

The logo consists of a dark gray square on the left. Inside the square, a white circle is partially visible, with its right side overlapping the square's edge. To the right of the square, the word "ptikos" is written in a dark gray, lowercase, sans-serif font. A registered trademark symbol (®) is located at the top right of the letter 's'.

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Opto-Mechanical Techniques for Compensation of High-Performance Imaging Lenses

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Overview

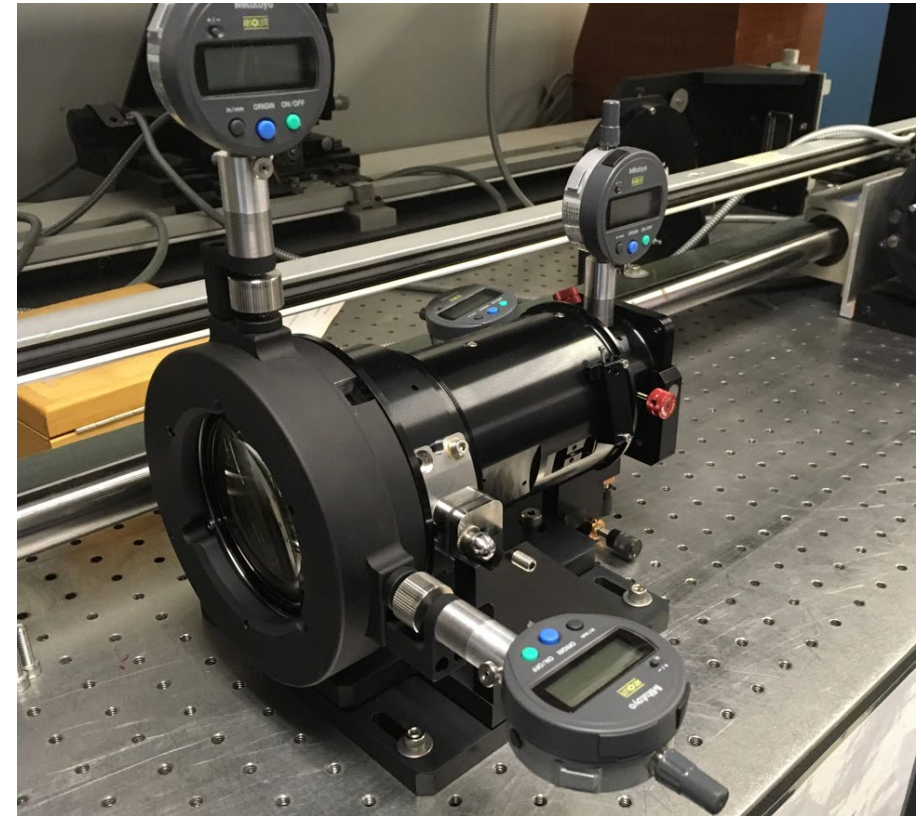
- Brief details on optical compensators
- An example optical system and the elements used for compensation
- Opto-mechanical implementation of external compensation mechanisms
- Opto-mechanical implementation of internal compensation mechanisms
- Closing remarks



Image from nearmap.com

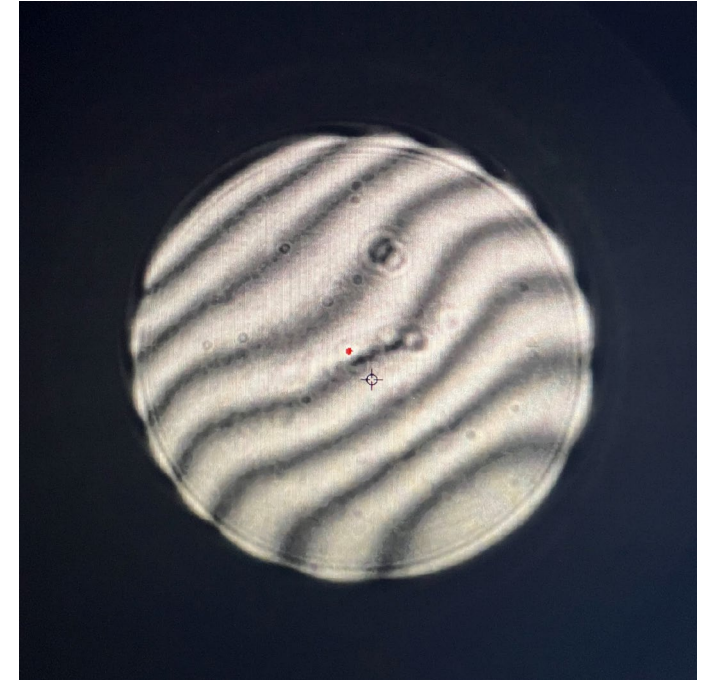
What are Optical Compensators?

- Adjustable optical elements intentionally built into the system
- Help recover performance lost due to alignment and manufacturing errors
- Can be used to correct specific aberrations: coma, astigmatism, etc.



Why are Compensators Needed?

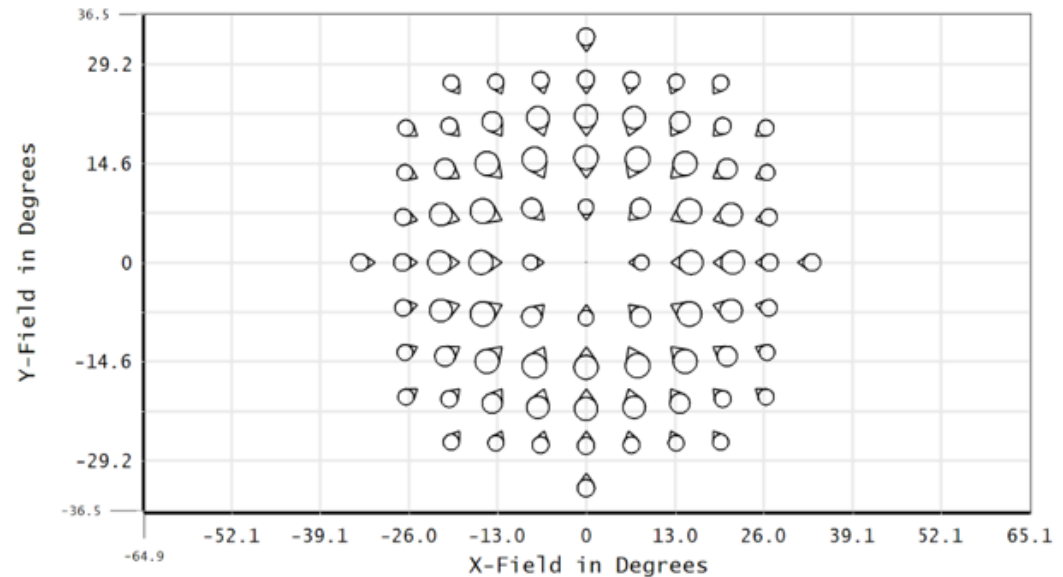
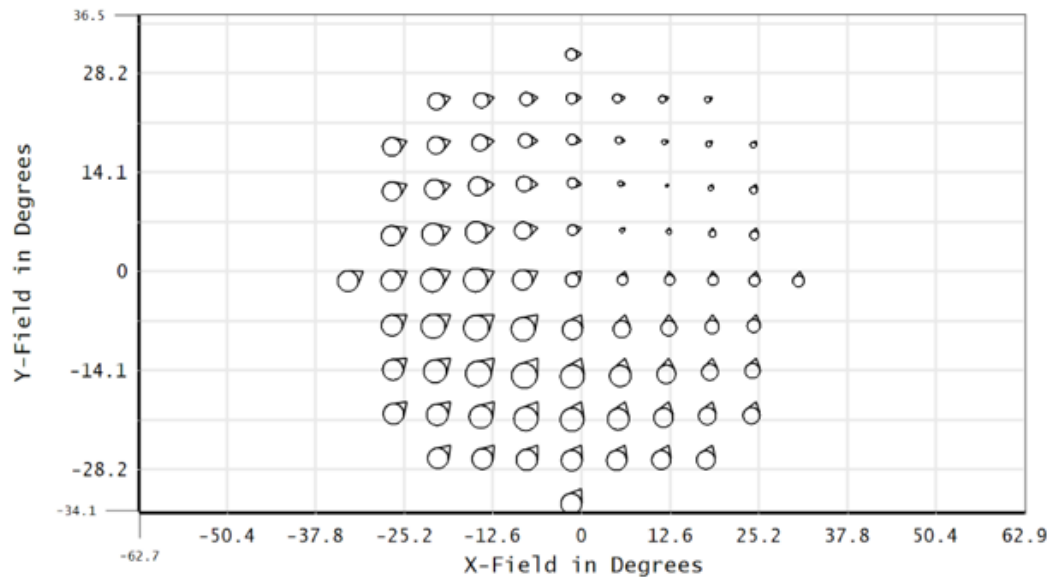
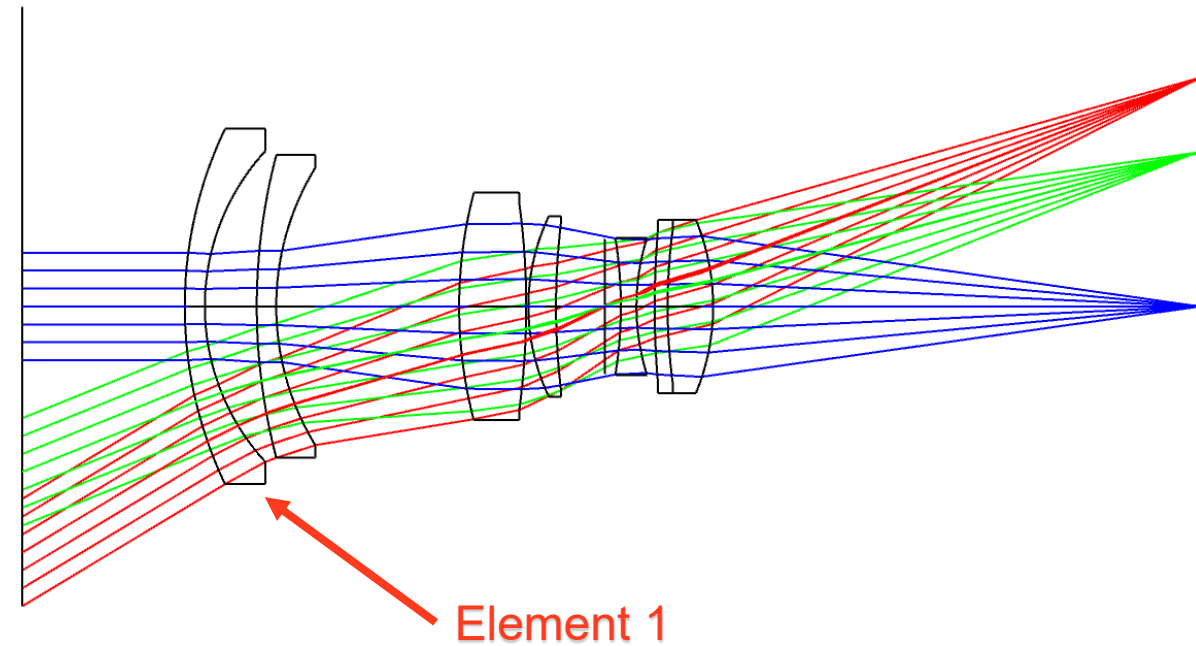
- Wait?! – I already toleranced my lens system and my Monte Carlo simulation shows good yields...
- Optical compensation is about performance recovery – making a low performer into a high performer
- Optical compensation can help reduce system to system variability
- Not all systems will require compensation, but designing it in can help reduce build risks and enhance optical performance



Non-ideal wavefront error for a lens prior to compensation

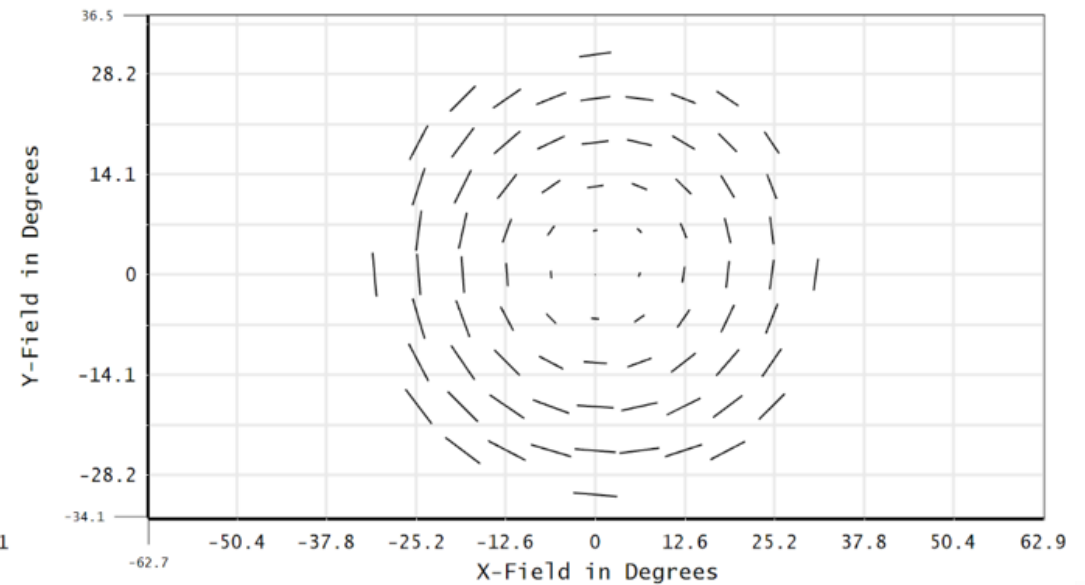
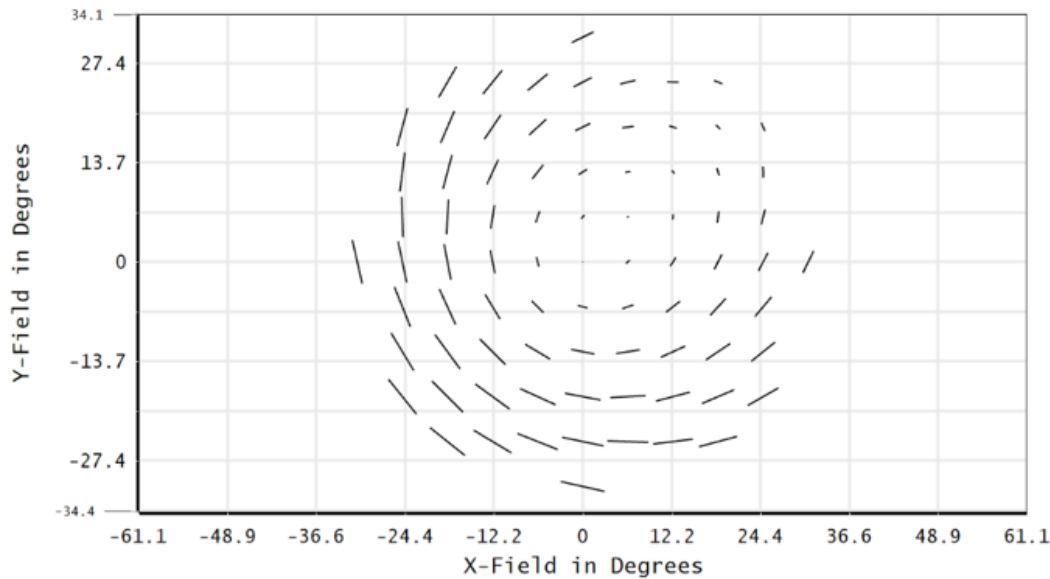
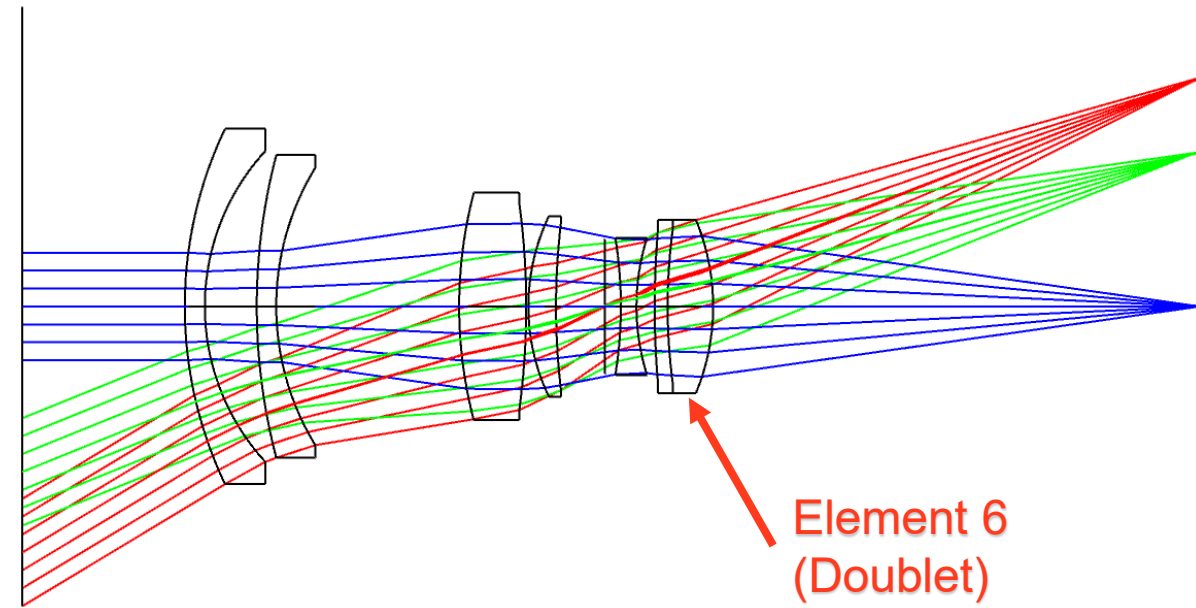
Optical Compensator Illustration

- An example can be seen with the system to the right
- Laterally displacing element 1 moves the zero coma point
- This element can be used to null coma on-axis



Optical Compensator Illustration

- Laterally displacing element 6 moves the zero-astigmatism point
- This element can be used to reduce astigmatism on-axis, but primarily can be used to balance astigmatism across the field
- It should be noted that optical compensators may have some smaller effects on other aberrations

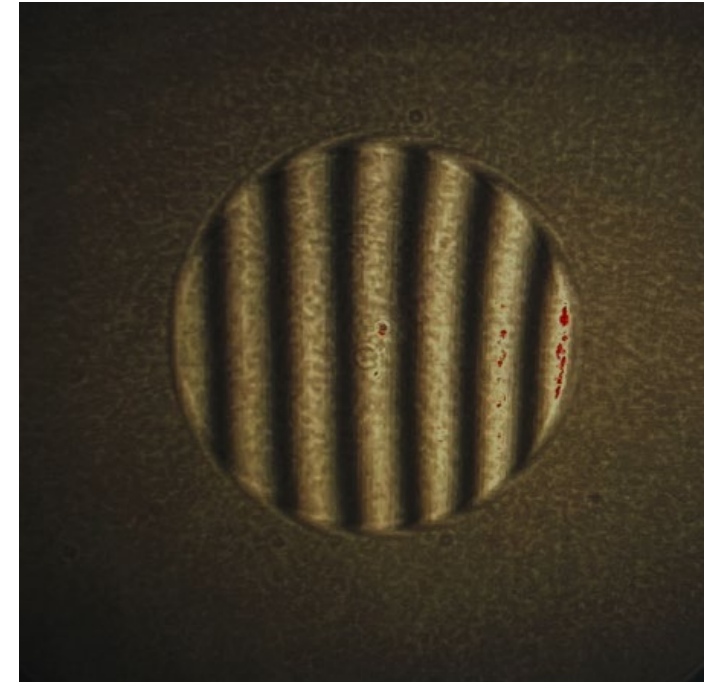


How Do We Move The Lenses For Compensation?

- Motion for compensation needs to be precise and deterministic
- Precision requirements will be in the single digit micron range
- There are a few architecture choices
 - External adjustment mechanisms
 - Internal adjustment mechanisms

What are We Measuring?

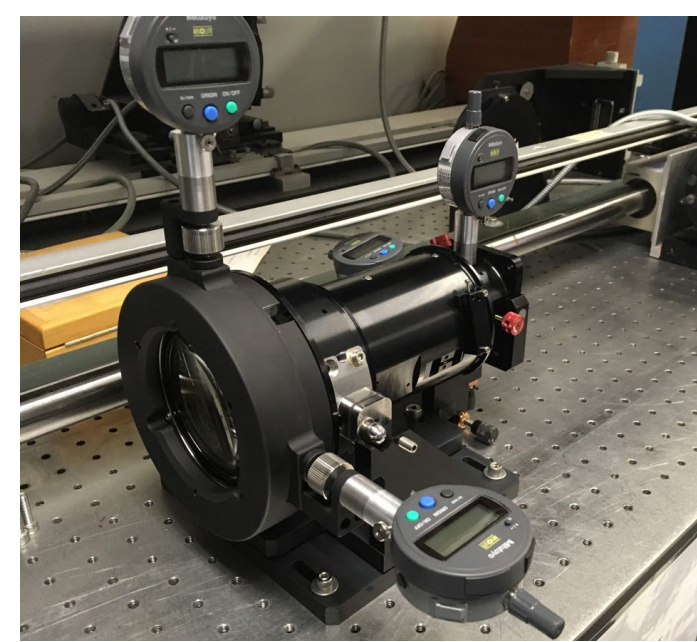
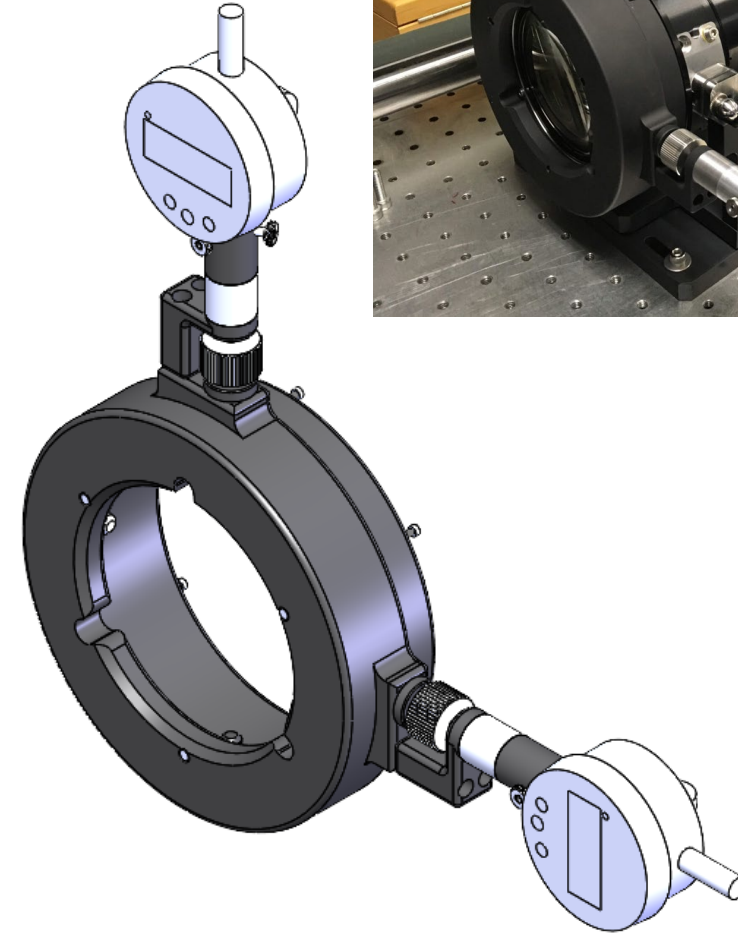
- Optical compensation typically takes place in front of an interferometer
- Interferometers are particularly useful as individual aberrations can be evaluated separately
- On-axis performance is easy to evaluate and gives insights into the performance
- For field performance or off-axis balancing, either an interferometer or MTF test system can be used



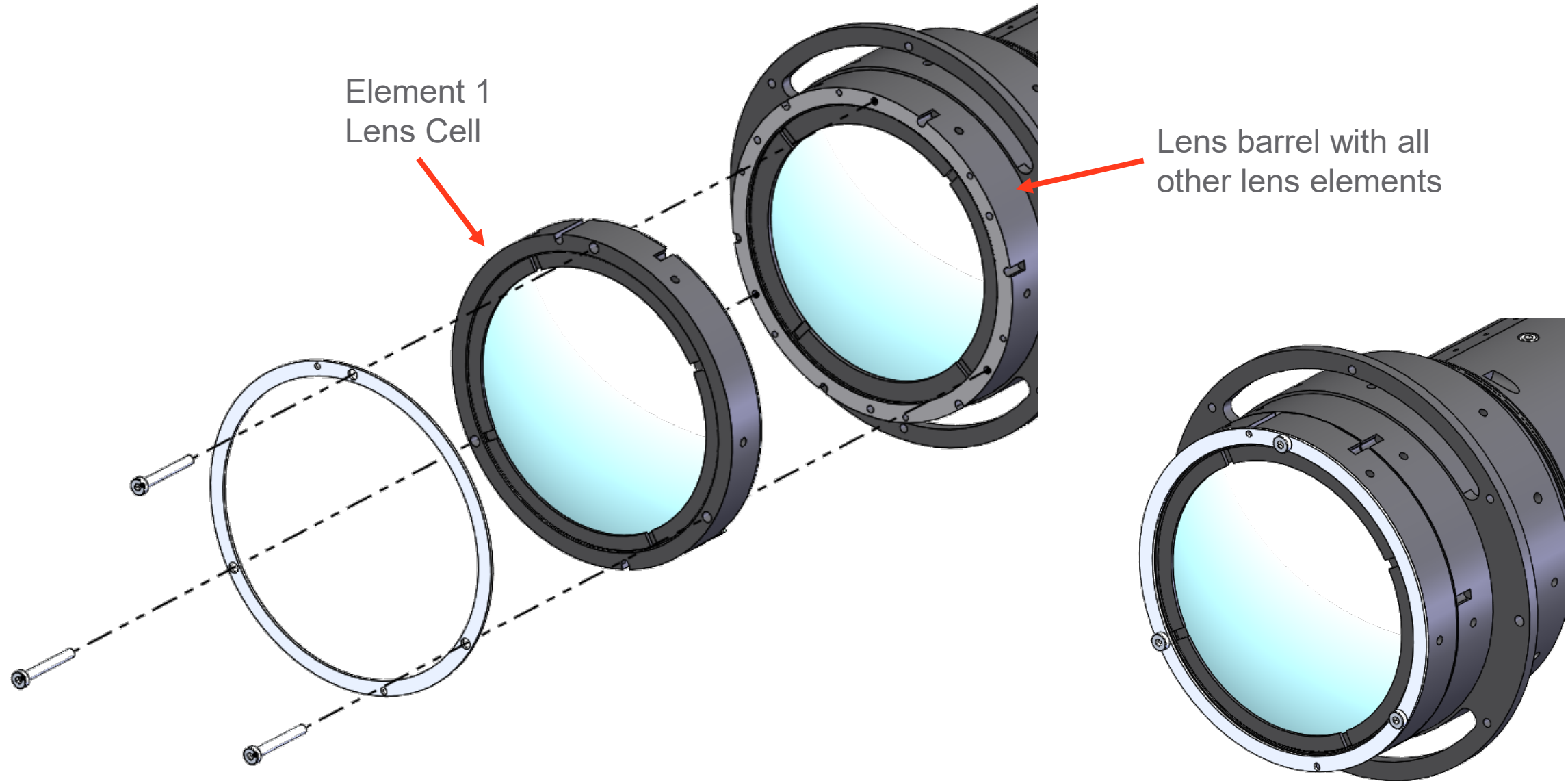
Wavefront after compensation

External Lateral Compensators

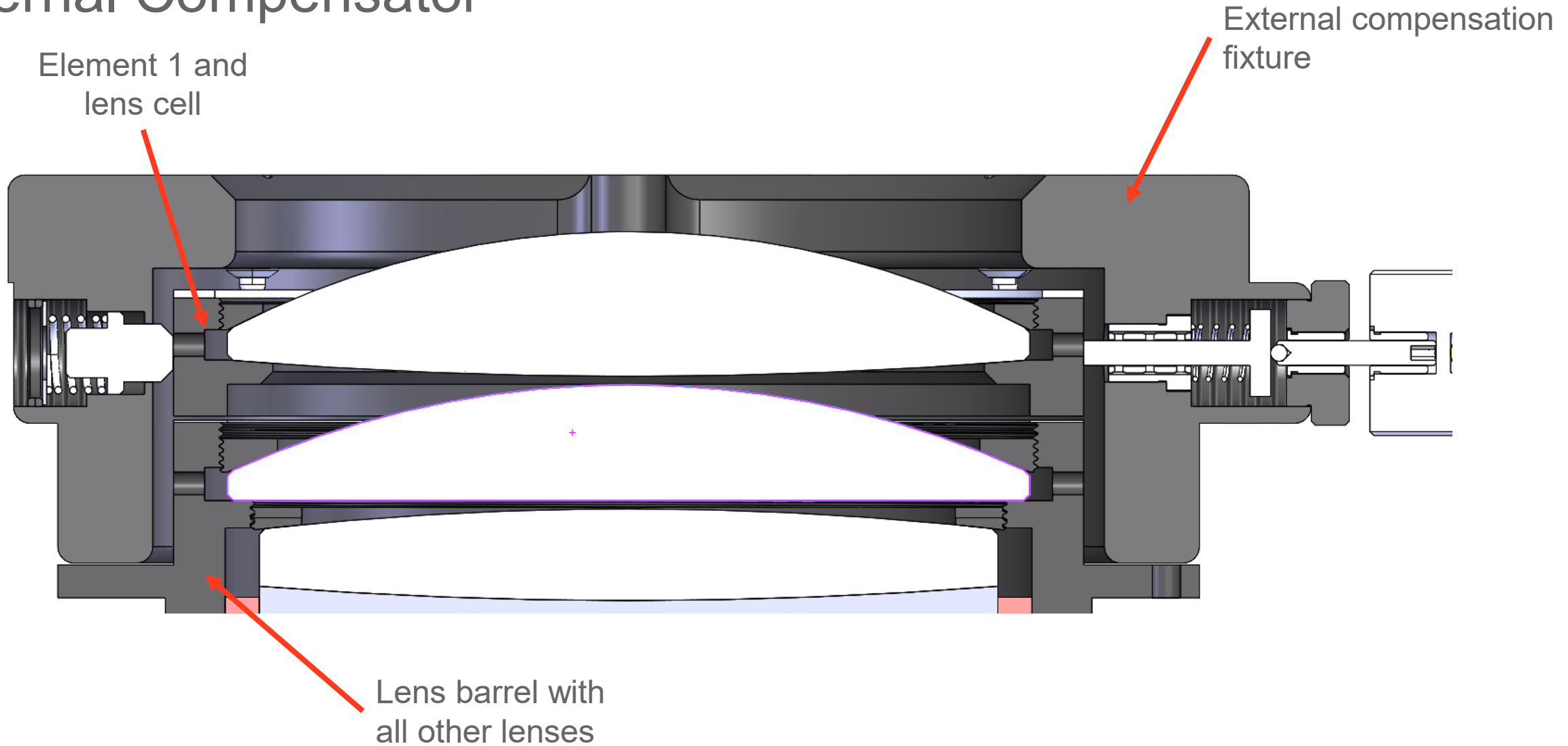
- External fixture mounts to the lens system
- In this case, element 1 is housed in a separable lens cell that can be laterally manipulated with the compensation fixture
- Fine pitch screws provide the precision adjustment and digital gauges allow for sensing positional movements



External Compensator – Starting Architecture

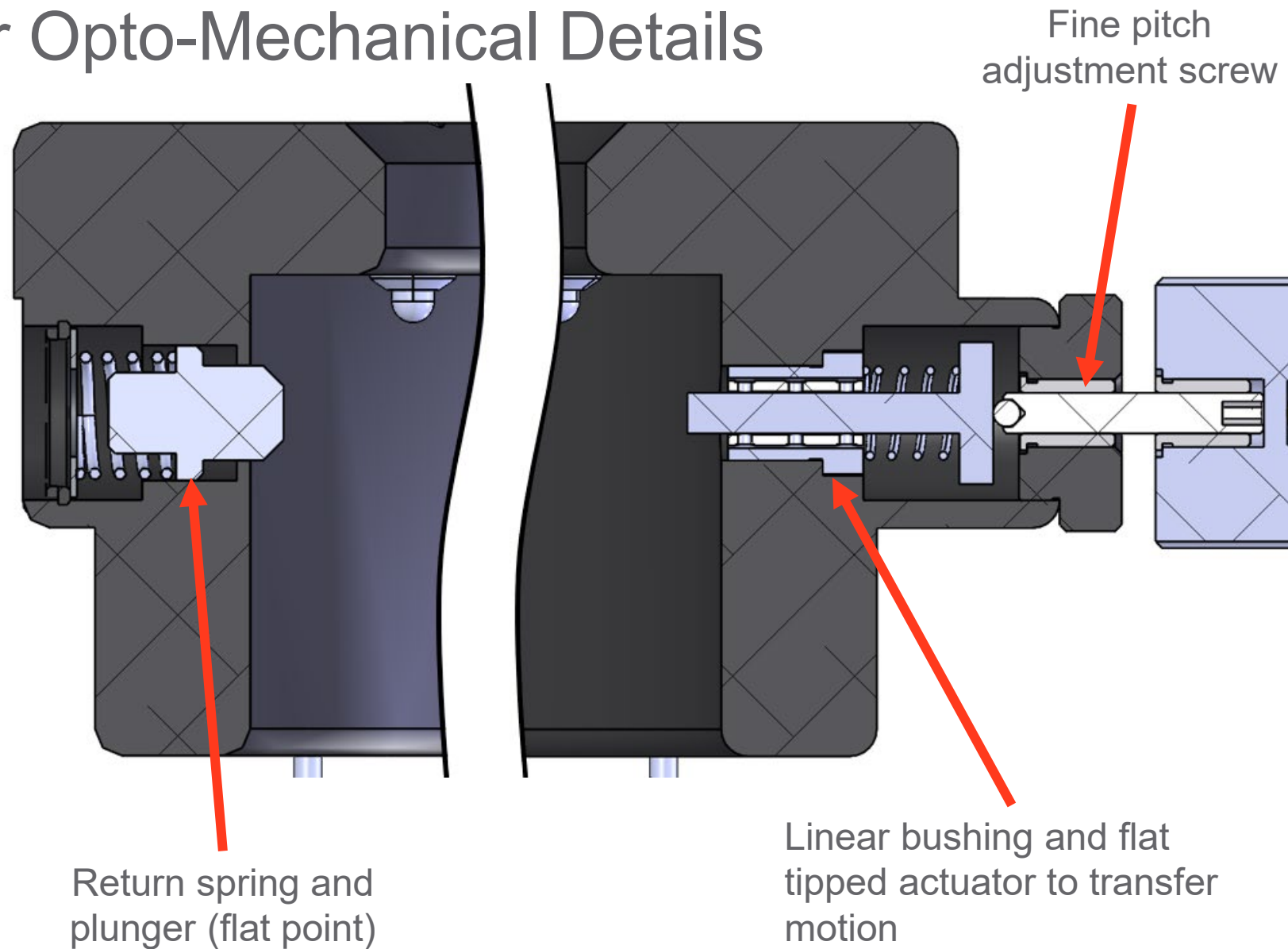


External Compensator



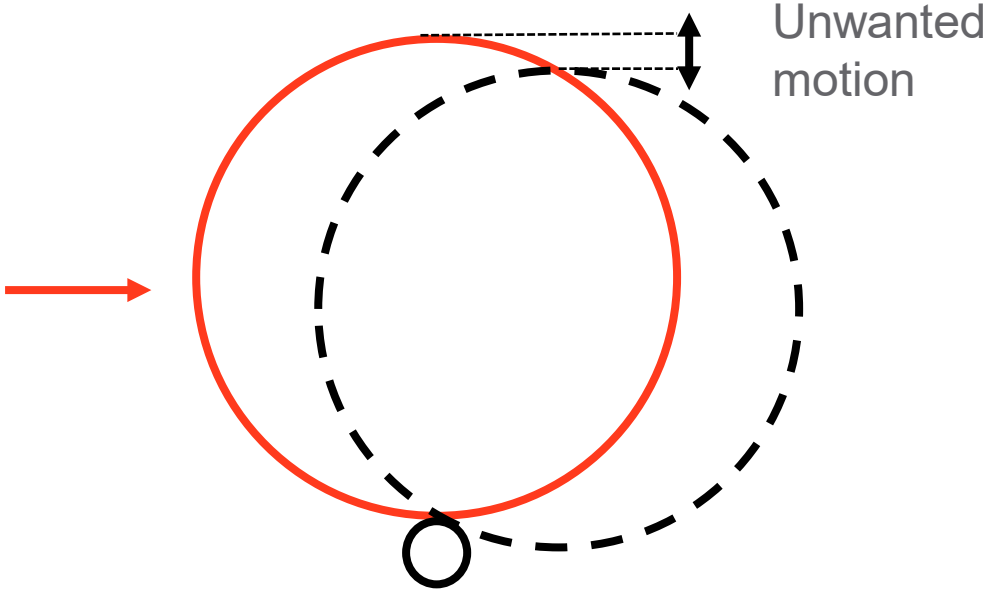
External Compensator Opto-Mechanical Details

- Foreshortened cross section (lens cell not shown)
- Spring plunger provides restoration force
- Fine pitch screw provides precision adjustment
- Linear bearing support the actuator that pushes on the compensator lens cell (flat contact)

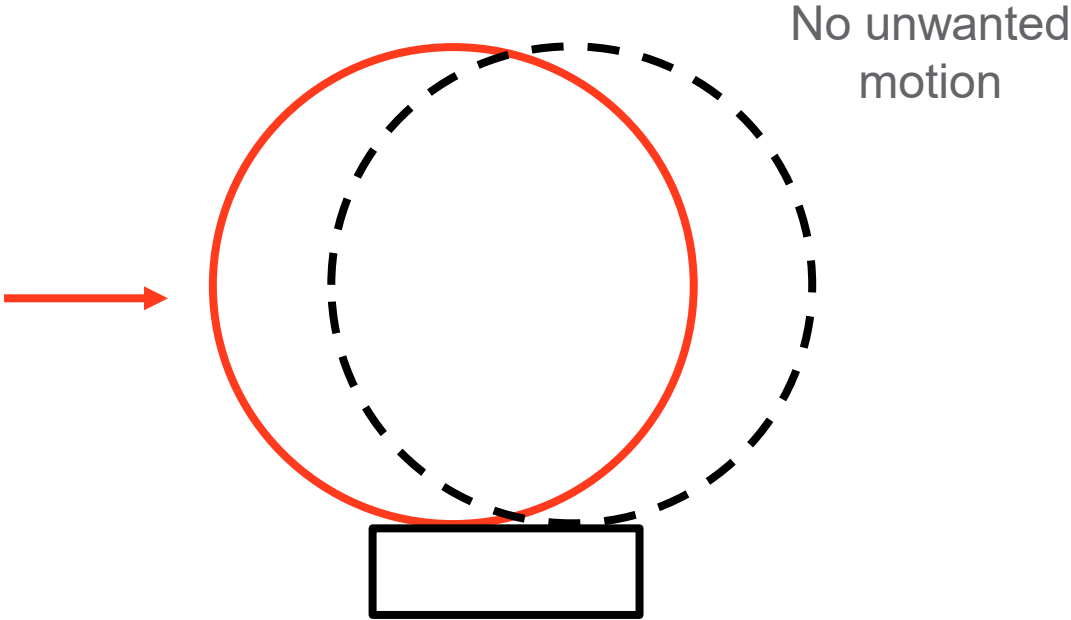


Avoiding Coupled Motion

Spherical Contact on Outside Diameter

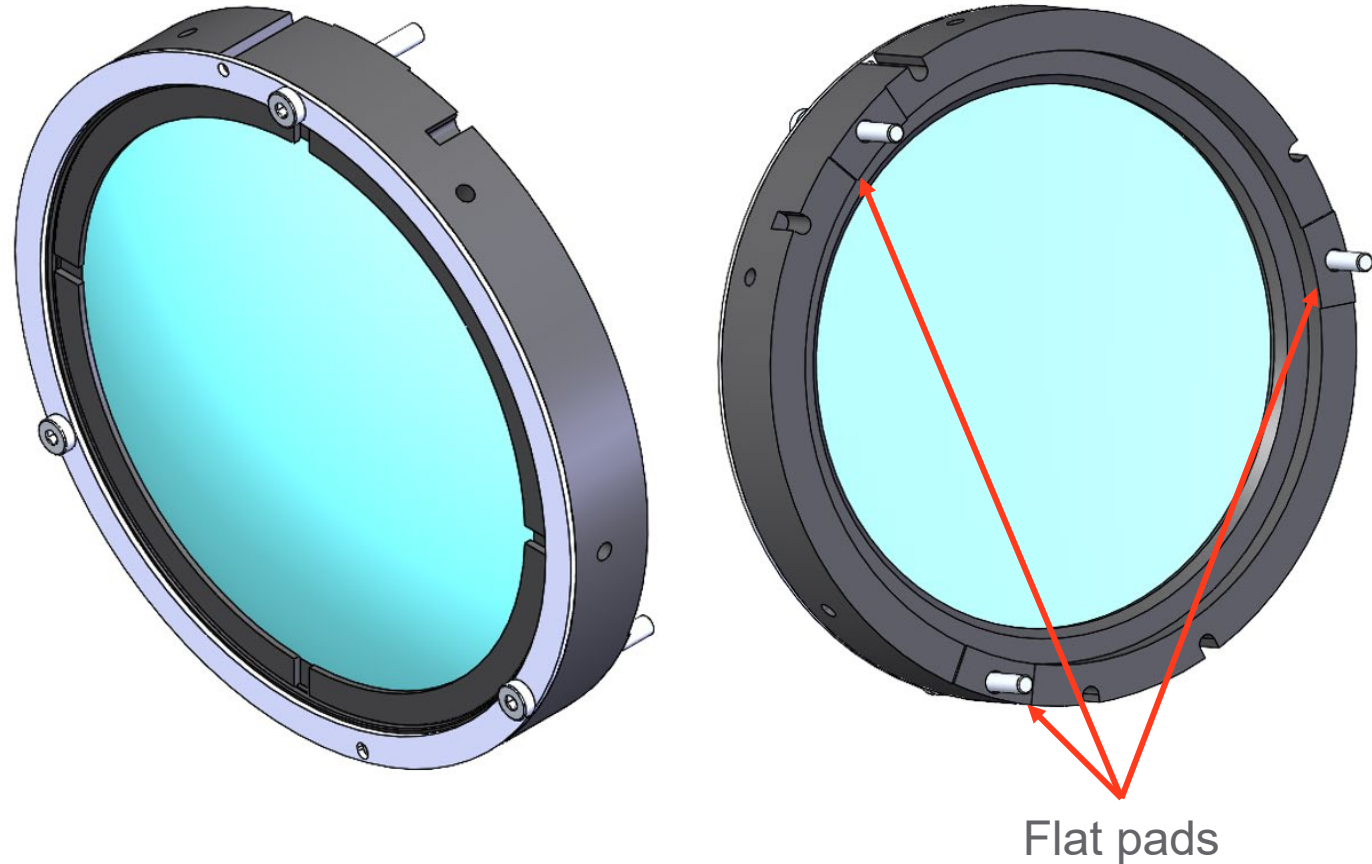


Flat Contact on Outside Diameter



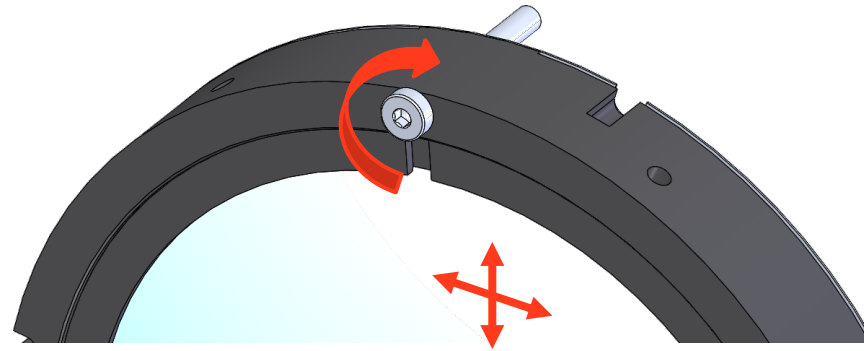
External Compensator Lens Cell Details

- 3 flat pads on back of cell interface with lens barrel
- Clamp plate on front of cell provides axial loading with minimal errors when tightening axial screws

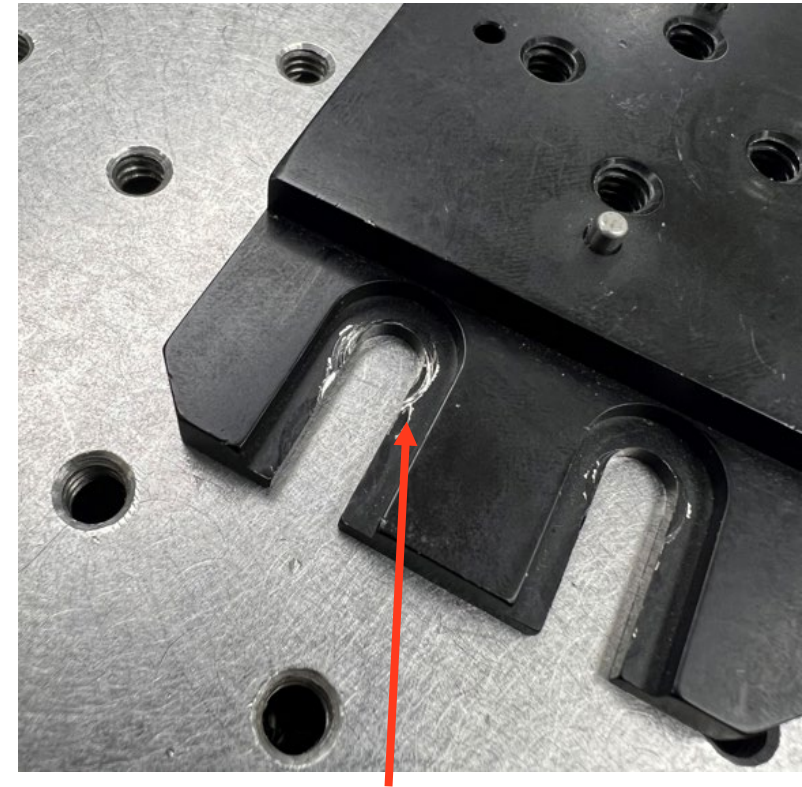


External Compensator Lens Cell Challenges

- Locking fasteners can 'bite' into the lens cell and cause unwanted motion when tightening
- At the micron level for precision, a washer may not offer enough of a mitigation against unwanted motion during locking



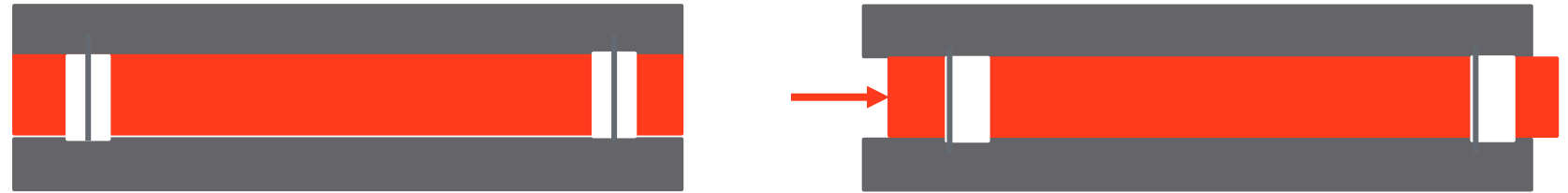
Tightening a screw can lead to small unpredictable motions



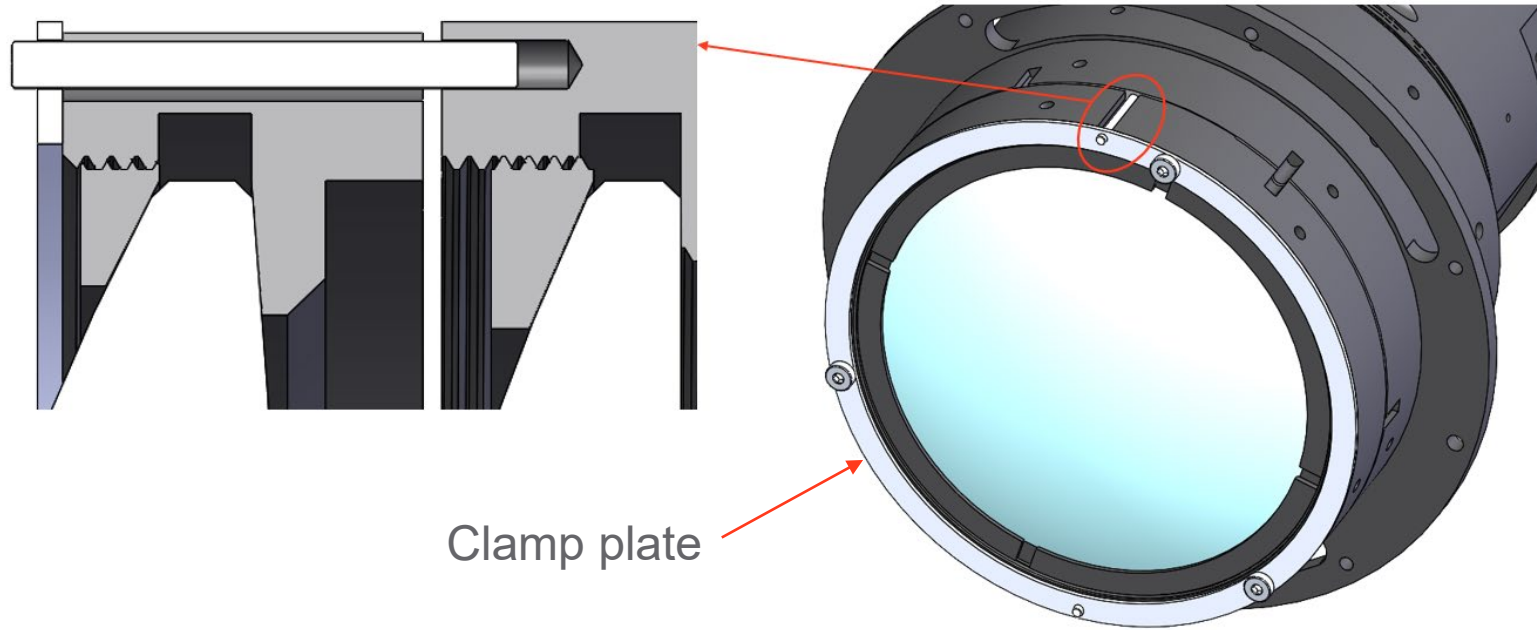
Fastener 'bite' marks shown on an optical breadboard component

External Compensator Lens Cell Clamp Plate

- A clamping plate or 'idler' plate can be used to provide resistance to unwanted motion when tightening fasteners
- A conceptual example shows three plates, with the red plate as the movable cell
- Pins provide the 'earth' connection to tie the clamp plate and lens barrel together



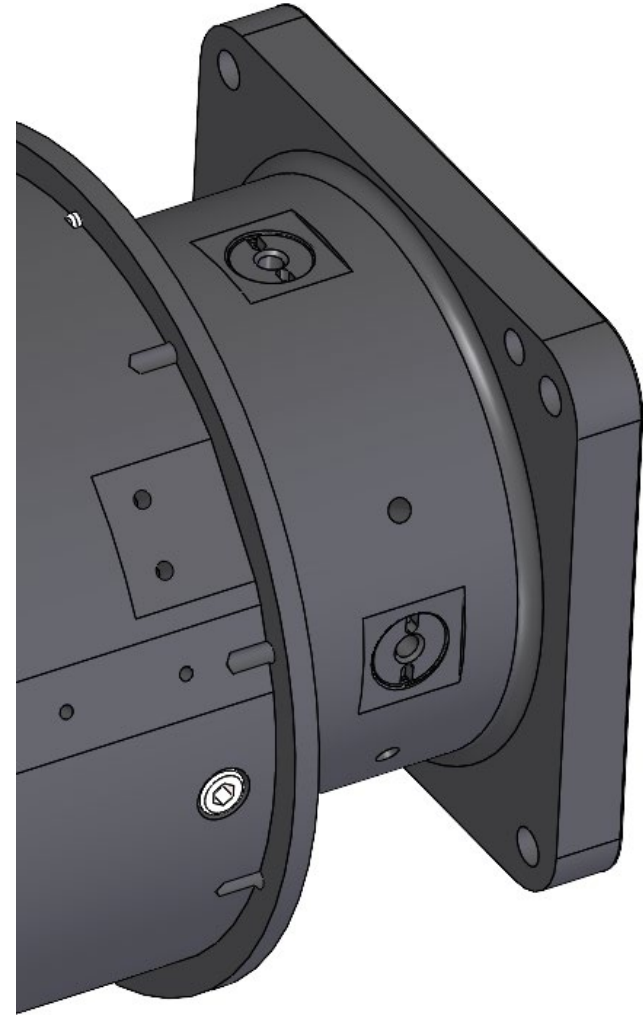
Gray plates are connected, only the red plate can move laterally



Clamp plate

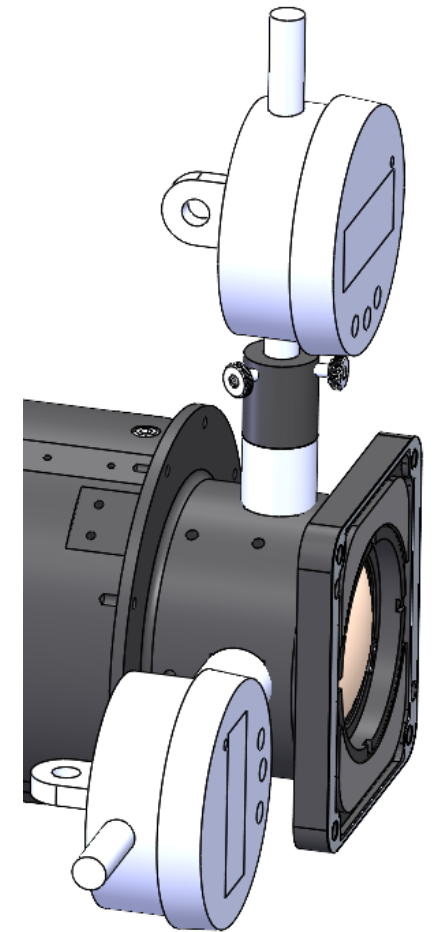
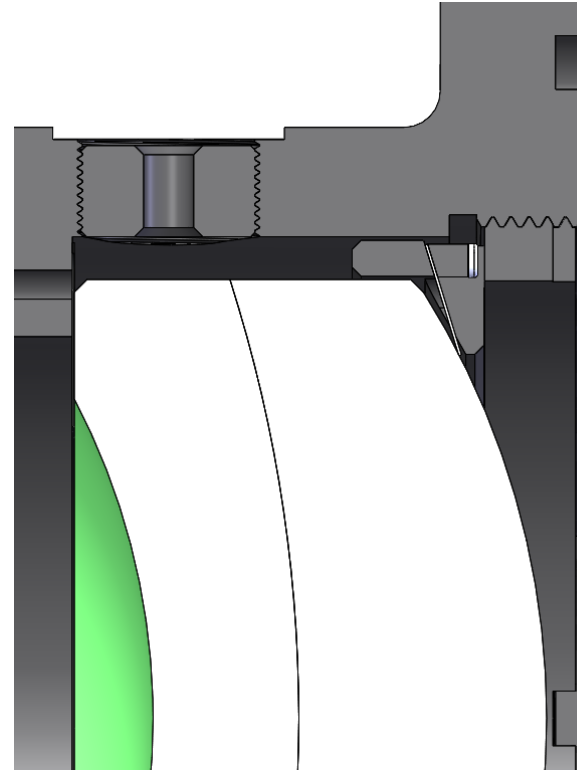
What About Space Limitations?

- Sometimes it is not possible to attach an external fixture to a lens
- Alternatively, an adjustment may need to be made periodically or during additional integration steps outside of the core lens assembly



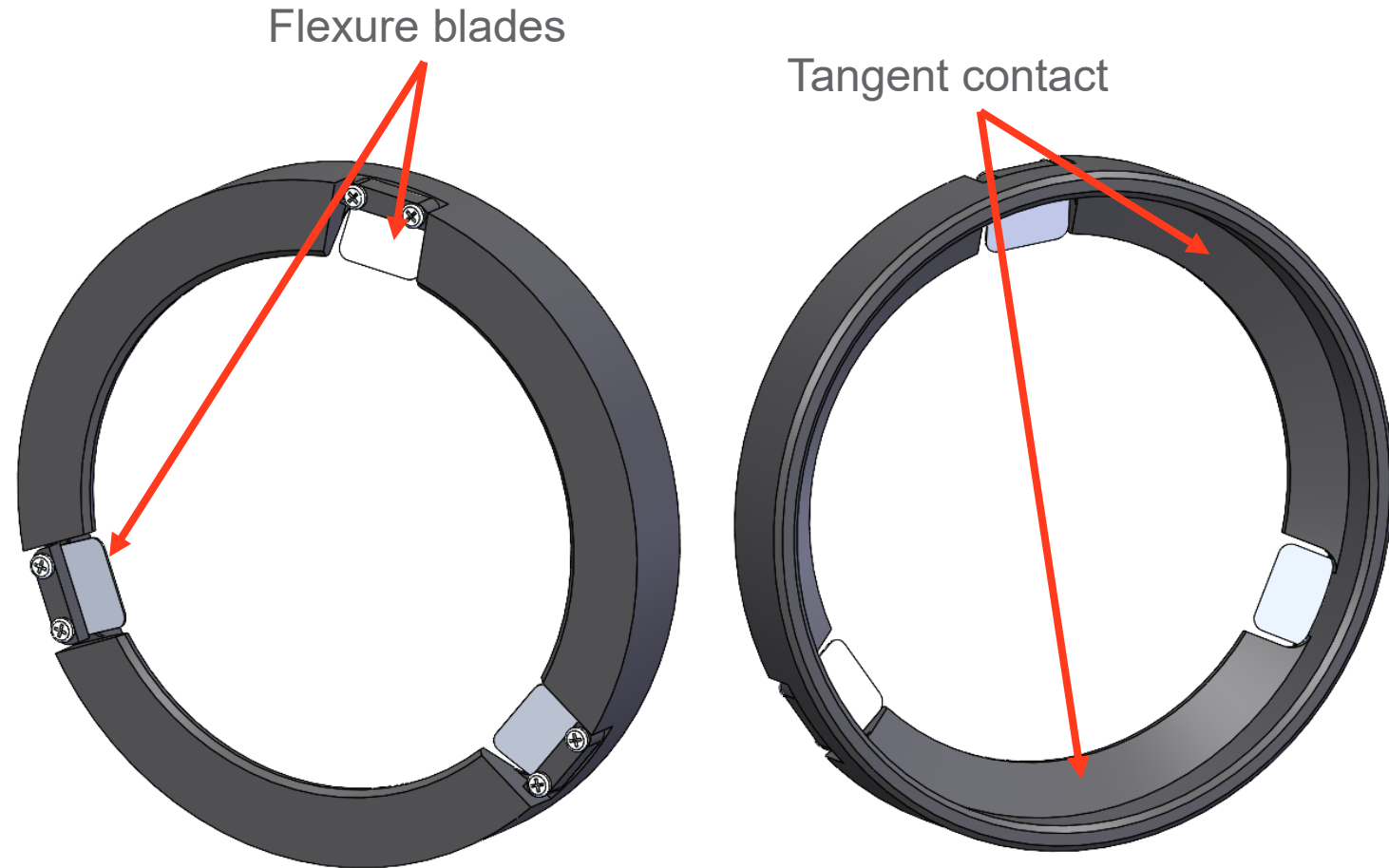
Internal Lateral Compensators

- When space is limited or external fixtures are not possible, internal compensation methods can be used
- In this case actuators are separable, but they could be simple adjuster screws fixed to the lens barrel
- A tangent spacer with 3 flexure tabs provides the axial preload force, while allowing lateral motion of the lens element (doublet lens)
- This lens contacts the barrel on a flat annulus and is easier to laterally position, lenses on convex or concave may 'roll' on the lens seat, which may not be ideal for compensation



Internal Compensator Opto-Mechanical Details

- 3 flexure blades make contact to the lens and provide spring preload
- The spacer has clearance within the barrel bore to provide motion range
- After compensation, when the spacer is fully seated, the machined tangent face makes contact with the lens surface for a more secure mounting scheme



Closing Remarks

- Opto-mechanical compensators can be a great way to maximize performance in a lens system
- These compensators can help correct for non-idealities in the build or alignment and can be designed to target specific aberrations
- External compensators allow for more complex or costly mechanisms to provide the adjustment while not contributing to the system level cost
- Internal compensators provide flexibility when space is limited while still producing precision adjustment and firm retention
- These are not the only implementations of opto-mechanical compensators, there are many other ways to accomplish this task

Thank You!



Questions?

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Anywhere light goes[®]