

CDS Hardware Update

High Reliability Ultra-Fast Shutter (HRUF)

D2200426-v1

Update 11/22/23

Dean Schaetzl for the CDS group

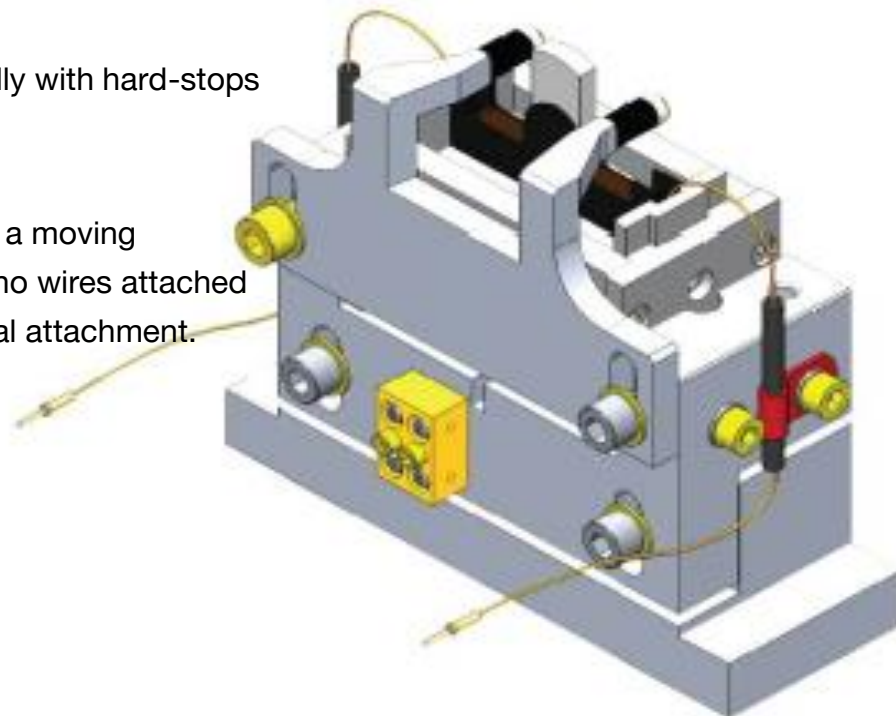
Fast Shutter Upgrade

High Reliability Ultra Fast (HRUF)

Responsible: D. Schaetzi
Updated: September 25, 2023

ECR: E1900177 DCC: E1900180

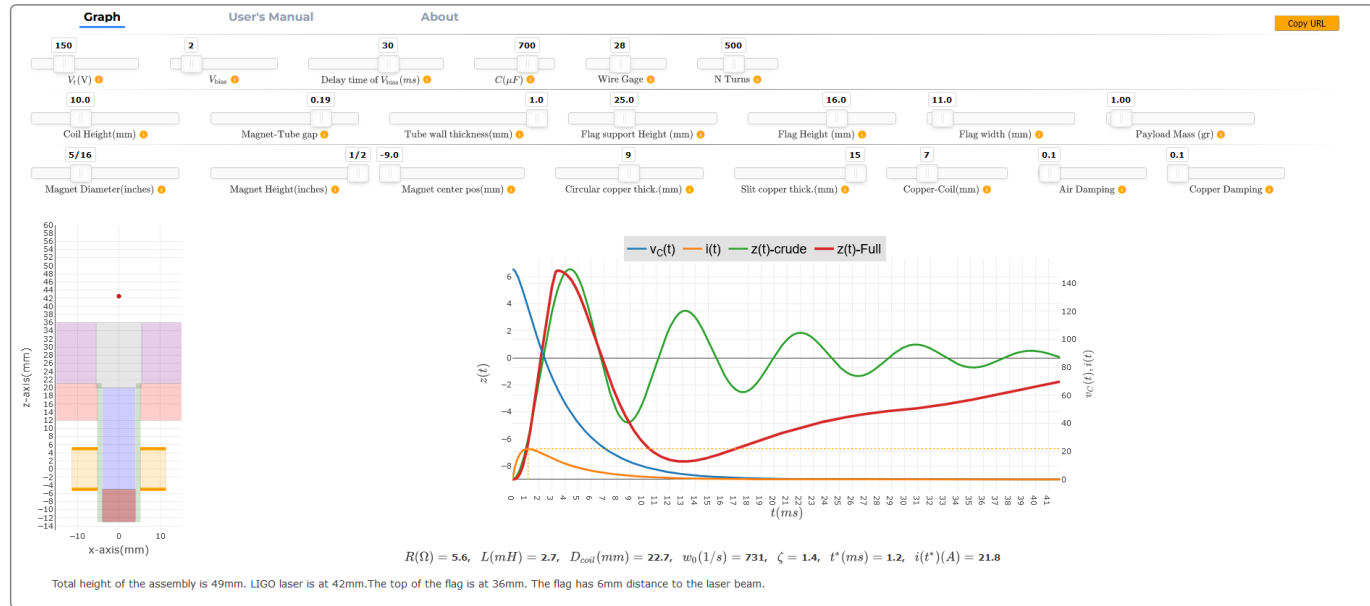
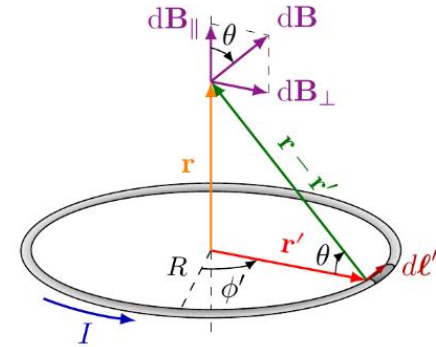
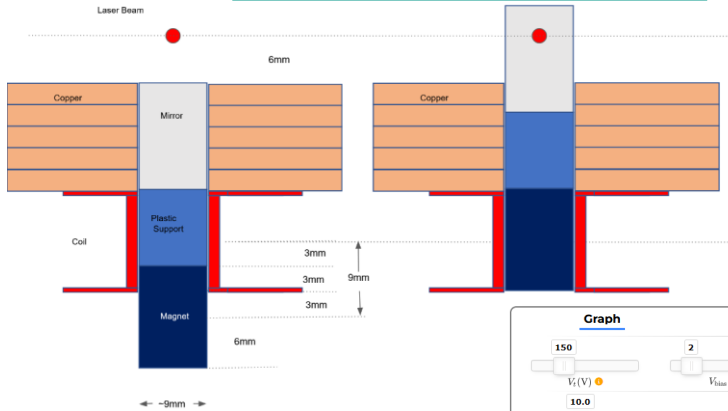
- Why do we have a Fast Shutter?
 - Optical energy stored in the LIGO arms during normal interferometer (IFO) operation is dumped into the antisymmetric (AS) port upon loss of lock. **The stored energy can be of order 50J**, which appears at the AS port as an optical transient lasting a few tens of milliseconds. In order to protect sensitive photodetectors in the AS port beampath from damage, a shutter is required to quickly block the laser beam upon a lock-loss event
- Current Fast Shutter design (D1003318)
 - Wires are attached to the moving parts
 - Work Hardening
 - Arresting of the shutter is done mechanically with hard-stops
 - Stress
 - Debris
 - Physical Shock (Stopping)
- New electro-magnetic ultra-fast shutter design of a moving payload consisting of magnets and a mirror with no wires attached
 - A non-moving coil requiring electrical attachment.
 - Self Arresting



Fast Shutter Upgrade High Reliability Ultra Fast (HRUF)

- How do we make it better?
 - We first want to build a mathematical model of the system to understand the parameters we can tune to optimize the behavior. ([modeling](#) by Serkay Ölmez)

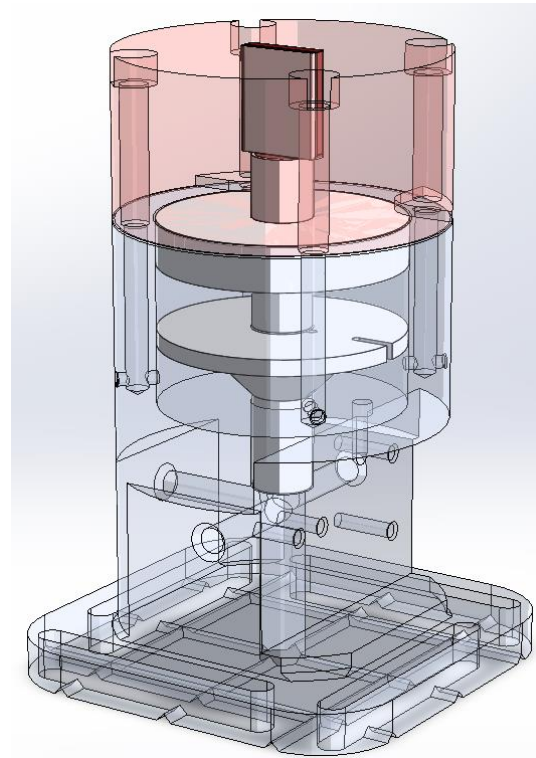
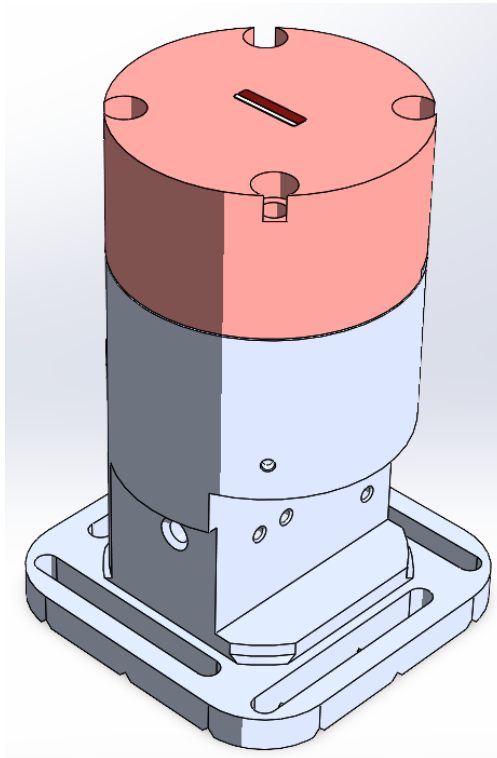
Real-Time Fast Shutter Simulator



Fast Shutter Upgrade

High Reliability Ultra Fast (HRUF)

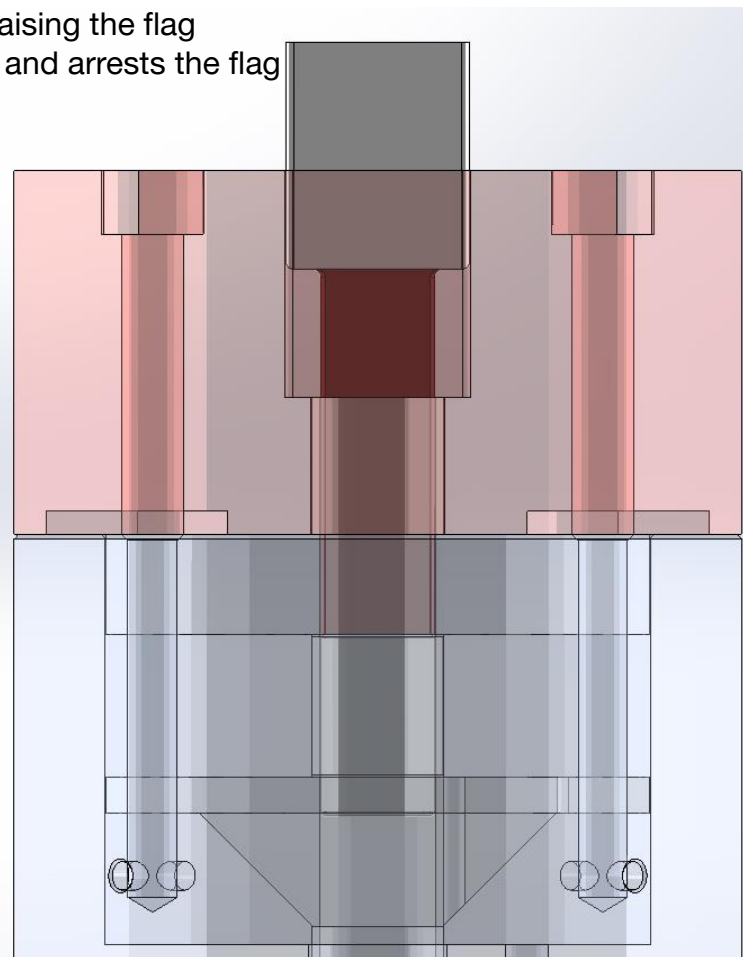
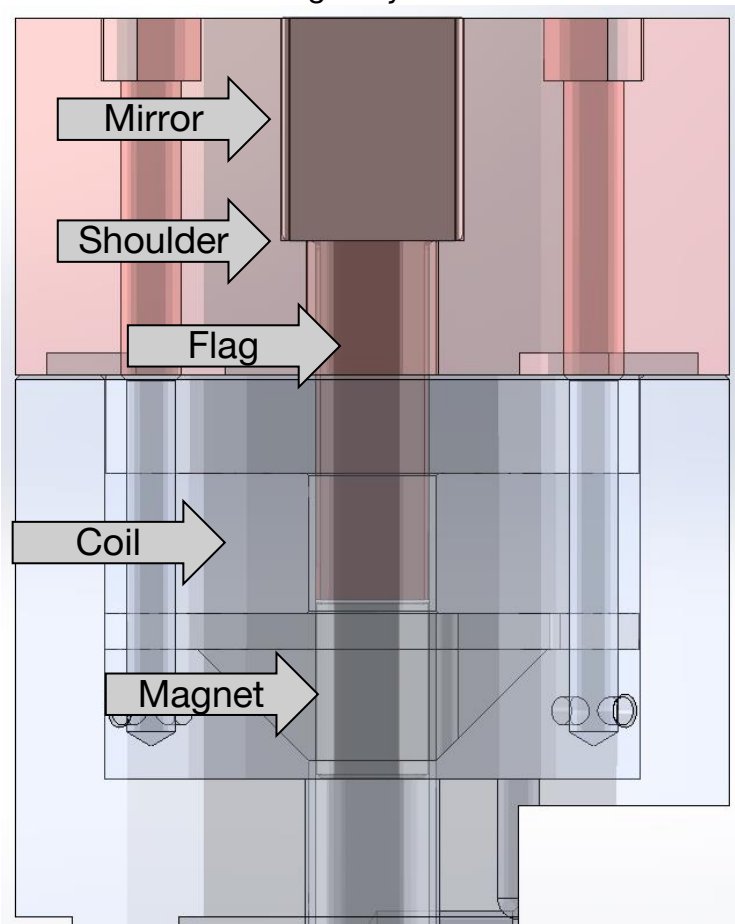
- A prototype was constructed and studied to create a moving shutter without the need for wires attached to the payload
- High-Reliability Ultra-Fast Mechanical Shutter (HRUF) Assy D2200426



Fast Shutter Upgrade

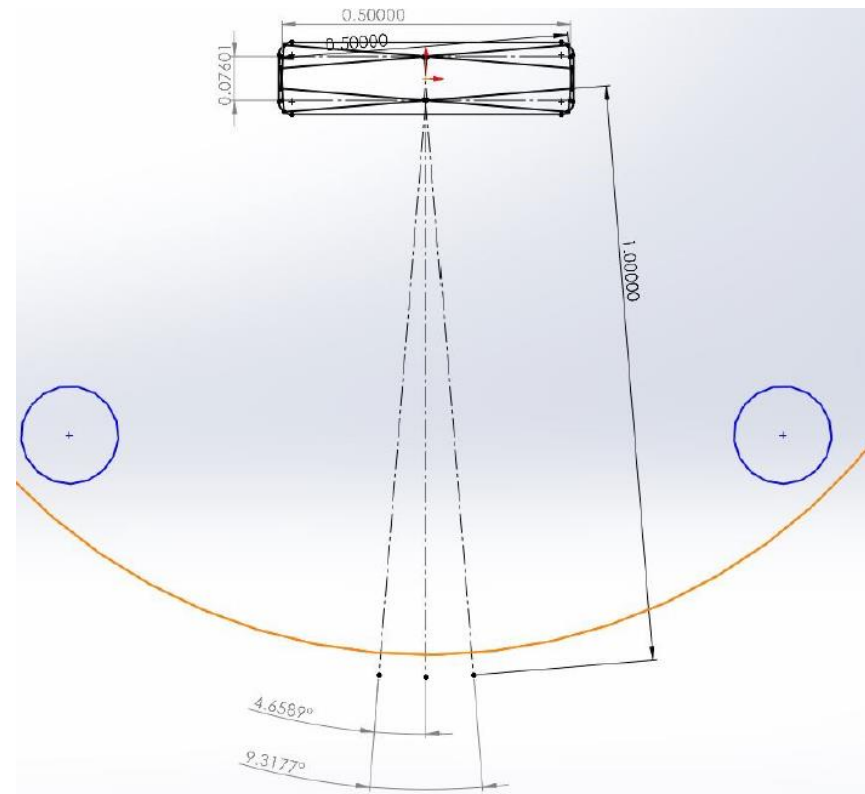
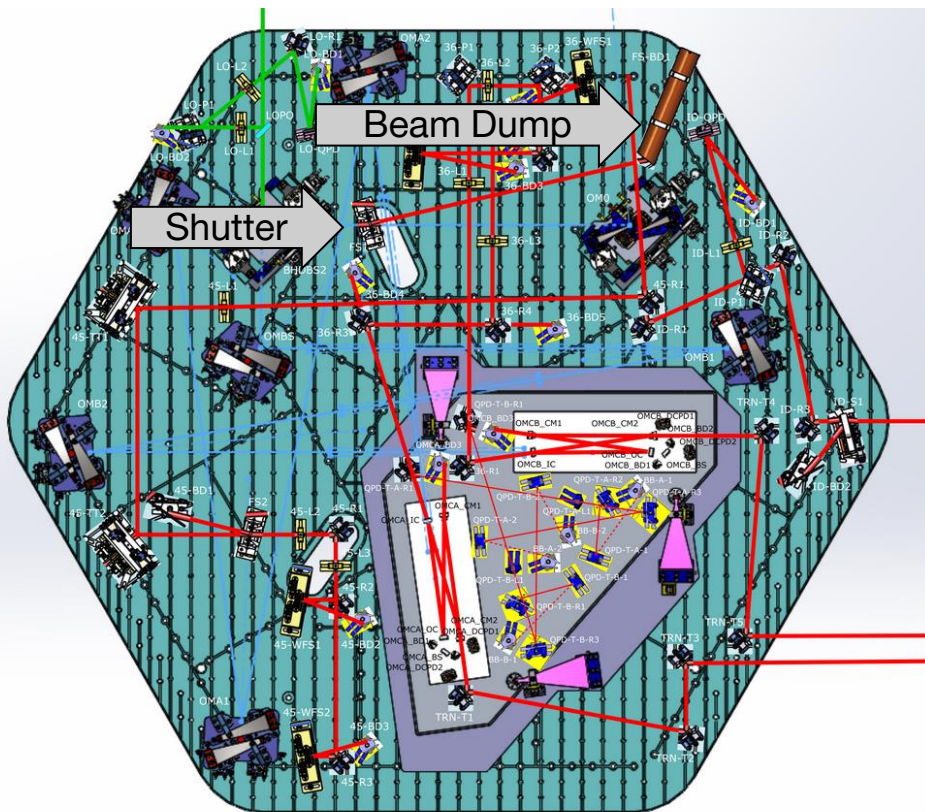
High Reliability Ultra Fast (HRUF)

- How Does it Work?
 - Magnet and flag rest on the flag shoulder just inside the coil
 - When activated the magnet pulls up into the coil raising the flag
 - The magnetic field interacts with the copper plate and arrests the flag
 - A holding current keeps the flag raised
 - Falls back under gravity



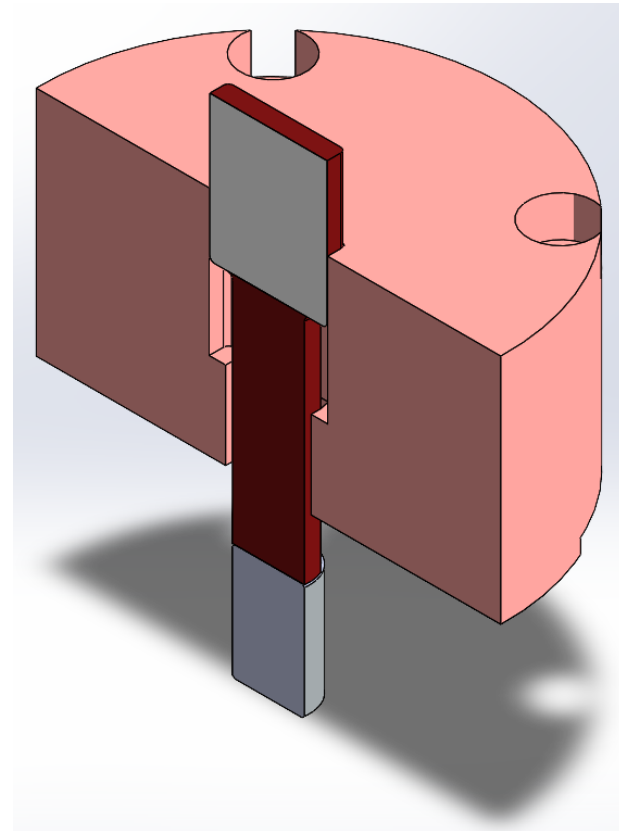
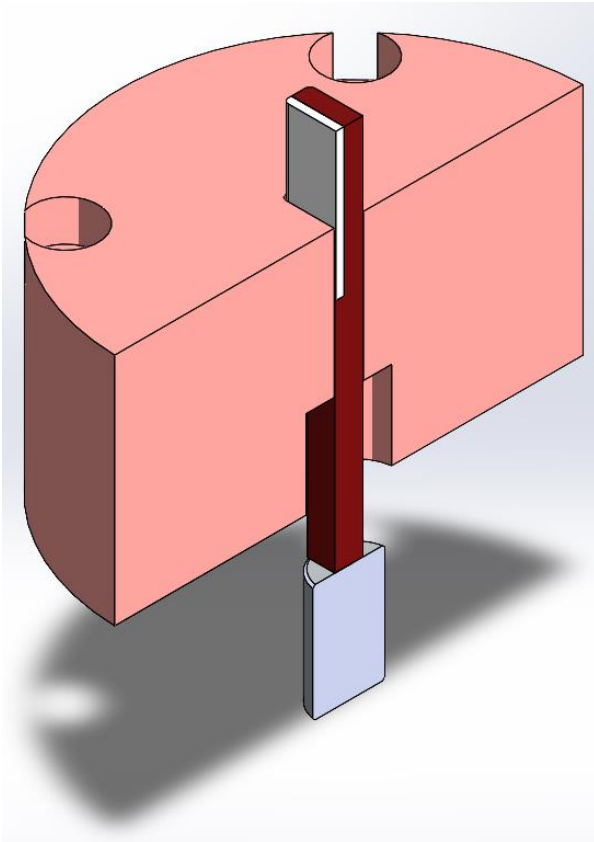
Fast Shutter Upgrade High Reliability Ultra Fast (HRUF)

- What have the issues been?
 - The throw to the beam-dump is relatively long so any rotation of the FS mirror on deployment could swing and “paint” the chamber
 - Tolerances must be kept very tight while still allowing free movement of the flag



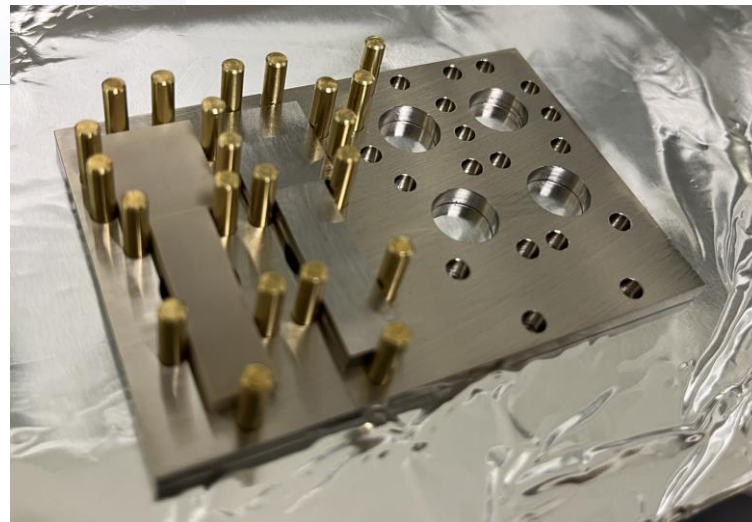
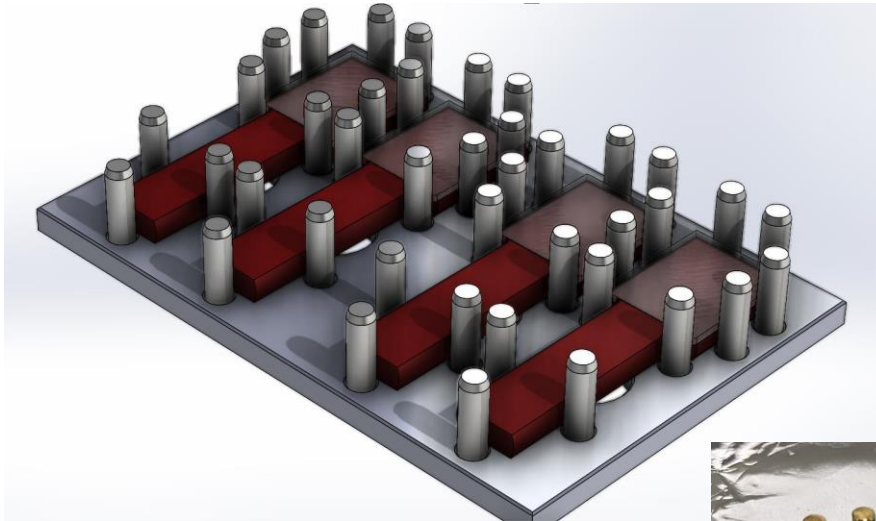
Fast Shutter Upgrade High Reliability Ultra Fast (HRUF)

- What have the issues been?
 - How do you assemble it?
 - What order?
 - Magnet-to-Flag
 - Mirror-to-Flag
 - The magnet doesn't fit through the copper plate (square peg in a round hole)
 - The mirror cannot be attached when the flag is in the copper



Fast Shutter Upgrade High Reliability Ultra Fast (HRUF)

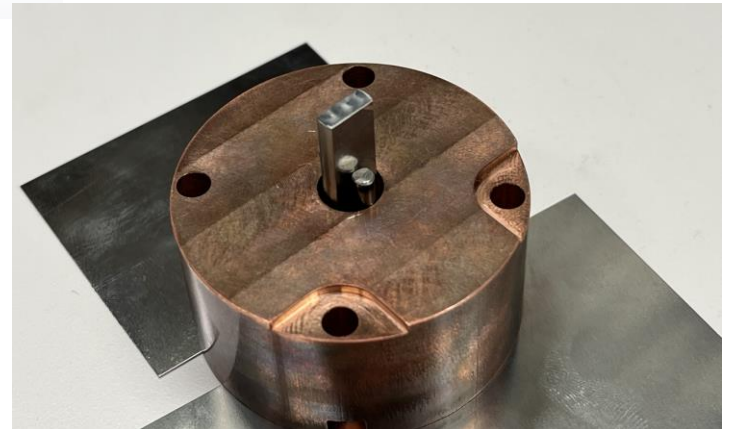
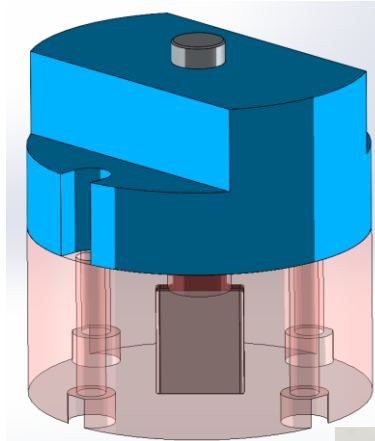
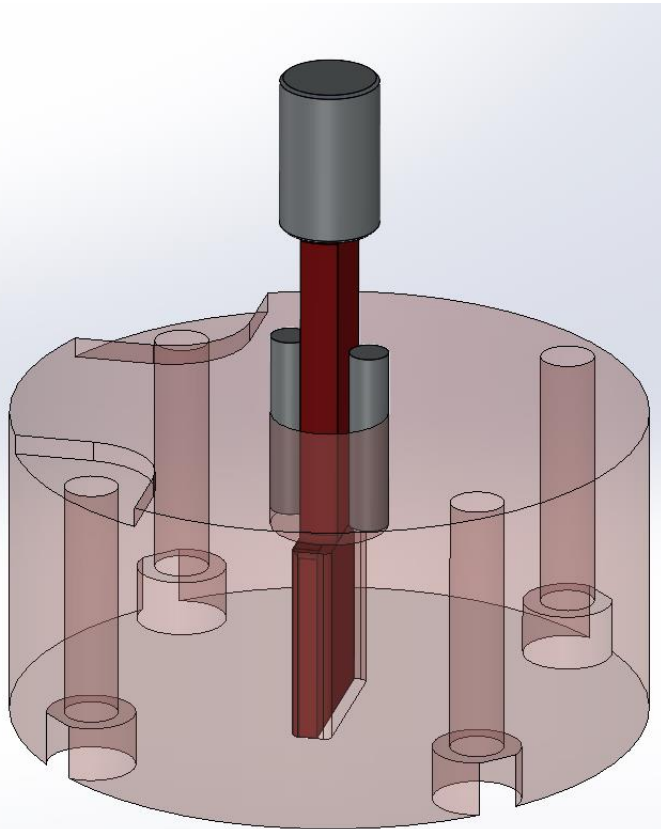
- What have the issues been?
 - The mirror cannot be attached when the flag is in the copper
- Mirror-to-Flag Fixture D2300217
 - Holds the flags still and positions the mirrors correctly for glue-up



Fast Shutter Upgrade High Reliability Ultra Fast (HRUF)

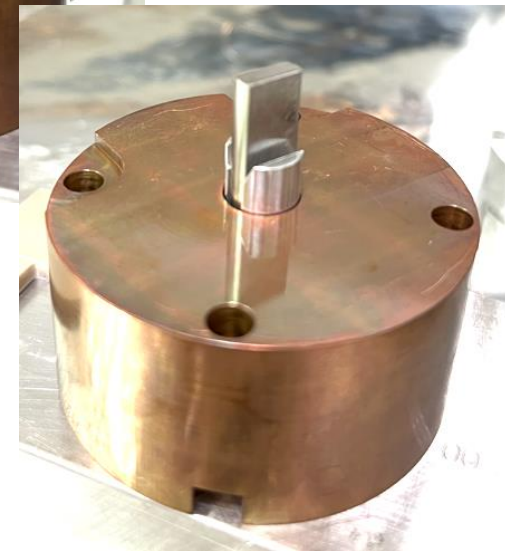
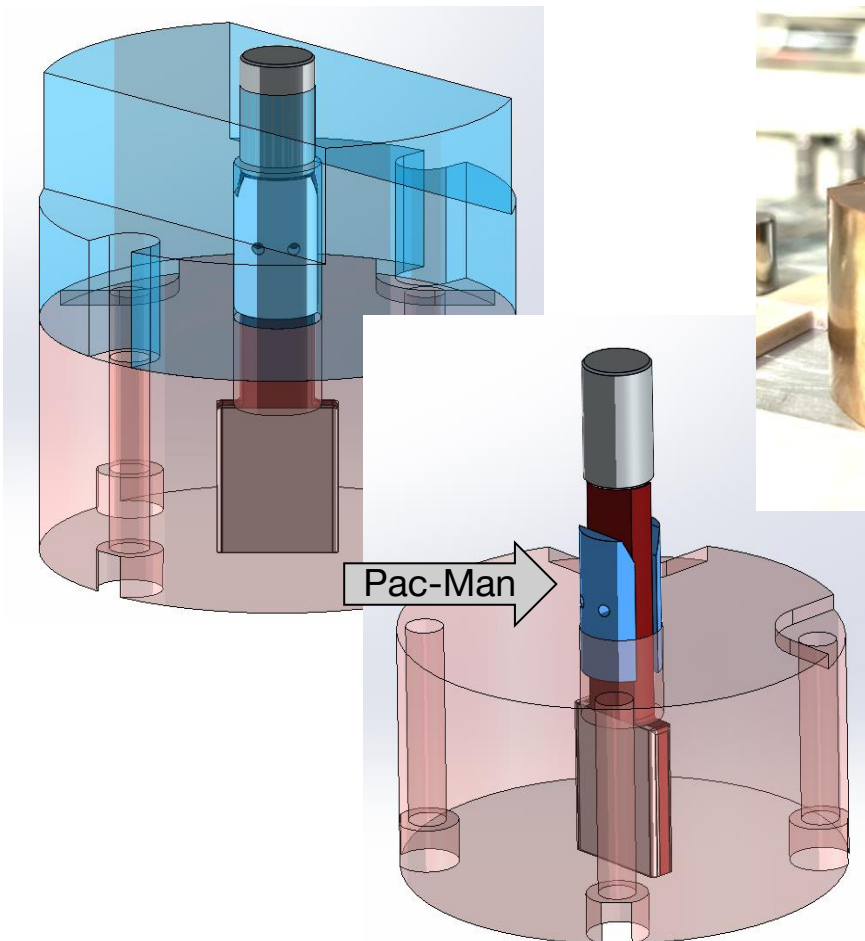


- First Attempt
 - We first attempted to glue a magnet-to-flag
 - The EP-30 Epoxy used was past expiration and did not properly cure
 - Precision pins were used to hold the flag relative to the copper and fixture but were still too magnetic and twisted during assembly



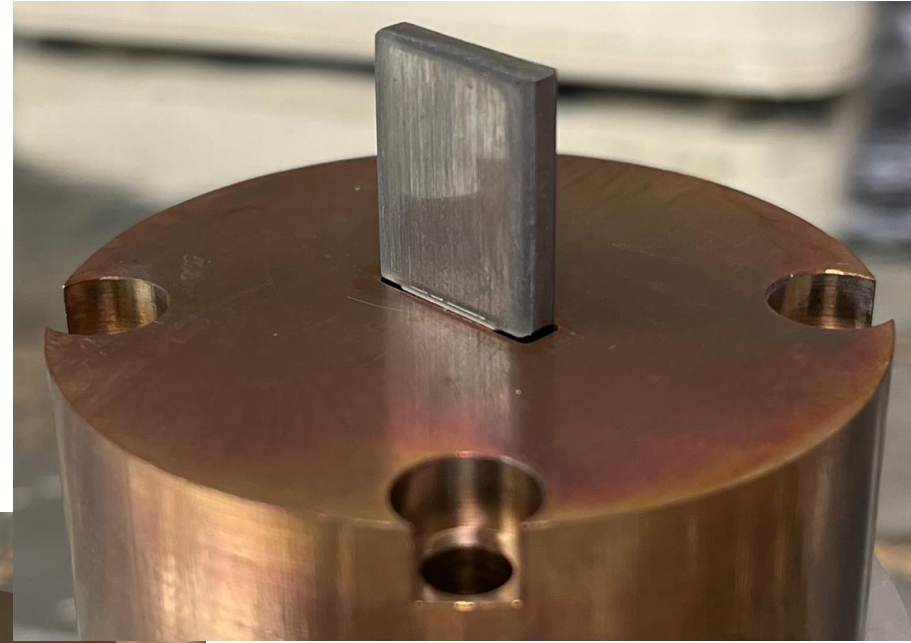
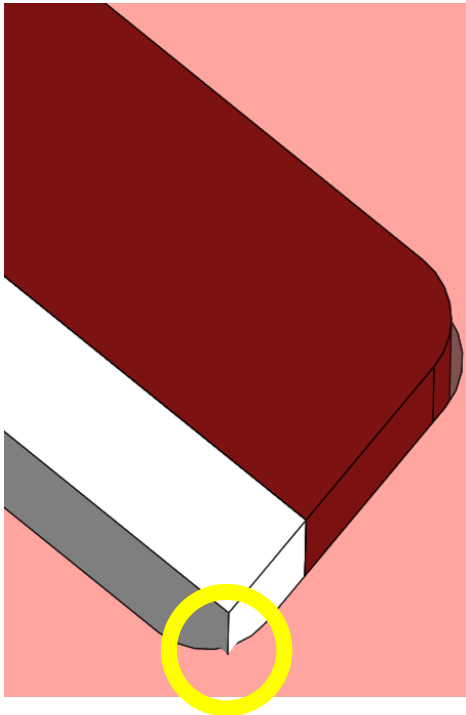
Fast Shutter Upgrade High Reliability Ultra Fast (HRUF)

- Magnet-to-Flag Fixture D2300218
 - The “Pac-Man” was developed to hold the flag and copper relative to the fixture
 - Must be short enough to be removed when the magnet is glued, but long enough to bridge the transition of the pieces



Fast Shutter Upgrade High Reliability Ultra Fast (HRUF)

- Gluing the Mirror-to-Flag
 - Gluing successful
- Mirror Edges not beveled
 - Tolerance revenge!
 - Manual shaping of test optics
- The depth of the mirror on the flag with the epoxy is tight and does not always fall smoothly
- $v2 = 0.005''$ taken out the flag thickness at the mirror



Fast Shutter Upgrade High Reliability Ultra Fast (HRUF)

- Initial test firing
 - Does not fall back down
 - Does not seem to break

Slow-Mo(ish)



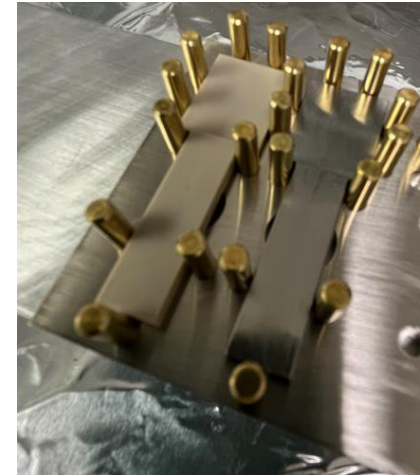
Real-Time



Fast Shutter Upgrade High Reliability Ultra Fast (HRUF)

- Timeline
 - All of the physical parts are in-hand or in production as of 9/13
 - Magnets and mirrors need to be epoxied together
 - Testing once the assembly is complete
 - Expenditures for 4 complete assemblies

■ Main Bodies	S615433	\$4809.11
■ Flag-to-Mirror Jig	S612944	\$1132.27
■ Magnet-to-Flag Jig	S607572	\$523.69
■ Copper Plates	S587290	\$1821.33
■ Bobbins	S586150	\$1296.54
■ Flags (Ti & PEEK)	S603440	\$2443.14
■ Terminal Cover	S616093	\$1885.25
■ Ti Flags, Pac-Man	S621897	\$3569.90



- 10/25/23
 - First epoxy test failed. Expired epoxy?
 - Parts sent to C&B for a proper Class B clean
 - 10/23 Parts back from C&B
 - 10/24 Test optic glued to flag
 - One PEEK and one Titanium
 - 10/27 Glue successful
 - Flag thickness possible issue
 - Flag redesigned
 - 11/7 New flags, M-to-F jigs arrived
 - Class B clean
 - 11/20 Glue -up failed
 - 11/22 Magnet-to-Flag glue-up curing