Experimental Design for Testing the Mechanical Constraint Effects of Eutectic Gallium-Indium

SLAC NATIONAL ACCELERATOR LABORATORY

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Background

LCLS II will use a pair of focusing optics (KB mirrors) to focus the X-ray to the interaction region of the endstation. Due to the high power nature of the beam, these mirrors must be cooled to prevent thermal deformation. To mechanically decouple the cooling system from the mirror, Gallium-Indium (GaIn) will be used as a thermal bridge between the top side of the mirror and the cooling system. Before this solution can be implemented, data on the force transmitted through the GaIn to the mirror must be acquired. This project utilizes the zero-backlash nature of compliant mechanisms to design a stage with a precision necessary to carry out the required measurements.

Keywords: LCLS II, mirrors, cooling, GaIn, flexure

Problem Statement

This project addresses the need for accurate data on forces applied to high precision optical mirrors by a cooling device through a coating of GaIn. This flexure based design will have to be capable of delivering significantly more accurate data than previous designs. To attain this high degree of accuracy, the pre-loaded flexure will be moved by a picomotor Piezo linear actuator, which will make it possible to control the positon of the mirror attached to the flexure to an resolution of 30nm.

Design Criteria

Criteria	Measurement	Success
Securely Hold Mirror	The mirror should not measurably move at all within the secure mirror housing.	✓
Expose Both Sides of Mirror	Leave >90% of both sides of the mirror exposed. [~93.6% exposed]	✓
Shift Mirror	Range of motion >1 mm in a single direction.	✓
Eliminate Backlash	System should have no measurable backlash.	✓
Restrain Movement	The flexure should have only one degree of freedom.	✓
Multipurpose	Flexure base should compatible with a standard ¼" 20 optical breadboard.	✓
Low Force Needed for Motion	Must move >.5mm when a force of ~10N is applied to the base of the flexure by the picomotor.	✓
Durability	Max. stress on flexure leaves must be < $6 \cdot 10^8$ Pa.	✓
Manufacturable	All parts must be able to be made in on site machine shop.	✓

Design

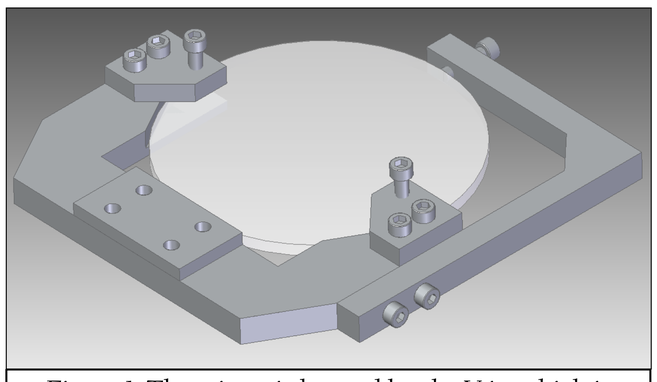
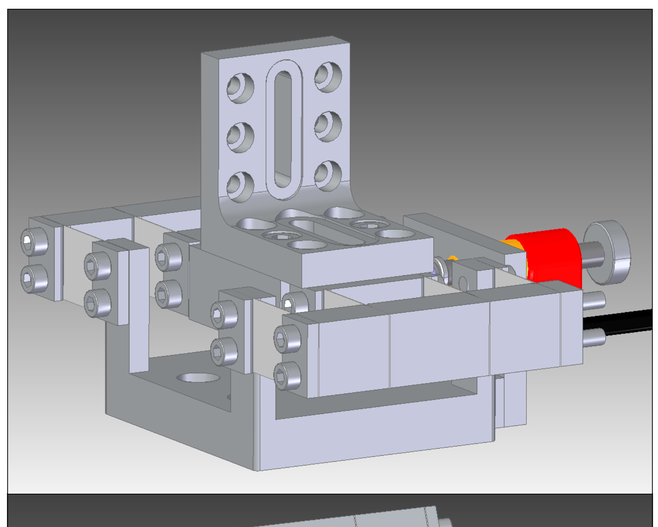


Figure 1: The mirror is located by the V in which it rests, and is secured by three nylon tipped screws, one on the top of the mirror and one on either side.



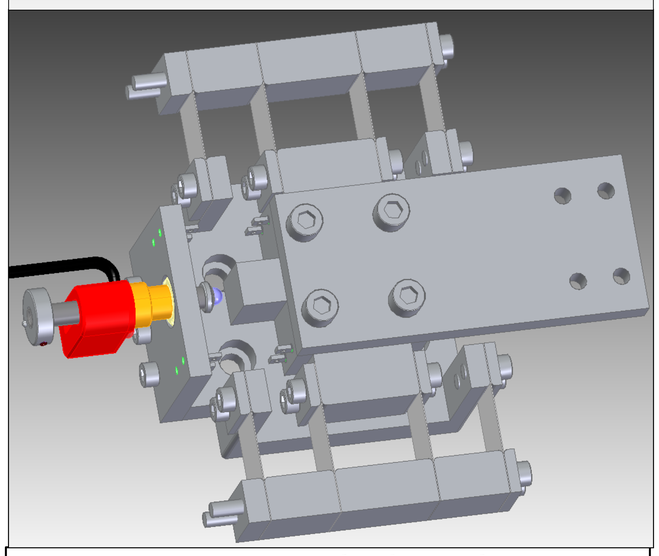


Figure 2 & 3: Horizontal and vertical mounts, respectively. The titanium flexure leaves themselves are only .01 inches thick, but capable of supporting more than 60N of force.

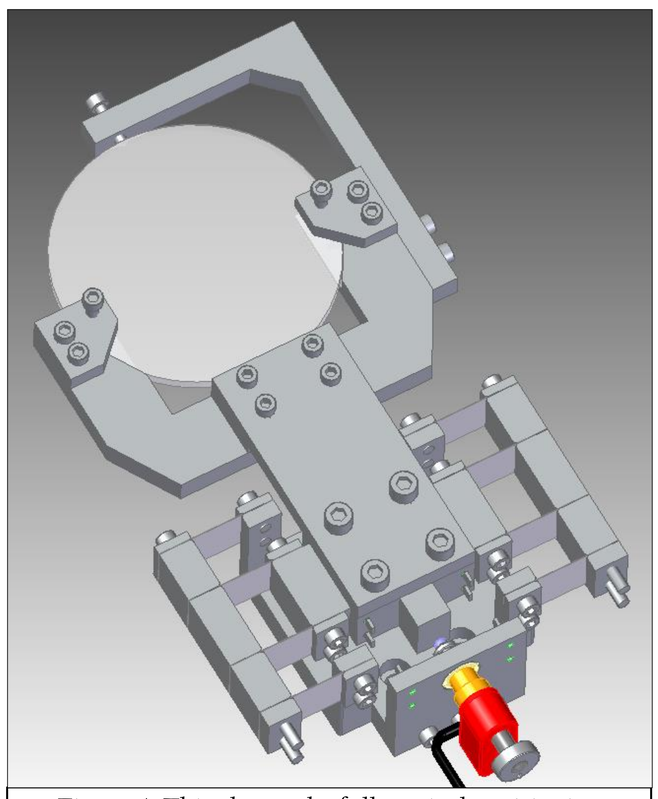


Figure 4: This shows the full vertical positioning orientation for the design.

Production

Figures 5 & 6: These technical drawings are used to communicate the exact nature of the desired parts to the machine shop where they will be made.

Technical Specs

Flexure:
- Material: **Titanium Ti-6Al-4V**
- Range of Motion: **12.70mm**

Picomotor:
- Range of Motion: **12.70mm**
- Axial Load Capacity: **22N**
- Positioning Resolution: **30nm**

Full Assembly, Including Picomotor:
- Vertical Orientation: **296mm x 147mm x 58mm**
- Horizontal Orientation: **216mm x 169mm x 140mm**

Conclusions

The finished product meets all design criteria. Future work for this project includes manufacturing and assembling the design, and then using it to conduct tests that will produce data that is expected to be significantly more accurate than previous data, which will aid in the design of high precision mirrors that will focus the X-ray beam produced by LCLS II.

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