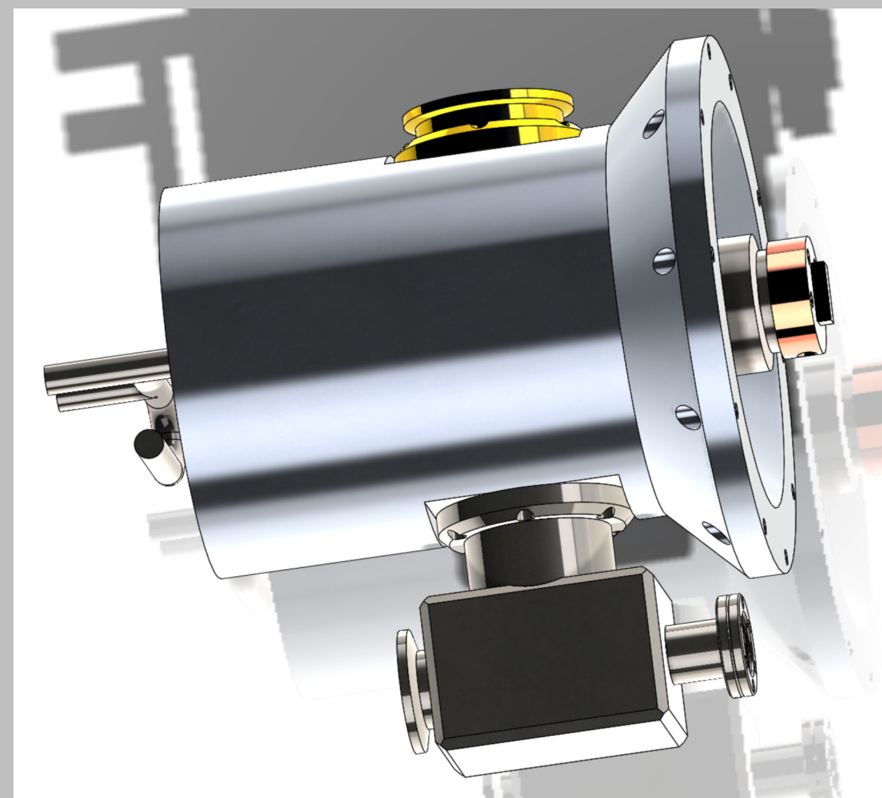
Dewar & Cooling

Rear Dewar Section

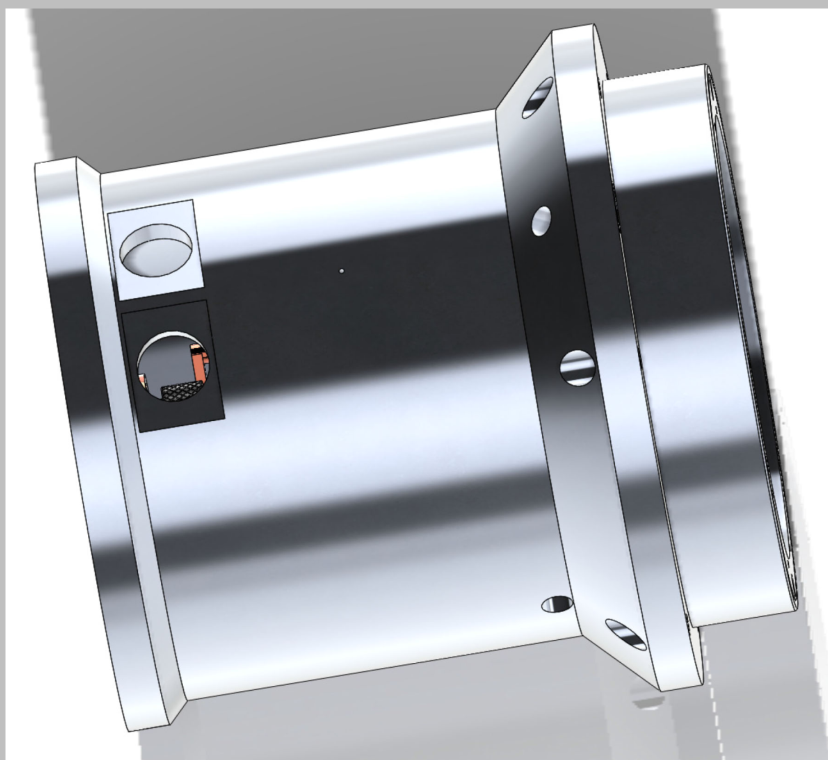
- PCC access port
- Vacuum pump port
  - KF40 equivalent port with KF40 to dewar adapter
- Telemetry Port
  - Custom SS304L tee to reduce o-ring usage
  - KF40 equivalent on dewar



Vacuum Telemetry

- Ion Pump
  - 2l/s pump
  - 80% efficiency while pumping noble gasses
  - Compact
- MKS 972 Vacuum Gauge
  - Micro-Pirani / Cold Cathode combination gauge
  - RS232 and LCD readout
  - Range: Atmosphere to 10E-8 Torr

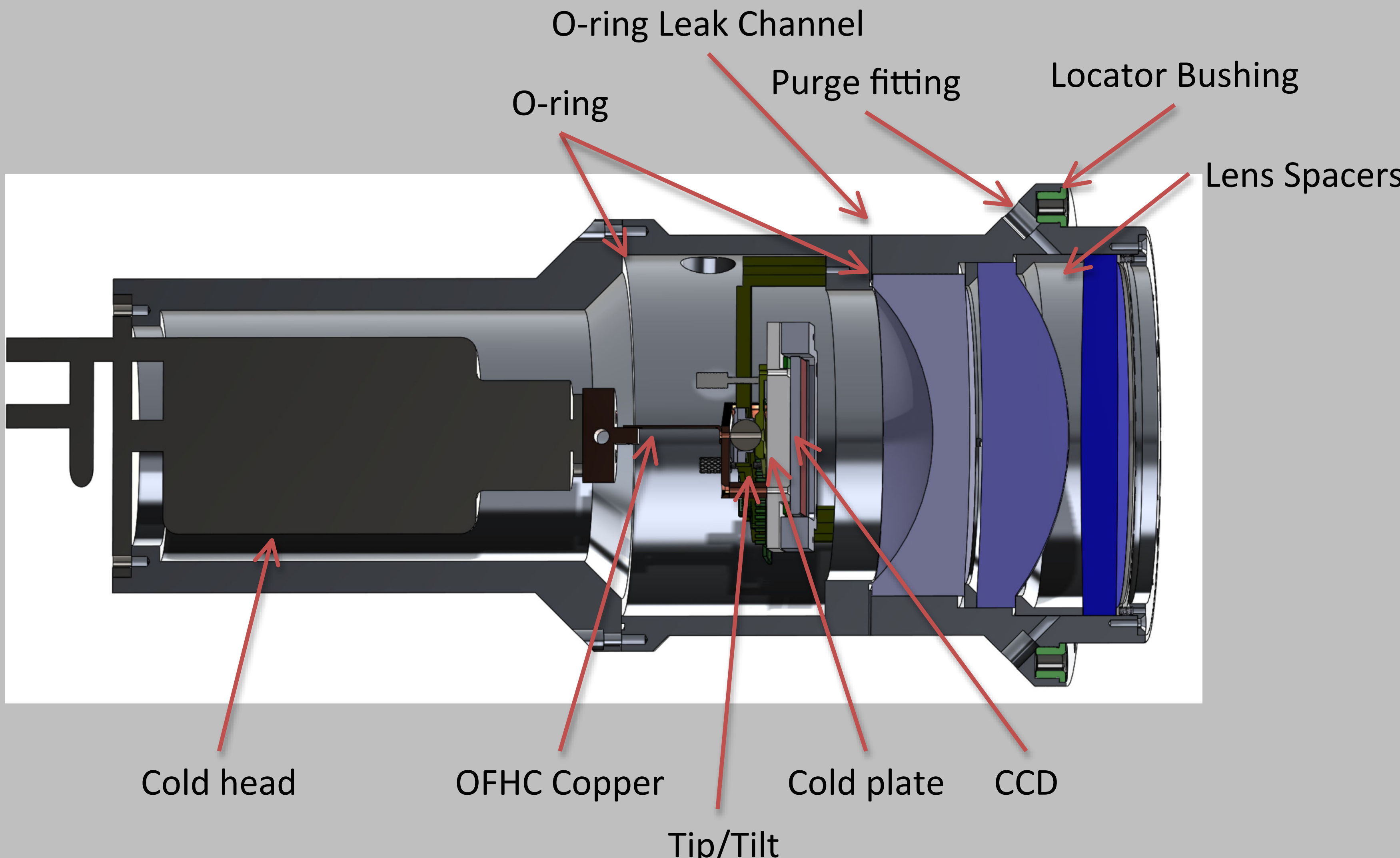
Front Dewar Section



- Two electrical hermetic connectors
  - 50 pin for dedicated to CCD
  - 25 pin for telemetry

- Chamfered mounting flange
- Integrated lens cells
- Dry air fittings for lens cell cavities
- O-Ring surface on front dewar wall and rear surface

Dewar Features



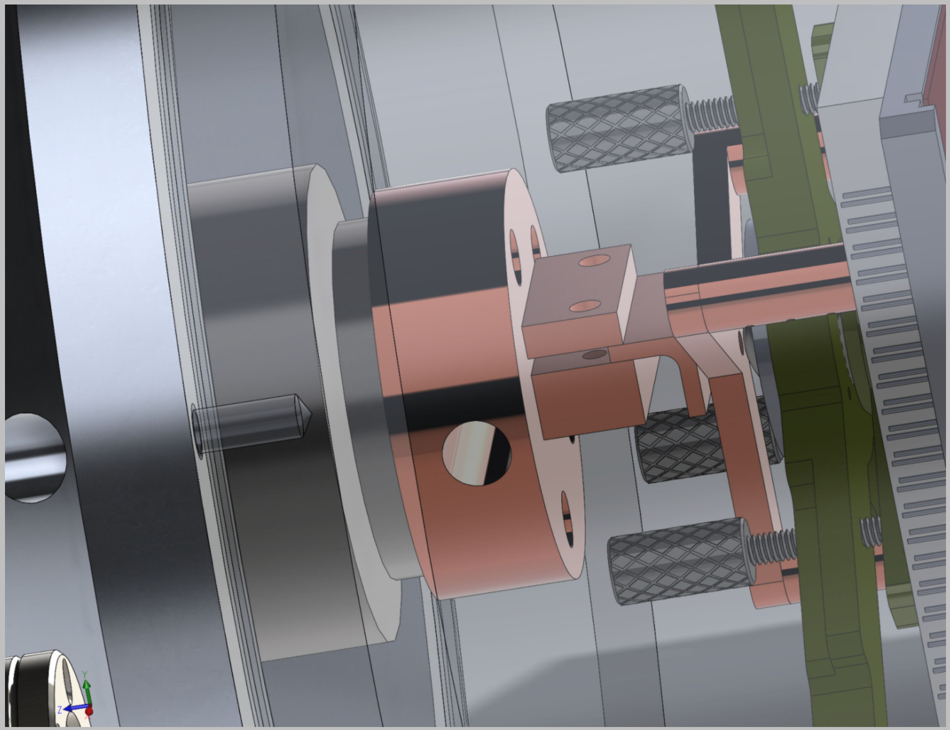
Assembly and Maintenance

Dis-assembly

1. Loosen bolts that connect front and rear half of dewar
2. Slide apart dewar halves making sure not to tension the cold strap
3. When rear dewar half is removed enough to access the cold strap attachment bolts, remove the cold strap attachment bolts

Assembly

1. Attach cold strap and tighten attachment bolts making sure not to stress the cold strap
2. Slide together two halves of dewar
3. Bolt together dewar



O-Ring Permeation

$$Q_{permeation} = \frac{k \Delta P A}{d}$$

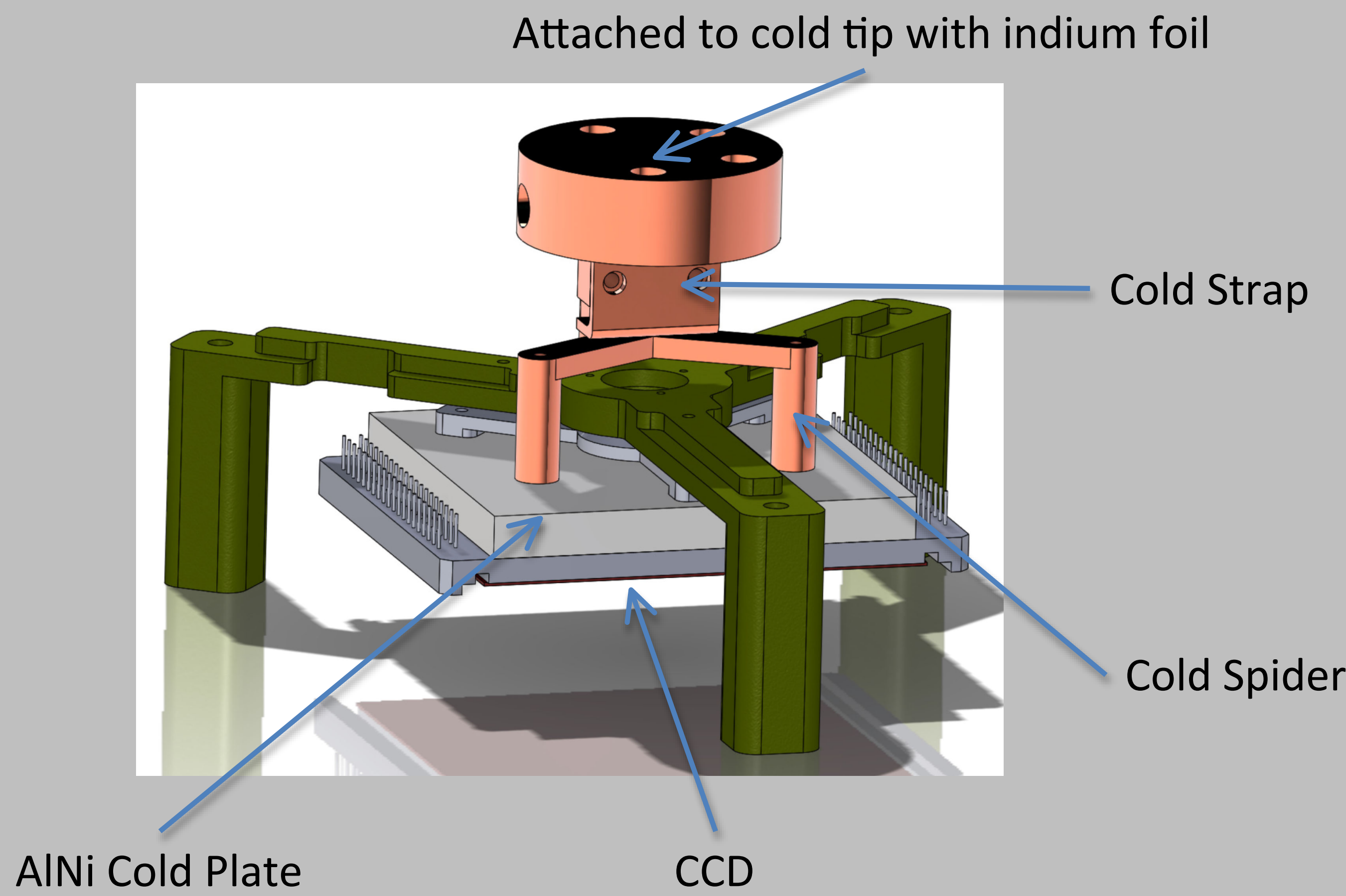
- Viton H_2O permeation
- k = 4.0×10^{-9} cm^3 cm sec^{-1} cm^2 atm

- O-Rings
  - One 5.99” diameter x 0.103” cross section = 4.5×10^{-10} cm^3 sec^{-1}
  - One 4.74” diameter x 0.103” cross section = 5.7×10^{-10} cm^3 sec^{-1}
  - One 3.625” diameter x 0.065” cross section = 3.0×10^{-10} cm^3 sec^{-1}
  - One KF40 at 1.6” diameter x 0.21” cross section = 7.0×10^{-8} cm^3 sec^{-1}
    - Might make this a CF flange
  - One KF25 at 1.1” diameter x 0.21” cross section = 1.0×10^{-8} cm^3 sec^{-1}
  - Two Dewar to KF40 fittings at 1.9” diameter x 0.103” cross section = 1.4×10^{-9} cm^3 sec^{-1}
  - Two Electrical Feed through at 1” Diameter x 0.07” cross section = 1.2×10^{-9} cm^3 sec^{-1}
- Total = 2.3×10^{-8} cm^3 sec^{-1}

Outgassing

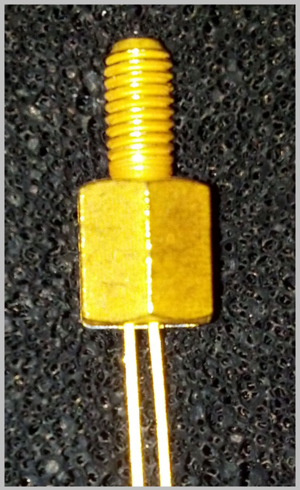
- Materials in Dewar
  - Rates in Torr Litres / cm^2 sec
  - Al 6061 - 8E-9 Torr Litres / cm^2 sec
    - Surface area = 986 cm^2
    - Outgassing = 8E-6 Torr Litre/ sec
  - G10 - 10^{-8} Torr Litres / cm^2 sec
    - Surface area = 153 cm^2
    - Outgassing = 2E-6 Torr Litre/ sec
  - OFHC Copper - 4.2E-9 Torr Litres / cm^2 sec
    - Surface area = 86 cm^2
    - Outgassing = 3.6E-7 Torr Litre/ sec
  - AlNi ???
  - SS304 - 9.3E-12 Torr Litres / cm^2 sec
    - Surface Area = 111 cm^2
    - Outgassing = 1.0E-9 Torr Litre/ sec
  - Total: 1.0E-5 Torr Litre/ sec

Cold Thermal Path



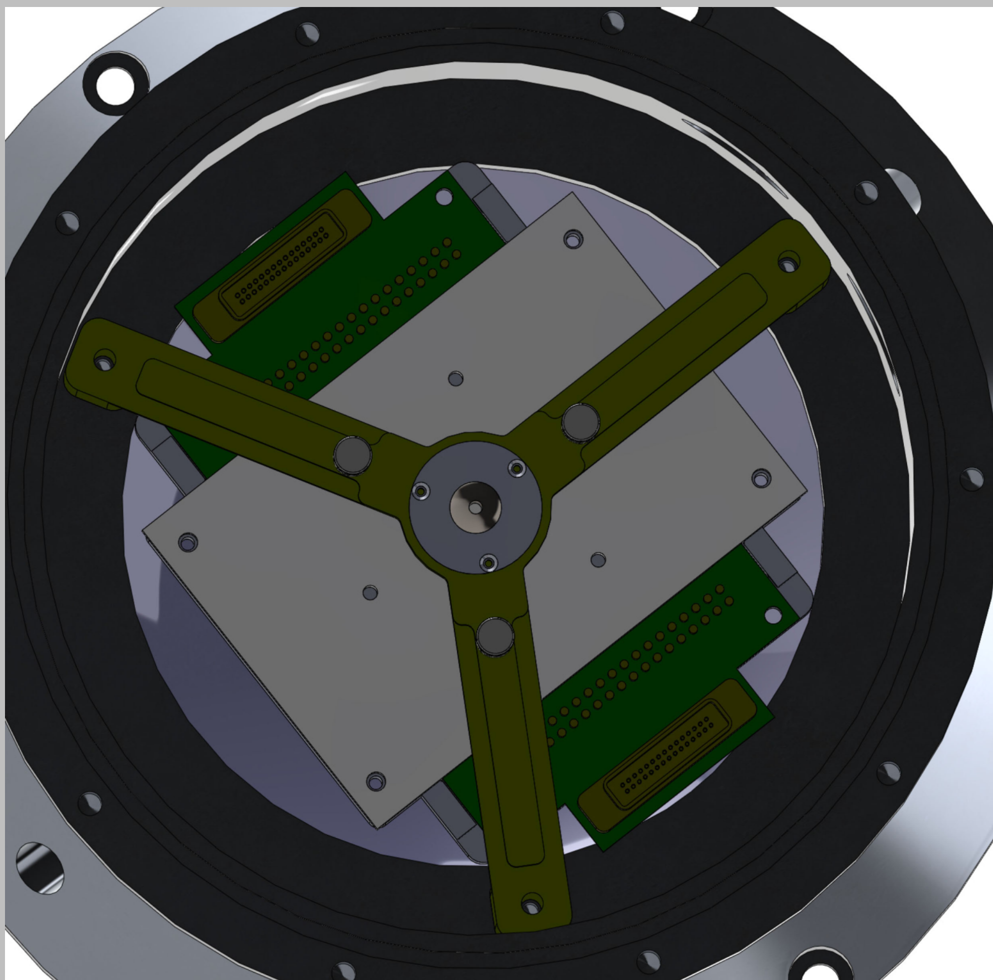
AlNi cold plate used as an electrical insulator while having good thermal conductance

Temperature Sensors



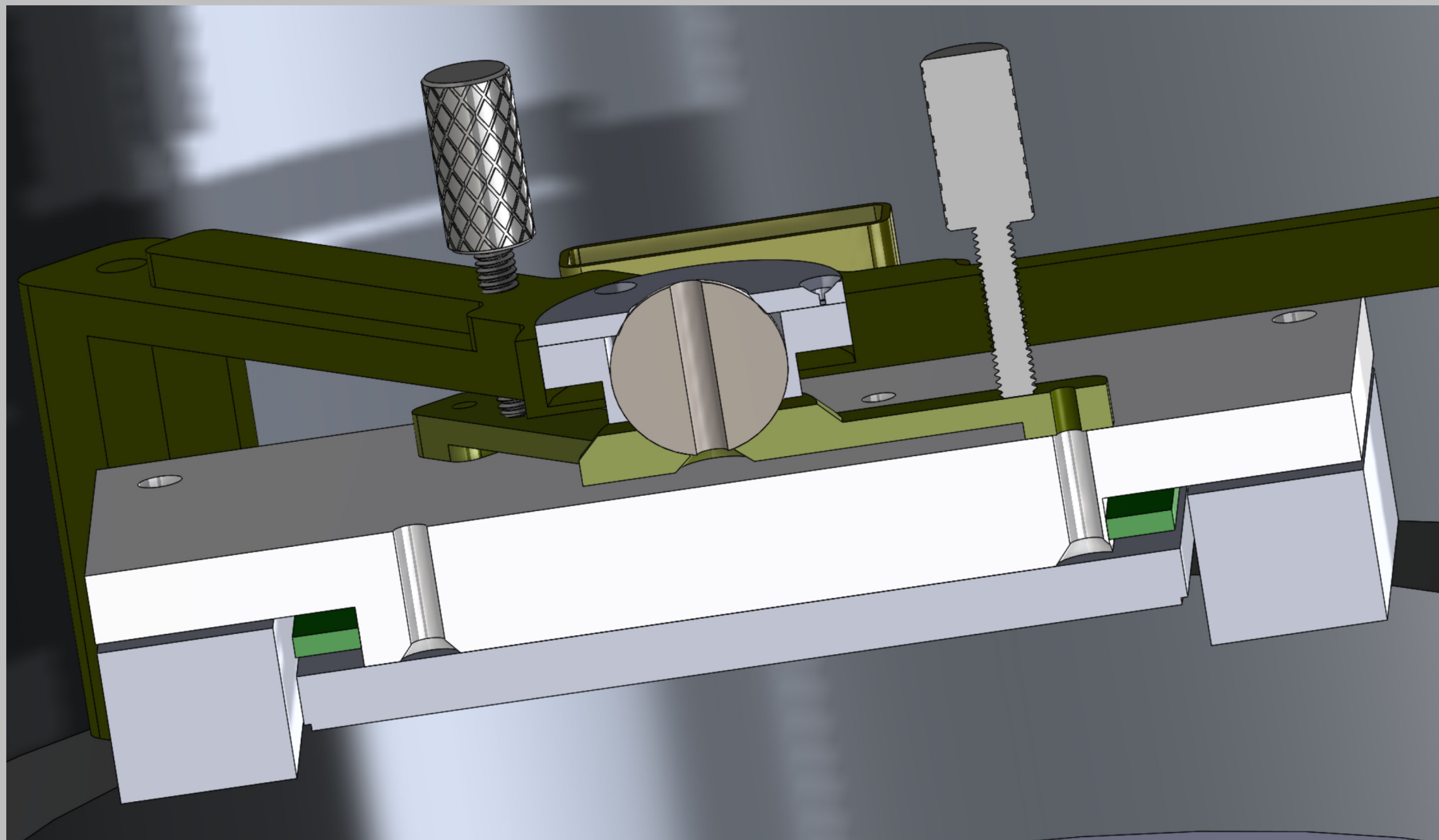
- This dewar will report two temperature values
  - Temperature of the cold head
  - Temperature of the cold plate
  - Calibrated sensor in cold plate
  - Un-calibrated redundant and cold tip sensor
- There will be a redundant temperature sensor in the cold plate
- The temperature sensors will be DT-670MT Silicon Diodes from Lakeshore Cryogenics
  - Range = 1.4K – 500K
  - Typical Sensitivity at LN2 temperatures +/- 32mK
  - Long Term Stability +/- 40mk
  - 100ms thermal response time
- Threaded package for easy removal/replacement

CCD Support Structure

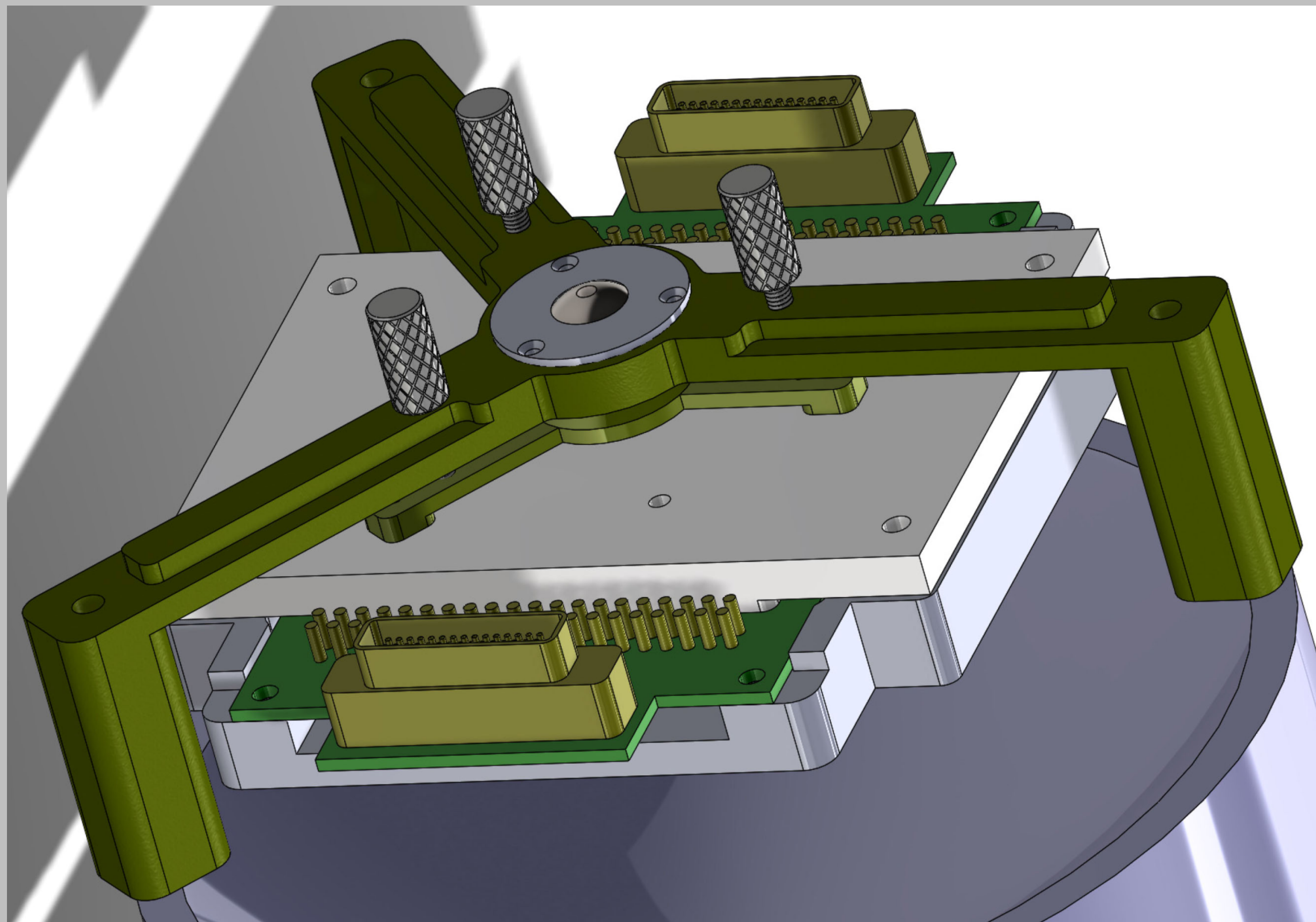


- G10 support structure indexes off inner edge of dewar
- 120 degree leg arrangement
- Structure connected to cold plate through ball bearing
- AlNi cold plate that is tensioned against the CCD by four shoulder bolts with springs
- Pre-amp board attached to CCD retainer
- Tip, tilt, and piston adjustment to compensate for any machining or optical error

Tip, Tilt, and Piston

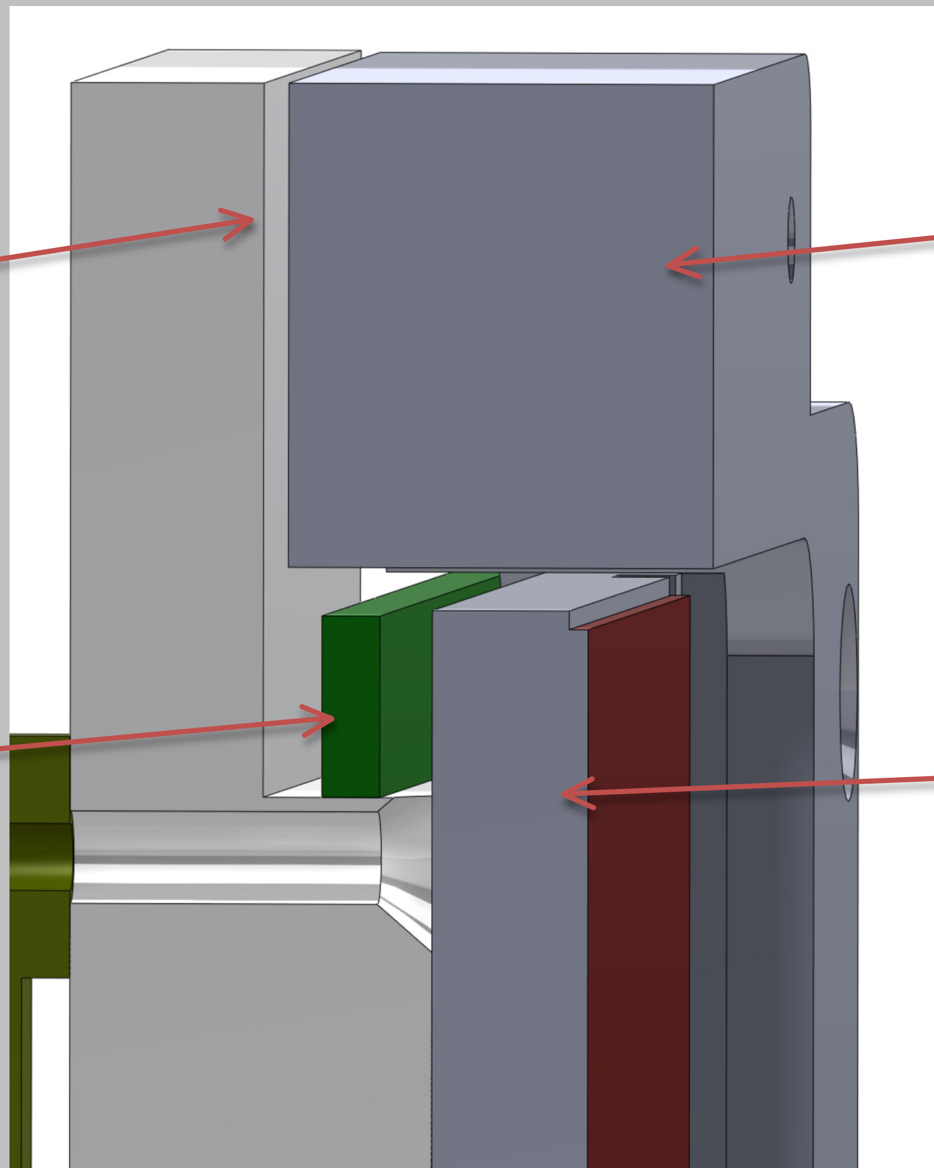


- Thumb screws for tip, tilt and piston
- Ball bearing anchored to cold plate spider
- Ball bearing pivots in capture component
- Spring force up on ball bearing capture



- Tip/tilt locked down by tightening top screws of bearing capture
- Piston locked down by set screws pressing against bearing capture

CCD/Cold Plate Interface

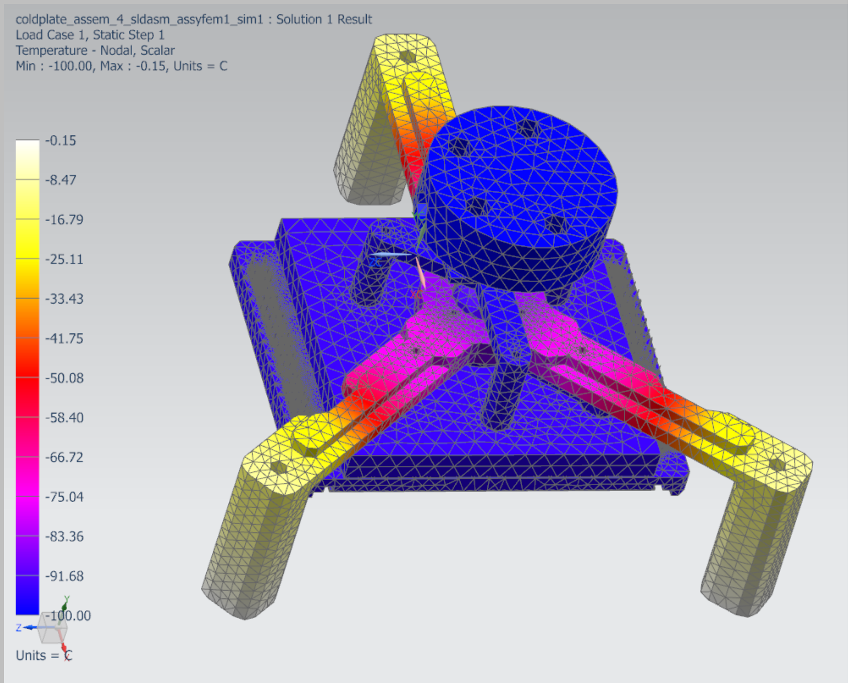


Preparation and Coating

- Preparation after machining
  - Based on NRAO procedure
  1. Degrease dewar with solvent and tap water (to remove cutting fluid and oil)
  2. Use Citranox to remove micro contaminants followed by hot water rinse and de-ionized water rinse
  3. Rinse with Methanol to remove any surface water
  4. Do not get water or fingerprints inside dewar
- Send off to coaters
- For thermal reasons the dewar will be Nickel plated (discussed further in a several slides)

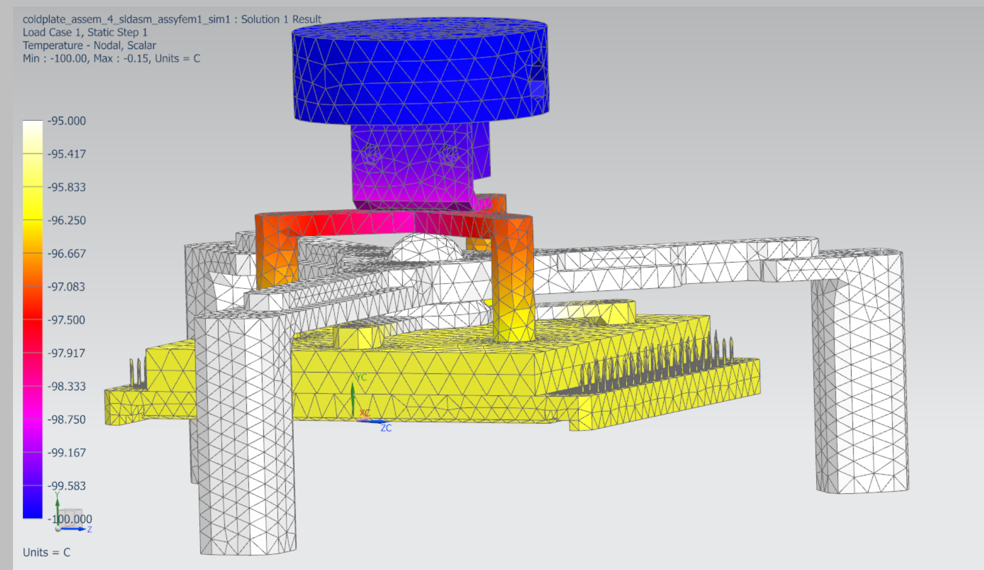
Thermal Modeling

- NX Nastran Thermal Analysis
- Top of cold tip adapter set to constant -100C
- Heat load of 1.2W placed on CCD
- G10 – Dewar attachment points anchored to 0C
- Idealized thermal contact between components

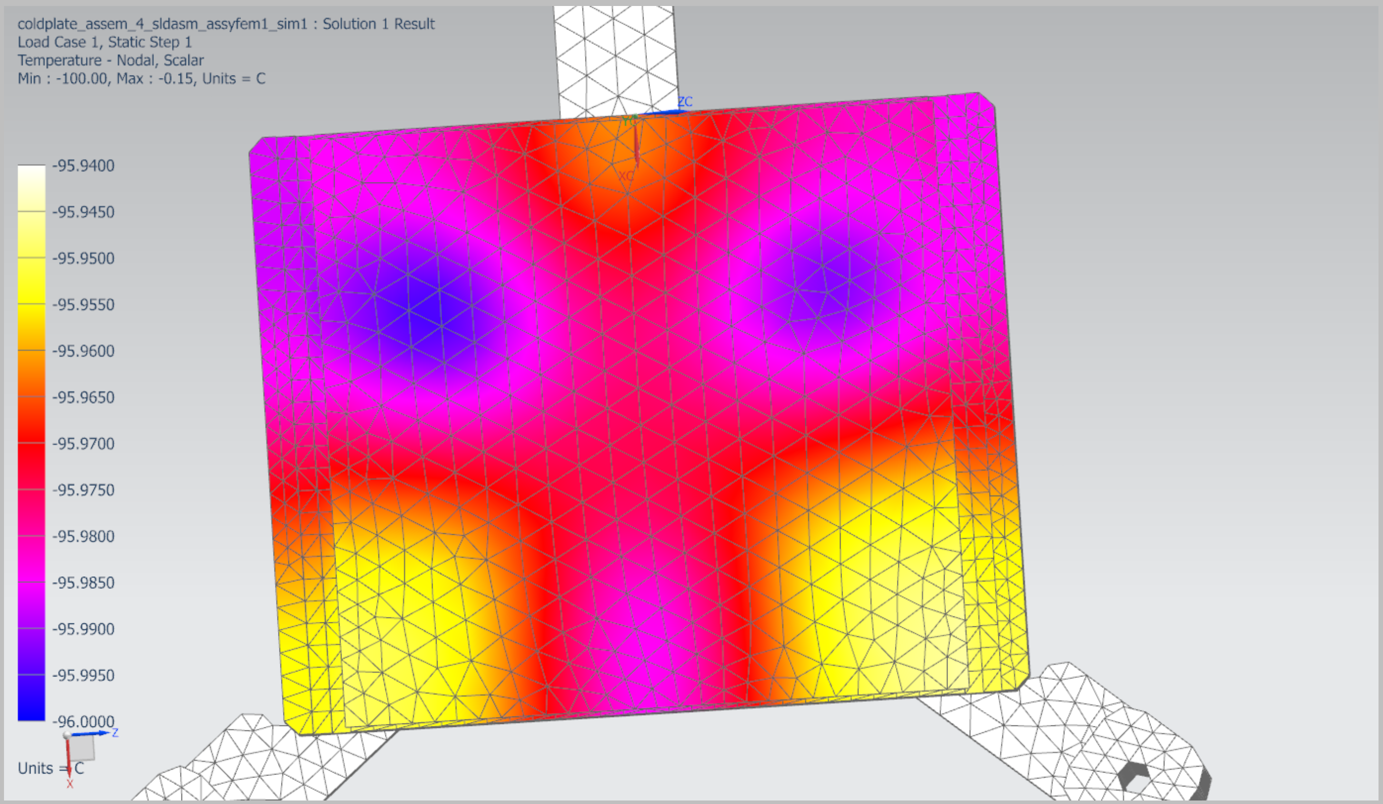


Thermal Gradient

- Temperature gradient of about 5C seen from cold tip to CCD
- This was done by minimizing the size of the cold strap
- The cold tip should be the coldest element in the dewar so as be the first to condense material
- OFHC copper construction
- 0.625” thick thermal strap



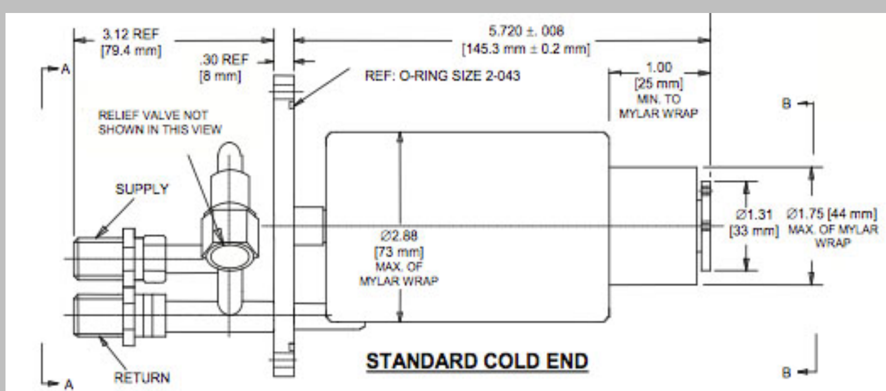
CCD Surface Temperature Gradient



- Temperature range across CCD 0.06K

Cooling System

- PCC based, closed loop, cryo-cooler (aka Cryotiger)
- Known advantages and disadvantages
- Three component system
  - Compressor (standard PCC unit)
  - Cold Head (standard cold head with PT30 gas)
  - Coolant Lines (50ft)
- Improvements to the current system
  - mitigating diurnal temperature variations
  - Shortening and insulating coolant lines could help resolve temperature fluctuations



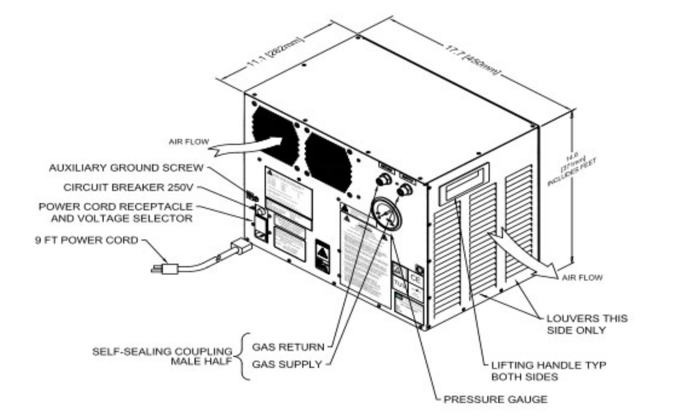
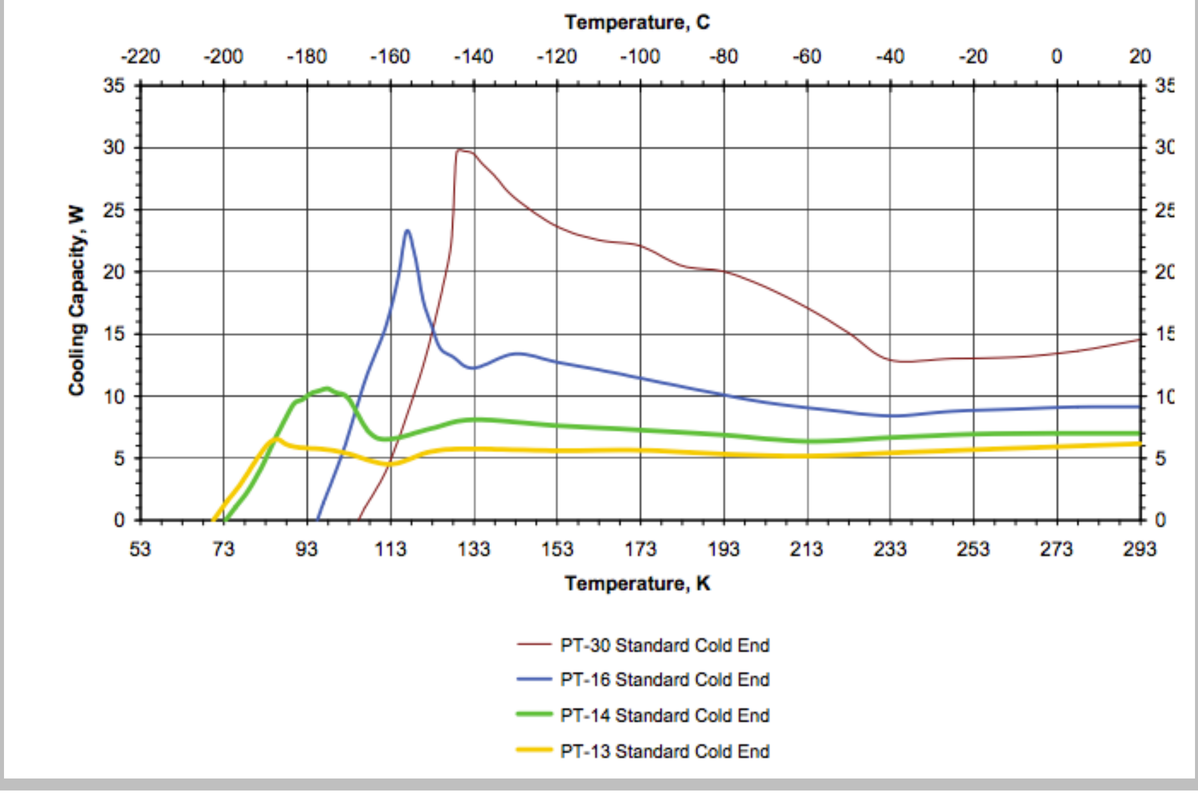


Figure 4-1: Compressor Outline

PCC Cooling Capacity

- To properly size, design, and implement equipment the total cooling capacity for a given temperature should be know
- Ideally this CCD should be kept at -100C, cooling further decreases sensitivity
- Cold tip should be around -105C to account for thermal transmission offsets
- Cooling capacity at -105C (168K) is 22 Watts



CCD Thermal Load

Readout frequency	Line time	Amplifier load	Power dissipation			
			Amplifiers	Serial clocks	Parallel clocks	Total
100 kHz	21 ms	10 kΩ	165 mW	17 mW	3 mW	185 mW
1 MHz	2.2 ms	5 kΩ	275 mW	170 mW	30 mW	475 mW
3 MHz	800 μs	2.2 kΩ	525 mW	510 mW	90 mW	1,125 mW

- Typical exposure readout to be between 100KHz and 1MHz.
- Thermal load is combination of all four amplifiers
- Transient thermal load (only when reading out CCD)

Wiring Thermal Load

- Temperature Sensor Wiring
  - Quad Twist Phosphor Bronze, 32ga
  - k = 50.03 W/m K
  - Two active sets (possible 3 with heater)
  - Q = 0.0015 W/wire
  - Q_{total} = 0.02 W
- CCD Wiring
  - Copper Wire (for grounds only), 30ga
    - k = 346 W/m K
    - 7 wires
    - Q = 0.016 W/wire
    - Q_{total} = 0.12 W
  - Constantan Wire (for signal), 30 ga
    - K = 19.5 W/m K
    - 43 wires
    - Q = 0.0009
    - Q_{total} = 0.04 W
- Wiring Total = 0.18 W

$$Q = \frac{kAdT}{s}$$

k = thermal conductivity constant

A = heat transfer area

s = material thickness

dT = 290K – 170K = 120K

Radiative Thermal Loading

- Subscript 1 = Inner, Subscript 2 = Outer
- A_1 = 0.1068 ft^2 ; T_1 = 170K
- A_2 = 0.3164 ft^2 ; T_2 = 290K
- bare aluminum ε = 0.25
- Cu ε = 0.05
- Nickel Plating ε = 0.07

$$Q = \frac{\sigma A_1 (T_2^4 - T_1^4)}{\frac{1}{\varepsilon_1} \frac{A_1}{A_2} (\frac{1}{\varepsilon_2} - 1)}$$

From NRAO "Guidelines for the Design of Cryogenic Systems"

- Use the above equation to determine thermal load due to radiative heat transfer
- Thermal load to bare Aluminum = 0.52W
- Thermal load to Nickel Plating = 0.12W
- Nickel Plating Cost = $150
- Long term benefits
  - The emissivity of Aluminum is an average between polished and heavily oxidized
  - Over time, with exposure to air, the surfaces will oxidize to the projected number
  - Nickel plating would seal the surface and prevent less outgassing as well as provide a stable, low, long term thermal load

Heat Loads

- CCD Amplifiers
  - Typical = 0.5W (Maximum = 1.125W)
- Temperature Sensors
  - 2 @ 1.0E-5 W
- Radiative Thermal Load
  - Uncoated dewar wall = 0.52W
  - Nickel Plated dewar wall = 0.12W
- Wires = 0.18W
- G10 Substructure = 0.64W
- Total Thermal Load = 1.5W (2.07 W Maximum)

Heater

- With an expected thermal load of 2W maximum and cooling capacity of 22W it is seen that the CCD will try to cool much below the expected value
- Why am I trying to decrease the thermal load?
  - It is my belief that minimizing the thermal load will allow for more stable temperature control
  - Environmental effects such as: ambient temperature, dome thermal load, and cryo-cooler efficiencies are uncontrollable variables
  - If these uncontrollable variables can be minimized and shifted onto a controllable variable then the overall performance / reliability / repeatability of the instrument will benefit
- Control variable
  - The temperature will be PID controlled through two heaters
  - A large heater (25W) on the back of the cold tip adapter will control gross temperature changes
  - A small heater (1W) on the back of the cold plate will control minor temperature changes
- For PID control and temperature feedback a Lakeshore 325 temperature controller will be used
  - Dual PID Control (More from Ed about specifics)
  - RS232 Input/Output
  - Designed for silicon diodes

Long Term Stability

- Why go into so much detail for such a standard imager?
  - Increased lifetime
  - Increased long term performance
  - Minimized down time
- Scheduled Maintenance
  - Replace Cold Head within 6 – 10 years - $5700
    - Shorter lifetime based on warm-up rate and contamination
  - Replace Compressor within 6 – 10 years - $5000
  - PT 30 Gas - $500/recharge
    - Assume recharge every other year
  - PCC External Driers - $900
    - Replaced every other year
  - O-Ring replacement in 5 years - $200
    - O-rings compressed for extended time will exceeded yield stress
  - Ion pump replacement after first year and every other year thereafter - $600
    - Based on cycling of vacuum, if vacuum is maintained then there will be less load on the ion pump
  - Shutter cylinder replacement every 1-2 years - $140/set
    - dependent on shutter cycles
    - Cylinder lifetimes yet to be tested in laboratory, manufacturer lifetime is unreasonable for APO site usage
- Yearly Cost - $1120
- Lifetime Costs - $21780