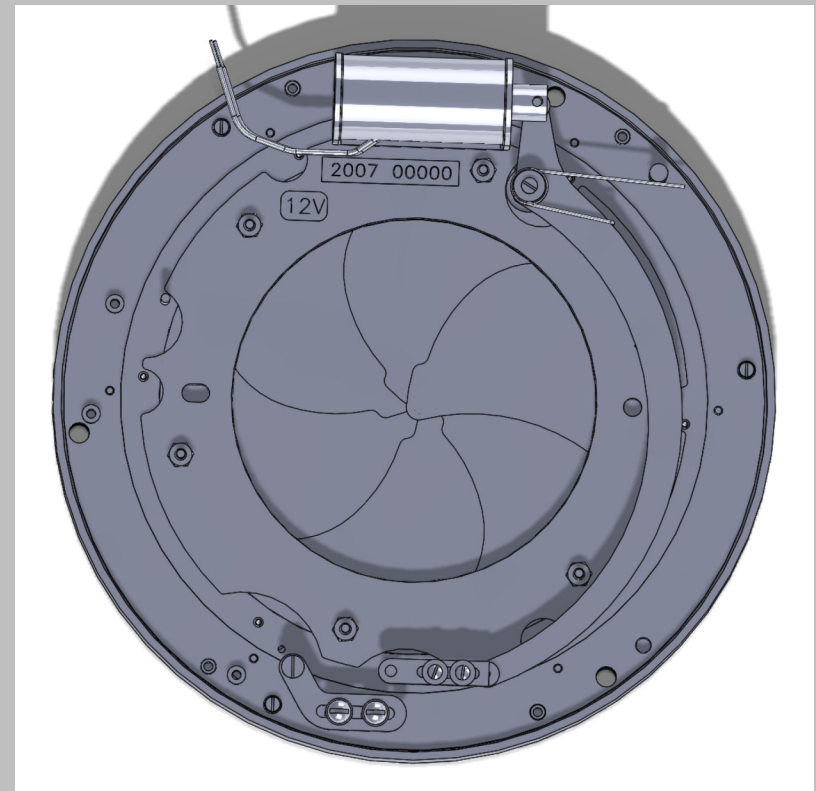


Shutter

- Types of Shutters
 - Iris Shutter
 - Rotary Photometric Shutter (used currently on SPICam)
 - Linear Photometric Shutter (designed for this instrument)
- Performance
- Design
- Usage
- Maintainability

Iris Shutter

- Pros:
 - Available off the shelf
 - Compact
 - Easy to implement
- Cons
 - Uneven lighting of CCD
 - Non-Maintainable
 - Few available for 140mm+ aperture
- Opening to closing window time = 0.112 seconds
- 11% light differential across CCD during 1 second exposure
- Insignificant differential with 1800 second exposure



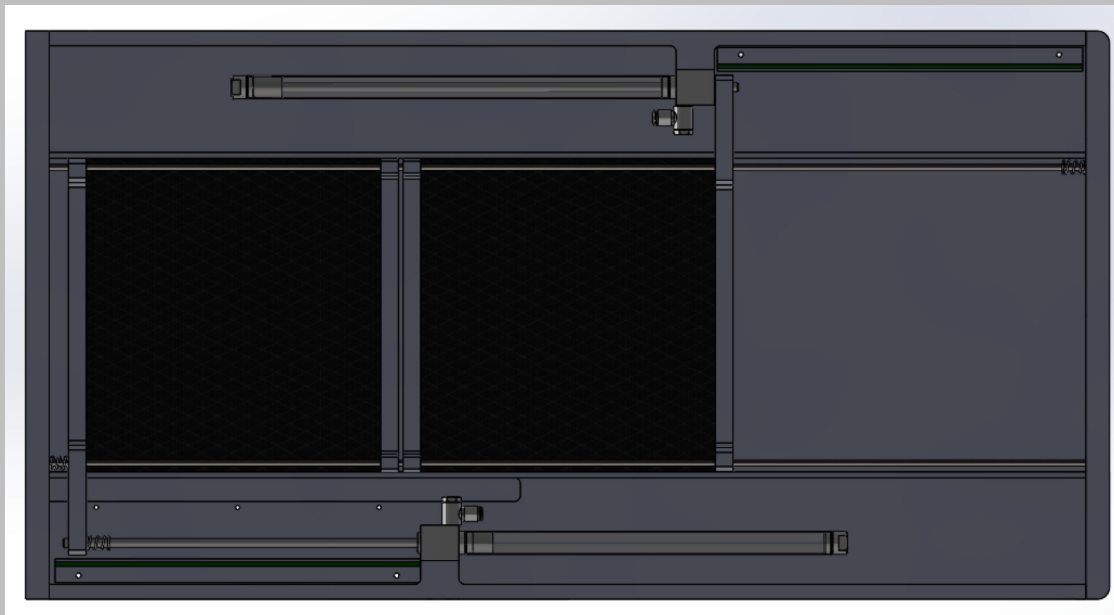
Rotary Photometric Shutter

- Type used in SPICam
- Stepper motor drives plate with hole
- Even light distribution across CCD
- Large in size



Linear Photometric Shutter

- Two plates that move independently of each other to reveal then cover the aperture
- Variable timing for slit size control during short exposures
 - Speed of cylinder less critical if slit size can be maintained
- Pneumatic driven to eliminate any added heat near optical path
- Low power electric solenoid
- High Maintainability



Performance

- Goal of better than 1% photometric accuracy (10ms of error @ 1 second)
- Continuous mode of at least 2Hz
- Minimum exposure time = 100ms
- Pneumatic Cylinders
 - 2ms cylinder repeatability
 - Quick to replace
 - Bimba or Air-Pel
- Hall sensor feedback
 - Know the exact exposure time independent of commanded exposure time
- Pneumatic Solenoid
 - SMC SY5100 Series
 - 32ms response time (this is a calibratable offset)
- System pressure = 80 – 100 psi (dependent on further testing)
- Pressure sensor to safely close the system if pressure drops below 80psi

Design

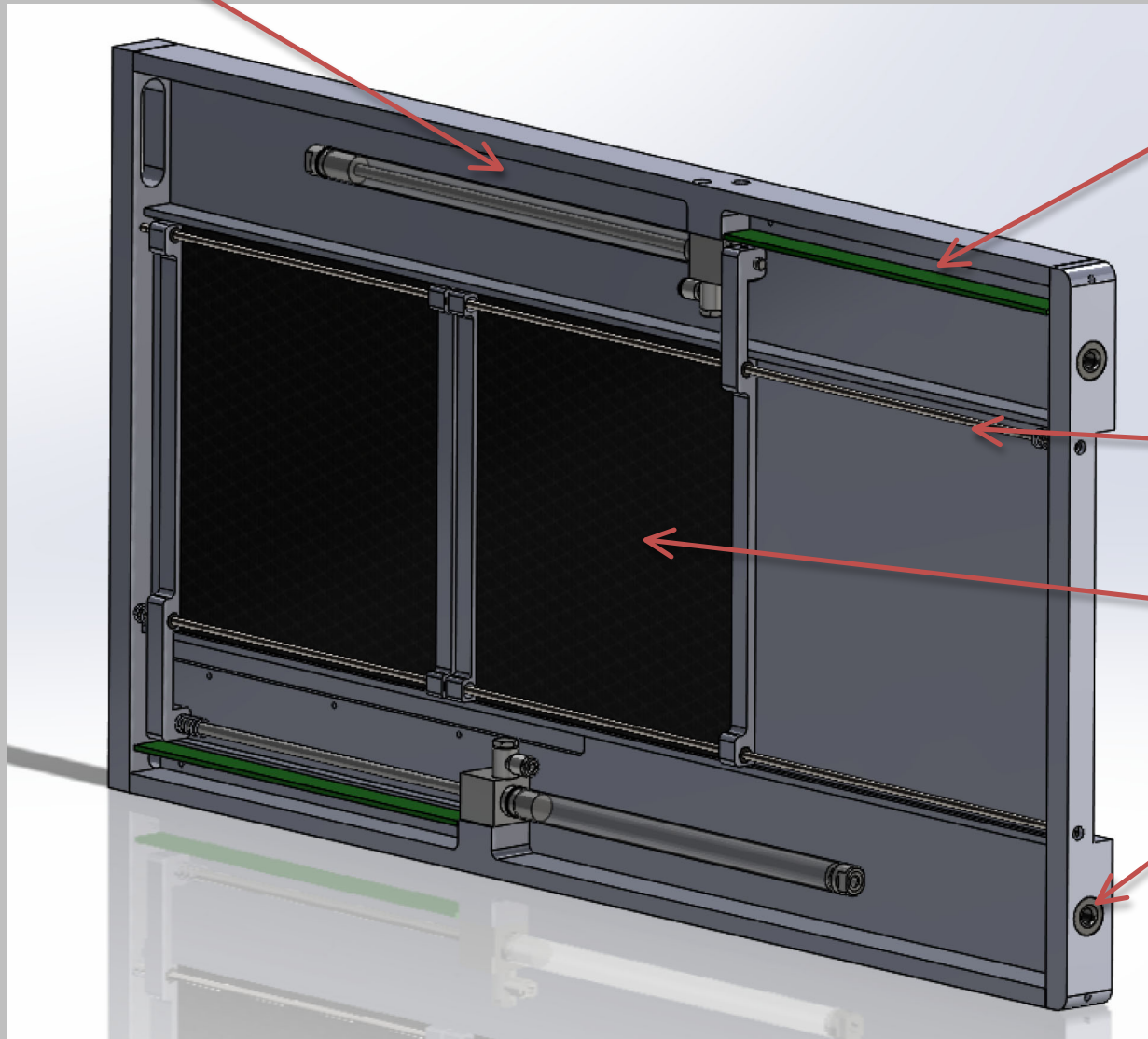
Pneumatic Cylinder

Hall Sensor PCB

Linear Guide

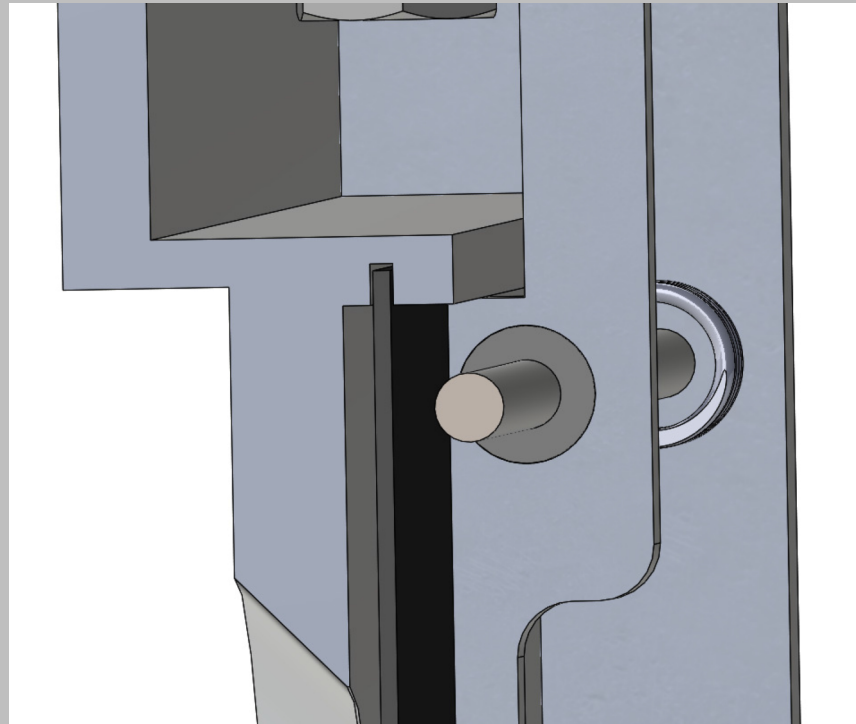
Shutter Plate

Locator Bushing



Design

- Three piece design for easier manufacture and assembly
- Carbon fiber shutter blades for reduced mass
- Light groove along bottom and top for stray light protection
- Linear bushings for accurate alignment
- Interior surfaces painted with Aeroglaze
- Knife edge on surface facing lenses for stray light rejection



Pneumatic Cylinders

- Pneumatic cylinders are not typically chosen for accurate shutters
- How is it they can be used?
 - Go with a nice cylinder (I will probably go with an AirPel cylinder, even though my testing was with Bimba)
 - Overdrive the shutter being careful of end limits
 - Shutter blade assembly is identical for both cylinders

- Extension Force = 15lbs
- Retraction Force = 12.2lbs
- Mass of shutter blade assembly = 0.20lbs
- Friction from linear bearings
 - Rulon J linear bearing
 - Coefficient of friction 0.12

$$F_{resistive} = \mu P$$

- Resistive force per bearing = 0.024lbs
 - Total resistive force = 0.096lbs
- Total force necessary to push shutter = 2.5% total cylinder force

$$F = pA = \frac{p\pi d^2}{4}$$

$$p = 100\text{psi}$$

$$d_{\text{ext}} = 0.4375 \text{ inch}$$

$$d_{\text{ret}} = 0.25 \text{ inch}$$

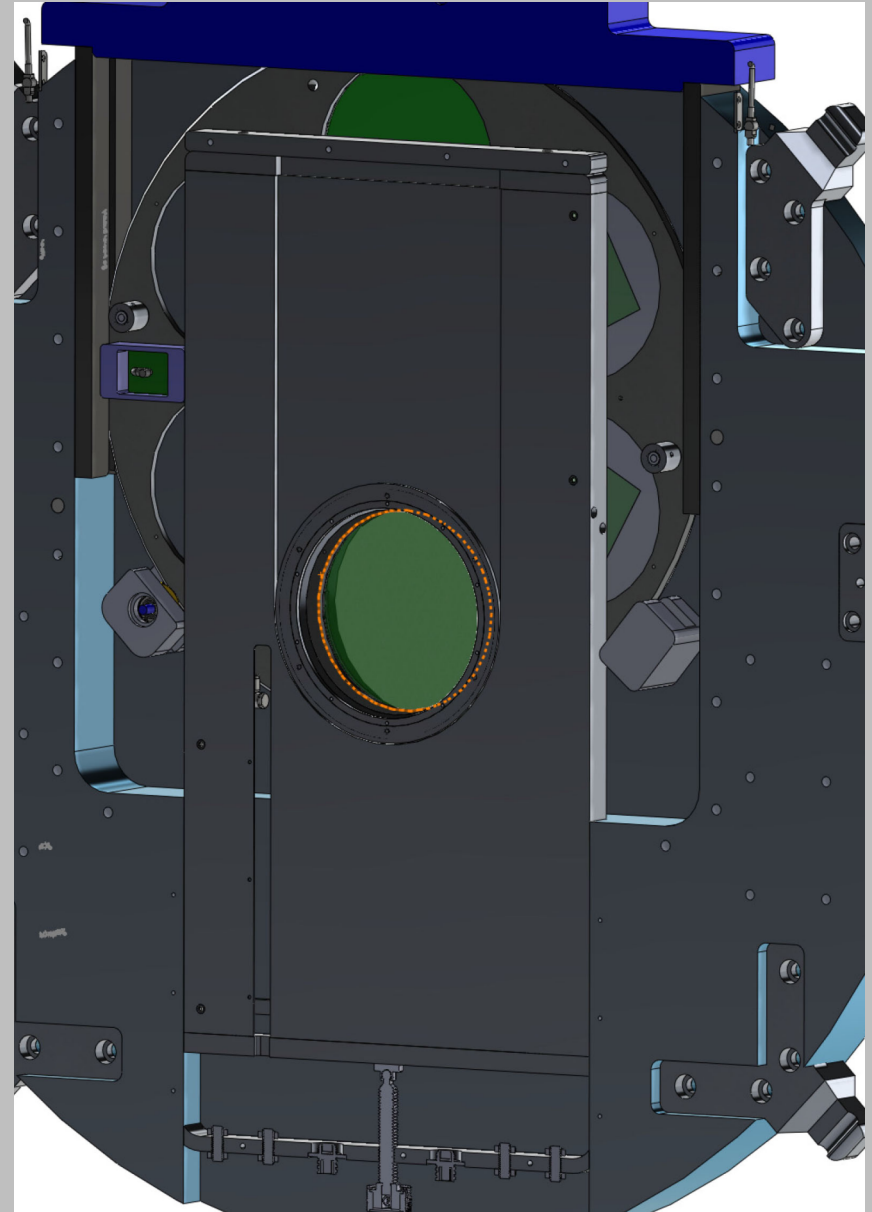
$$d_{\text{ret}} = d_{\text{outer}}^2 - d_{\text{inner}}^2$$

How it will work



Fit into instrument

- Shutter slides into recess in mounting plate
- Locator system pins the shutter at set position
- Recess in back of housing makes allowance for close fit to lens barrel (as well as blocking stray light)
- Shutter tensioned into place by bolt pushing shutter against locators



Maintainability

- Pneumatic cylinders easily replaceable
 - Remove shutter
 - Unthread the cylinder rod
 - Remove two bolts (on outside of housing) holding pneumatic cylinder in position
 - Replace, rebolt, rethread, re-install in instrument
- Lifetime
 - The cylinder will last the lifetime of the instrument, but...
 - I do not believe it will maintain the same accuracies throughout that lifetime
 - Replace cylinders every year or two (when performance is starting to decrease)
 - Cylinders are inexpensive

Demonstration

- Initial testing with Bimba Cylinders, but will probably go with AirPel cylinders due to anti-stiction properties
- Plan to build complete shutter unit and run it through tests to determine long term feasibility
- Only if it passes these tests will it be implemented