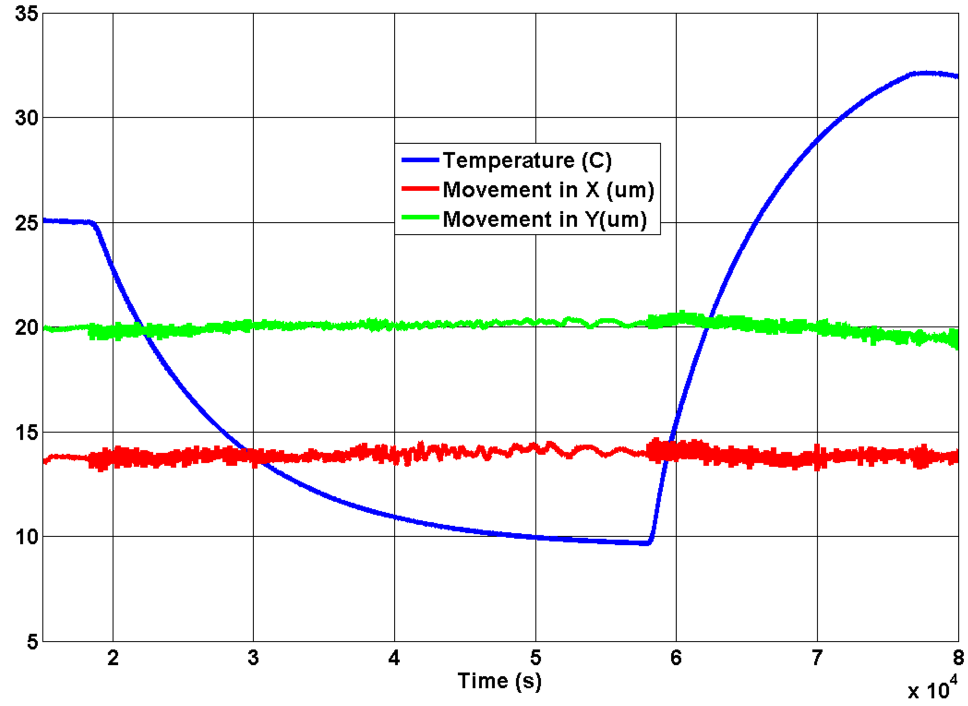
FIOS stability experimental set-up

- FIOS with two beam splitters and three QPDs on a Zerodur baseplate
- Two of the QPDs are mounted to Zerodur posts
- Third QPD is attached to the prototype mount



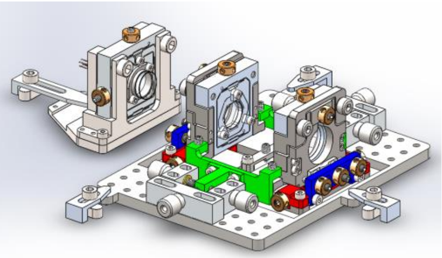
FIOS stability experimental set-up

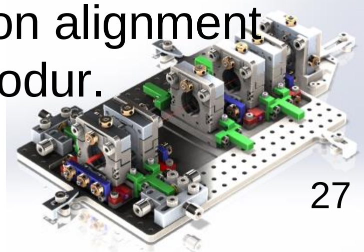
- Experiment is still a work in progress…
- Positive initial results regarding the QPD mount stability
  - Graph below shows the difference in movement between a 'perfectly stable' Zerodur mounted QPD and the Ti-Al mount
  - Temperature cycle starts at ~25degC dropping to 10degC and rising to ~30degC



Conclusions

- We have a challenging time ahead to assemble and test the imaging systems!
- Can these imaging system mechanics be used in future for eLISA?
- Yes, because:
  - The majority of the components in the design are from materials suited to the space environment
  - (fused silica optics, Al, Ti, etc.)
- No, because:
  - The mechanisms were specifically designed for the requirements of this task
  - (it is unlikely that we would want them to be removable!)
- But, we will gain a strong understanding of the imaging systems optical design and this knowledge will lead directly into the OB design for eLISA.
- And, we in Glasgow, have great experience in precision alignment of optics and robust methods of attaching them to Zerodur.





Final Scores

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The last time they met it was…

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The last time they met it was…

…and we'll gloss over the fact that Scotland won't be in Brazil this year! …

Final Scores

…and we've yet to find out who will win in this year's Ryder Cup…

RYDER CUP 2014

GLENEAGLES SCOTLAND 2014

Final Scores

…and we've yet to find out who will win in this year's Ryder Cup…

RYDER CUP 2014
GLENEAGLES
SCOTLAND 2014

Of course, this is not about being competitive!

In Glasgow, it would be our pleasure to collaborate on eLISA with the USA, and for that matter all of our LISA friends around the globe.

Thank you.