iSHELL

PDR - Findings (1 April 2013)

- Ambitious science goals have led to a complex instrument involving many sophisticated mechanisms, simplify
- Optics are ready to procure but recommend wider search for vendors for cost savings
- Risk from scattered light and light leaks is underestimated (baffling is incomplete)
- Optical alignment and assembly plan is incomplete
- Lack of systems engineer is a risk
- Significant budget and schedule risk

PDR - Major recommendations

- Identify core science instrument configuration that would, with reduced risk, accomplish a more limited science program within budget and schedule of NSF award (ends Sep 2014)
- PDR panel believe a de-scope strategy will result in a valuable instrument – unique at *LM* and potentially unequalled at *JHK*. Allow for restoration of de-scoped capabilities
- Simplify mechanisms
- Investigate fixed filter slit viewer/guider

Key Science from Science Team

Key Science Case	*Spectroscopy*	*A&G*	*Source size*
Comets	*LM′*	*K* and *L* (daytime)	extended
Atmosphere of Mars	*L*	*K*	extended
Atmospheres of Jupiter and Saturn	*LM′*	*M′* acquisition	extended
Jupiter H_3^+ Juno mission support	*L*	*nbL* acquisition	extended
Atmospheres of hot giant planets	*KL*	*K*	point source
RV searches for young planets	*K*	*K*	point source
Young binaries and PMS calibration	*HK*	*K*	point source
Protostellar envelopes	*M′*	*K*	point source
Protostellar evolution	*LM′*	*K*	point source
Magnetic fields and rotation	*HK*	*K*	point source
Stellar library	*JHKLM′*	*K*	point source

Spectral Formats at PDR

Exp. name (Mode)	*Wavelength coverage (μm)*	*Orders Covered*	*XD (line/mm)*	*Blaze wavel. (μm)*	*Blaze angle (deg.)*	*Order sorter (μm)*	*Slit length (arcsec)*	*XD tilt (degrees)*	*XD size (mm)*	*Custom grating?*
J	1.15-1.35	279-237	800	1.25	29.9	1.05-1.45	5.0	39.4	40x40	Yes
H	1.50-1.80	211-176	530	1.67	25.7	1.40-1.90	5.0	35.2	40x40	Yes
K	1.97-2.52	160-125	290	2.19	18.5	1.80-2.60	5.0	28.0	40x40	Yes
J1	1.15-1.26	280-255	1200	1.2	46.0	1.05-1.45	10.0	56.0	55x40	No
J2	1.25-1.35	255-236	1200	1.2	46.0	1.05-1.45	15.0	61.5	55x40	-
H1	1.50-1.66	211-191	847	1.67	45.0	1.40-1.90	10.0	51.6	50x40	Yes
H2	1.60-1.75	198-181	847	1.67	45.0	1.40-1.90	15.0	55.0	50x40	-
H3	1.68-1.83	188-173	847	1.67	45.0	1.40-1.90	15.0	57.1	50x40	-
K1	1.84-2.03	171-156	720	1.90	43.1	1.80-2.60	15.0	54.1	50x40	No
K2	2.02-2.18	156-144	720	1.90	43.1	1.80-2.60	15.0	58.9	50x40	-
K3	2.12-2.34	148-135	600	2.16	40.4	1.80-2.60	15.0	51.6	50x40	No
K4	2.32-2.52	135-125	600	2.16	40.4	1.80-2.60	15.0	56.4	50x40	-
L1	2.80-3.10	184-167	450	3.14	45.0	2.70-4.20	15.0	51.3	50x40	Yes
L2	3.02-3.30	171-157	450	3.14	45.0	2.70-4.20	15.0	55.0	50x40	-
L3	3.14-3.42	164-151	450	3.14	45.0	2.70-4.20	15.0	57.3	50x40	-
L4	3.28-3.67	157-141	360	3.70	42.0	2.70-4.20	15.0	48.5	50x40	No
L5	3.65-4.01	141-129	360	3.70	42.0	2.70-4.20	15.0	53.5	50x40	-
L6	3.84-4.18	134-124	360	3.70	42.0	2.70-4.20	25.0	56.2	50x40	-
M1	4.55-5.27 s	113-98	210	5.0	31.7	4.50-5.50	15.0	40.4	40x40	No
M2	4.55-5.27 l	113-98	210	5.0	31.7	4.50-5.50	15.0	40.4	40x40	No

- Requires *LM* and *JHK* immersion gratings (i.e. two)
- 11 XD grating positions
- Five custom gratings at about $25k each

Spectral Formats at PDR

Exp. name (Mode)	*Wavelength coverage (μm)*	*Orders Covered*	*XD (line/mm)*	*Blaze wavel. (μm)*	*Blaze angle (deg.)*	*Order sorter (μm)*	*Slit length (arcsec)*	*XD tilt (degrees)*	*XD size (mm)*	*Custom grating?*
~~J~~	~~1.15-1.35~~	~~279-237~~	~~800~~	~~1.25~~	~~29.9~~	~~1.05-1.45~~	~~5.0~~	~~39.4~~	~~40x40~~	~~Yes~~
~~H~~	~~1.50-1.80~~	~~211-176~~	~~530~~	~~1.67~~	~~25.7~~	~~1.40-1.90~~	~~5.0~~	~~35.2~~	~~40x40~~	~~Yes~~
~~K~~	~~1.97-2.52~~	~~160-125~~	~~290~~	~~2.19~~	~~18.5~~	~~1.80-2.60~~	~~5.0~~	~~28.0~~	~~40x40~~	~~Yes~~
J1	1.15-1.26	280-255	1200	1.2	46.0	1.05-1.45	10.0	56.0	55x40	No
J2	1.25-1.35	255-236	1200	1.2	46.0	1.05-1.45	15.0	61.5	55x40	-
H1	1.50-1.66	211-191	847	1.67	45.0	1.40-1.90	10.0	51.6	50x40	~~Yes~~
H2	1.60-1.75	198-181	847	1.67	45.0	1.40-1.90	15.0	55.0	50x40	-
H3	1.68-1.83	188-173	847	1.67	45.0	1.40-1.90	15.0	57.1	50x40	-
K1	1.84-2.03	171-156	720	1.90	43.1	1.80-2.60	15.0	54.1	50x40	No
K2	2.02-2.18	156-144	720	1.90	43.1	1.80-2.60	15.0	58.9	50x40	-
K3	2.12-2.34	148-135	600	2.16	40.4	1.80-2.60	15.0	51.6	50x40	No
K4	2.32-2.52	135-125	600	2.16	40.4	1.80-2.60	15.0	56.4	50x40	-
L1	2.80-3.10	184-167	450	3.14	45.0	2.70-4.20	15.0	51.3	50x40	~~Yes~~
L2	3.02-3.30	171-157	450	3.14	45.0	2.70-4.20	15.0	55.0	50x40	-
L3	3.14-3.42	164-151	450	3.14	45.0	2.70-4.20	15.0	57.3	50x40	-
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L6	3.84-4.18	134-124	360	3.70	42.0	2.70-4.20	25.0	56.2	50x40	-
M1	4.55-5.27 s	113-98	210	5.0	31.7	4.50-5.50	15.0	40.4	40x40	No
M2	4.55-5.27 l	113-98	210	5.0	31.7	4.50-5.50	15.0	40.4	40x40	No

5” slit

- Requires one *JHKLM* immersion grating
- 7 XD grating positions
- No custom gratings, saving at about $150k

Spectral Formats after De-scope

Exp. name (Mode)	*Wavelength coverage (μm)*	*Orders Covered*	*XD (line/mm)*	*Blaze wavel. (μm)*	*Blaze angle (deg.)*	*Order sorter (μm)*	*Slit length (arcsec)*	*XD tilt (degrees)*	*XD size (mm)*	*Custom grating?*
Spare 1										
J1	1.15-1.26	462-420	1200	1.10	41.3	1.05-1.45	5.0	56.0	50x40	No
J2	1.26-1.35	420-390	1200	1.10	41.3	1.05-1.45	5.0	61.3	50x40	-
H1	1.50-1.69	350-308	720	1.90	43.1	1.40-1.90	5.0	44.6	50x40	No
H2	1.61-1.82	323-289	720	1.90	43.1	1.40-1.90	5.0	47.6	50x40	-
K1	1.95-2.26	265-229	497	2.25	34.0	1.80-2.60	5.0	41.0	50x40	No
K2	2.24-2.53	231-205	497	2.25	34.0	1.80-2.60	5.0	45.8	50x40	-
L1	2.80-3.10	184-167	450	3.10	45.0	2.70-4.20	15.0	51.3	50x40	No
L2	3.02-3.30	171-157	450	3.10	45.0	2.70-4.20	15.0	55.0	50x40	-
L3	3.14-3.42	164-151	450	3.10	45.0	2.70-4.20	15.0	57.3	50x40	-
L4	3.28-3.67	157-141	360	3.70	42.0	2.70-4.20	15.0	48.5	50x40	No
L5	3.65-4.01	141-129	360	3.70	42.0	2.70-4.20	15.0	53.5	50x40	-
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M1	4.55-5.27 s	113-98	210	5.0	31.7	4.50-5.50	15.0	40.4	40x40	No
M2	4.55-5.27 l	113-98	210	5.0	31.7	4.50-5.50	15.0	40.4	40x40	No

- Trade off shorter slit length and reduced wavelength range at *JHK* against need for against custom XD gratings and need for *JHK* immersion grating

De-scope Summary

- Only one immersion grating (*JHKLM*)
- No custom XD gratings, all replicas
- Simplified XD mechanism
  - Fewer positions (12 → 8)
  - Simplified position sensing (no Kaman sensor)
- Reduce number of filters to only those needed for order sorting and A&G
  - No imaging-only filters
  - Use same 8-position wheels for order sorter and slit viewer filter wheels
- Simplified bearings in mechanisms
- Allow for upgrade
  - *JHK* immersion grating
  - Custom XD gratings
  - More filters
- This meets all of the PDR recommendations

Cold Optics Procurement – PDR estimate

Item	Vendor	ROM
OAPs	Corning/OFC	$200 k
Custom lenses and mirrors	Optical Solutions, Inc.	$178 k (formal)
Fold mirrors	Advanced Optics	$2 k
Slit mirrors	Max Levy Autograph	$29 k
XD gratings (custom)	Bach Research	$125 k (5)
XD gratings (replicas)	Newport (Richardson)	$6 k (6)
Filters	Past projects	$100 k ($5 k each)
	Total ROM	$640 k

Cold Optics Procurement – Final

Item	Vendor	PO
OAPs	Durham Precision Optics	$28.0 k
Custom lenses and mirrors	ISP Optics	$40.0 k
Fold mirrors	Advanced Optics	$1.8 k
Slit mirrors	Max Levy Autograph	$29.7 k
XD gratings (replicas)	Newport (Richardson)	$5.4 k (5)
XD grating (replica)	Thor Labs	0.8 k (1)
Filters (custom)	Materion (formerly Barr)	$86.0 k (9)
Filters (COTS)	Andover Corp.	$1.3 k (3)
	Total PO	$192.2 k

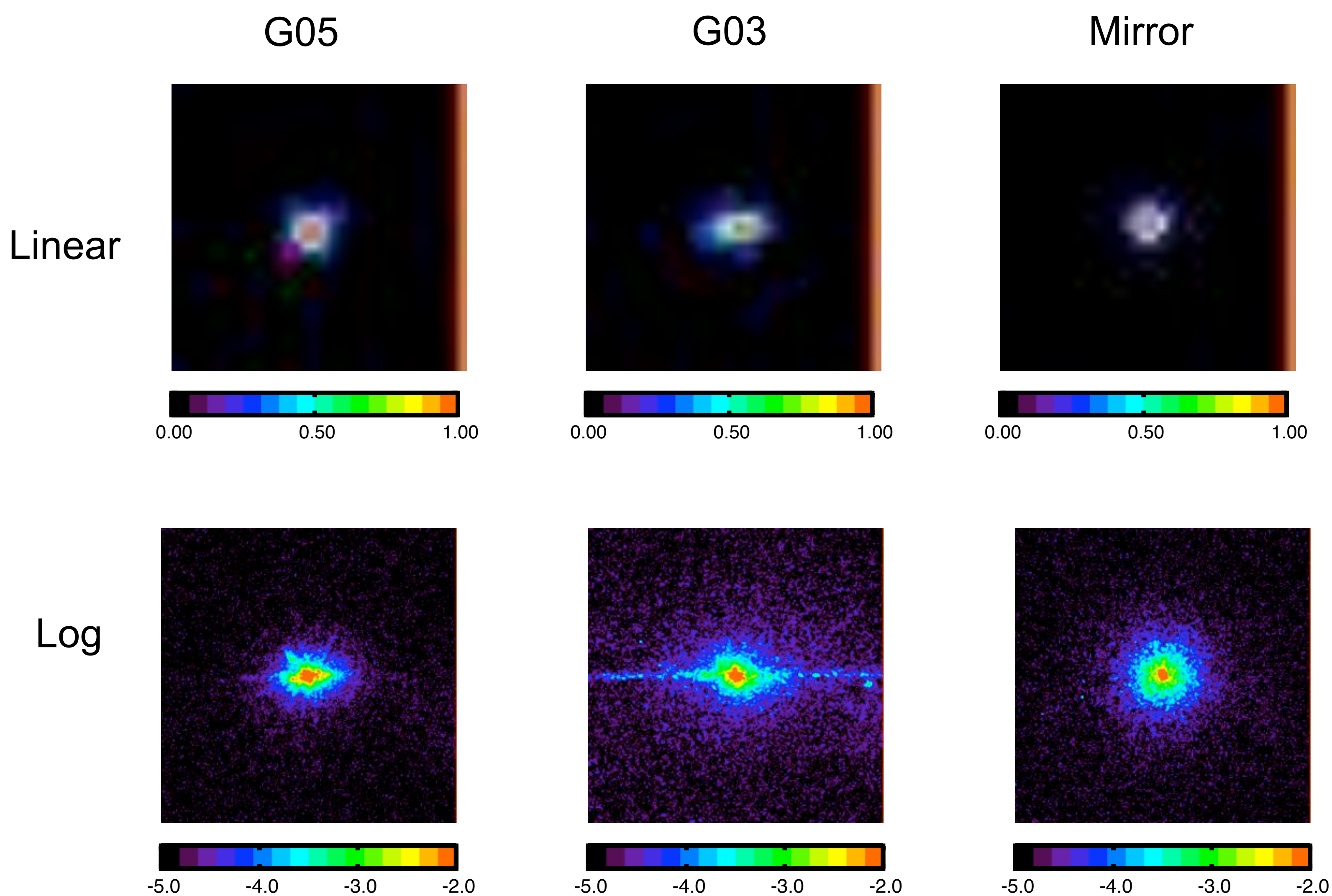
Calibration System - Estimate

Item	Vendor	ROM
Th-Ar lamp + power supply	PHOTRON	$2 k
QTH lamp (10W)	Oriel	$0.04 k (2)
IR source	Oriel	$0.6 k (2)
Lamp power supply	Oriel	$4 k (2)
Ellipsoidal reflectors	Edmund Optics	$0.2 k
Integrating sphere	Labsphere, Inc.	$3 k
Pupil lens	ISP Optics	$2 k
Spherical mirror	ISP Optics	$2 k
Fold mirrors	Advanced Optics	$1.5k
Translation stages	Micos	$6 k (2)
	Total ROM	$22 k

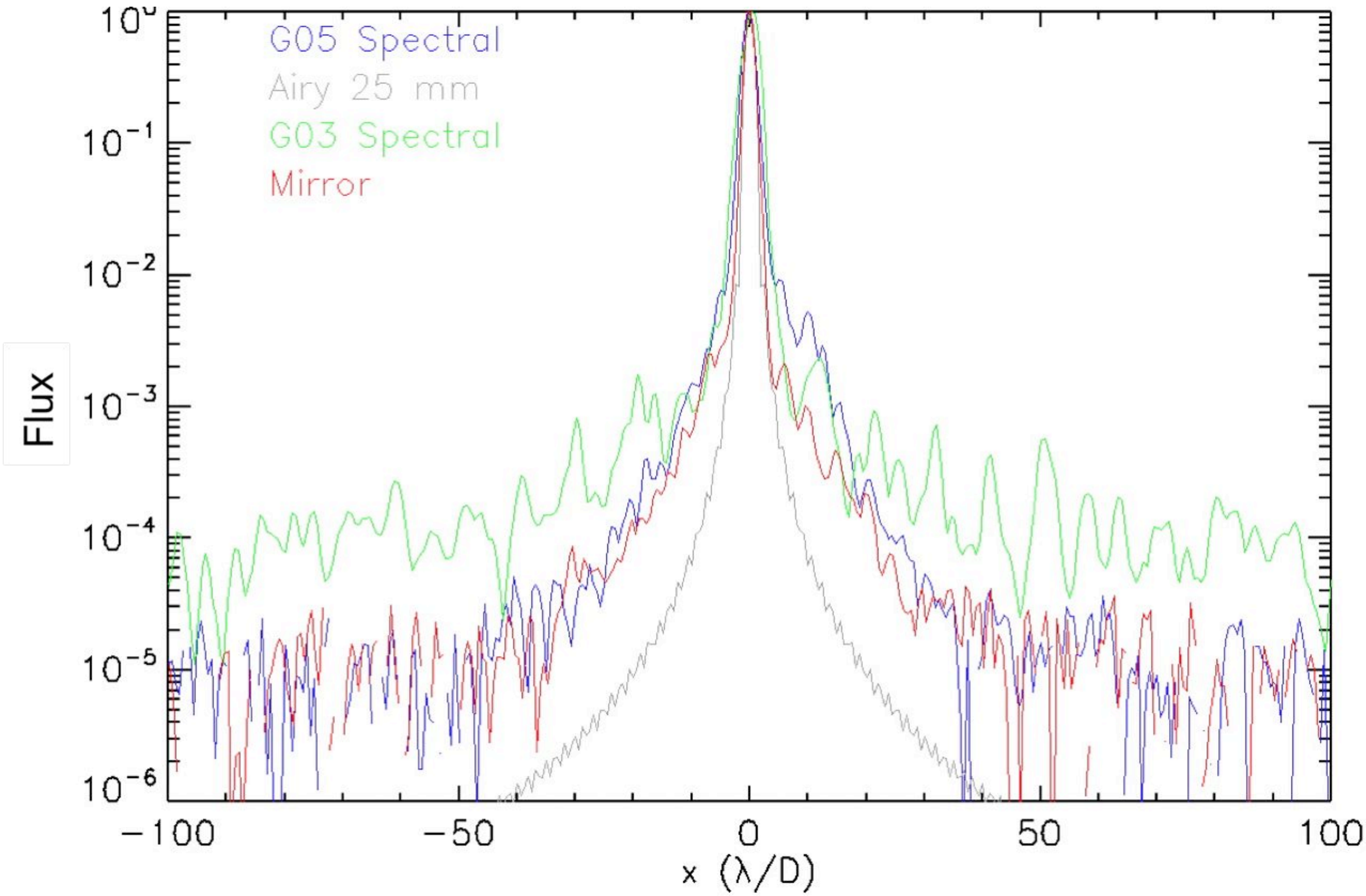
Immersion Grating Update

- New grating, G05, fabricated by contact lithography
- Best performing R3 grating produced by UT in last three years
- Out performs G03 in terms of high frequency periodic errors and isotropic scattered light but has some low frequency periodic errors
- Grating is acceptable for iSHELL but UT will try to produce better gratings (*JHKLM* and *JHK*)

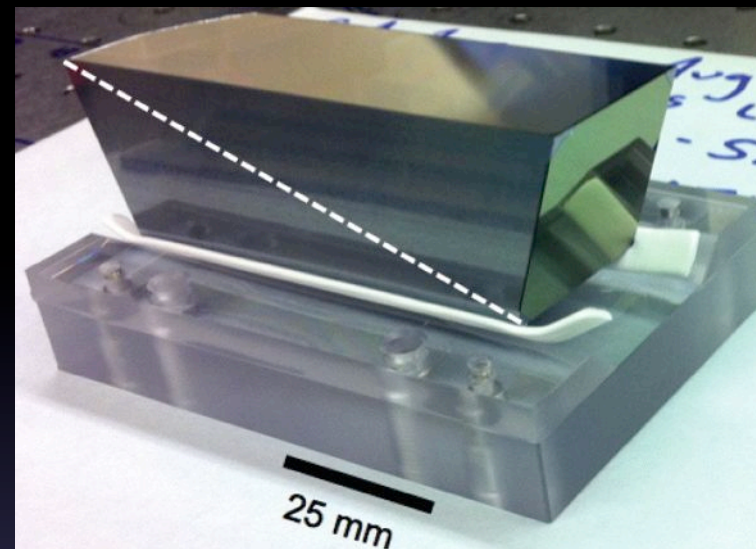
Immersion Grating PSF

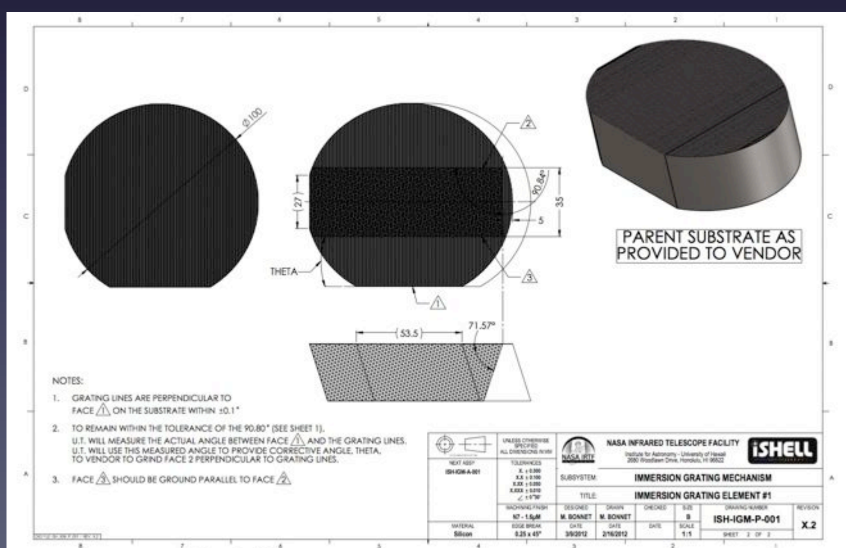


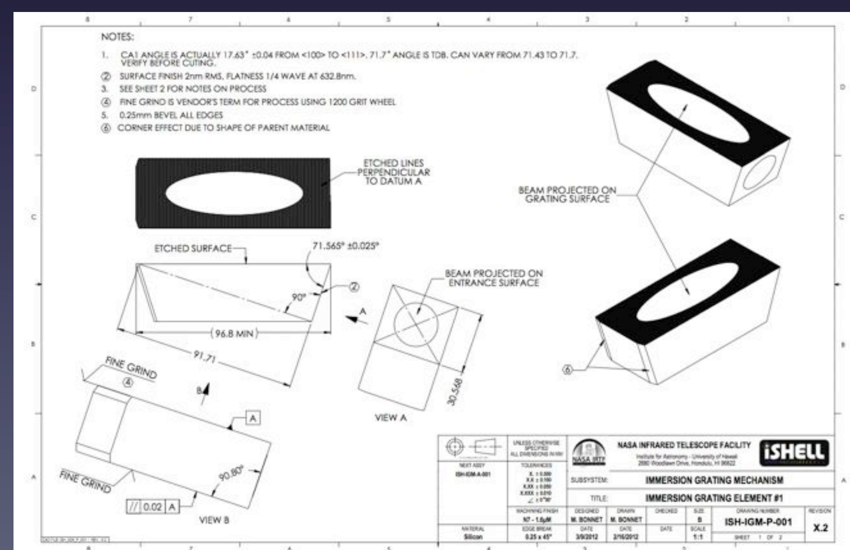
G05 Spectral Purity Plot



Next step: cut substrate to shape

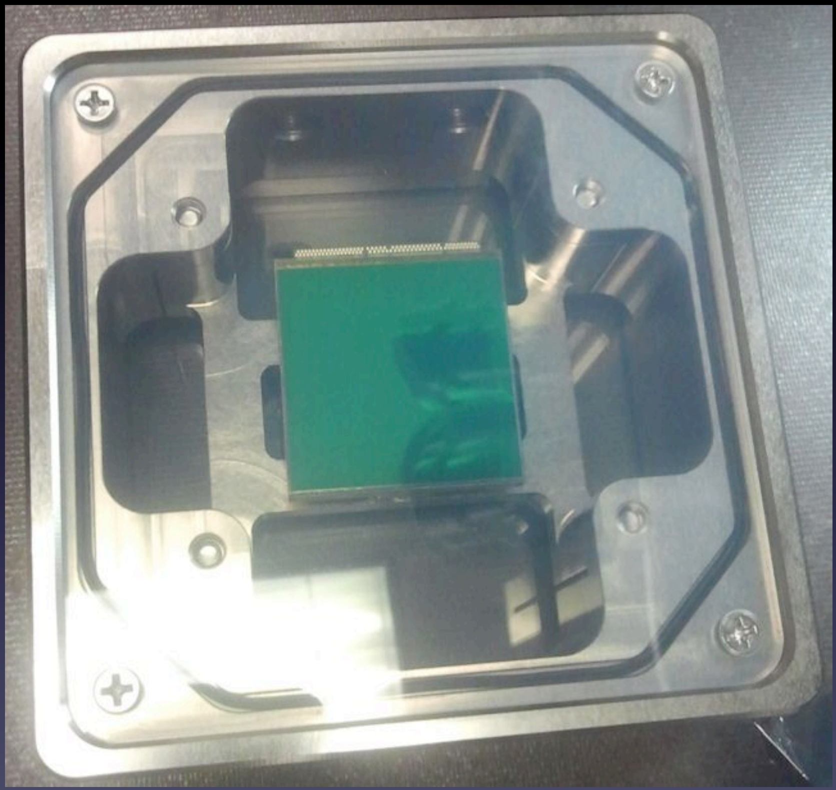




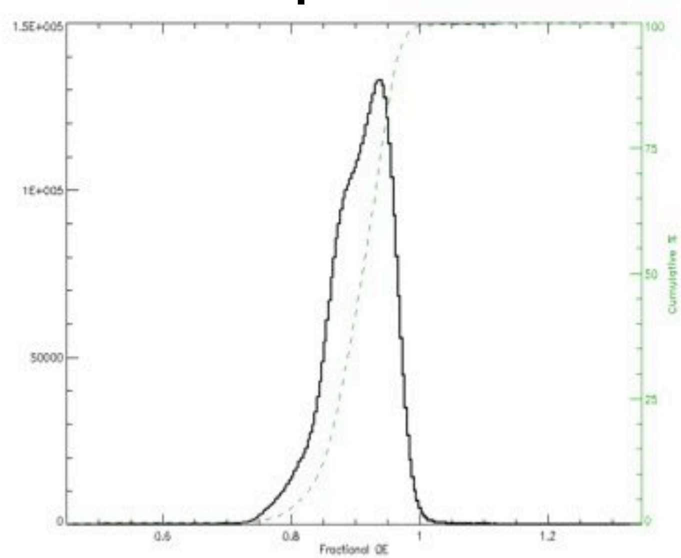


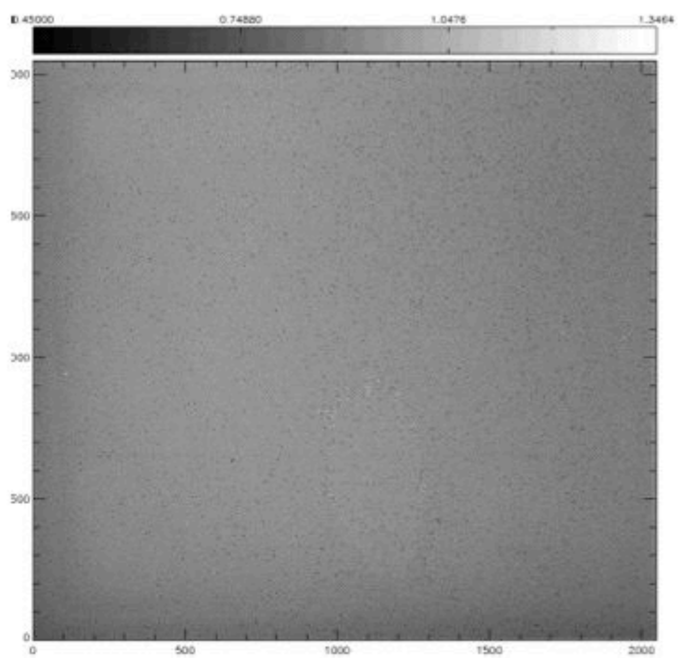
iSHELL Hawaii 2RG Array Update

- New science grade array delivered 9/11/13
- Replacement for original science grade array that had the design flaw in the pixel interconnect structure

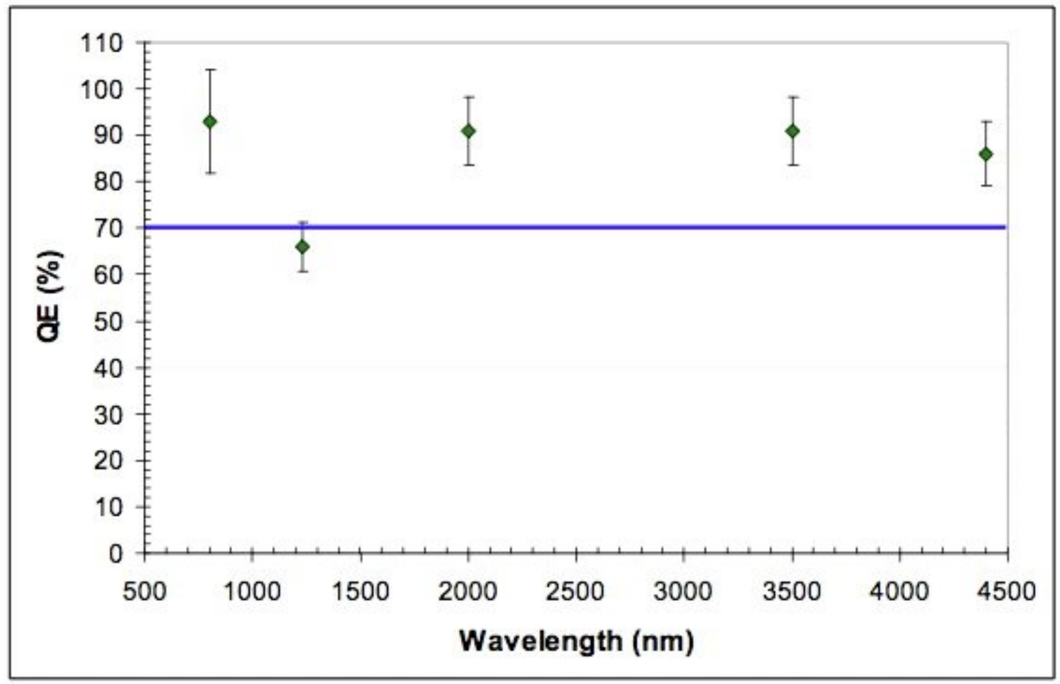


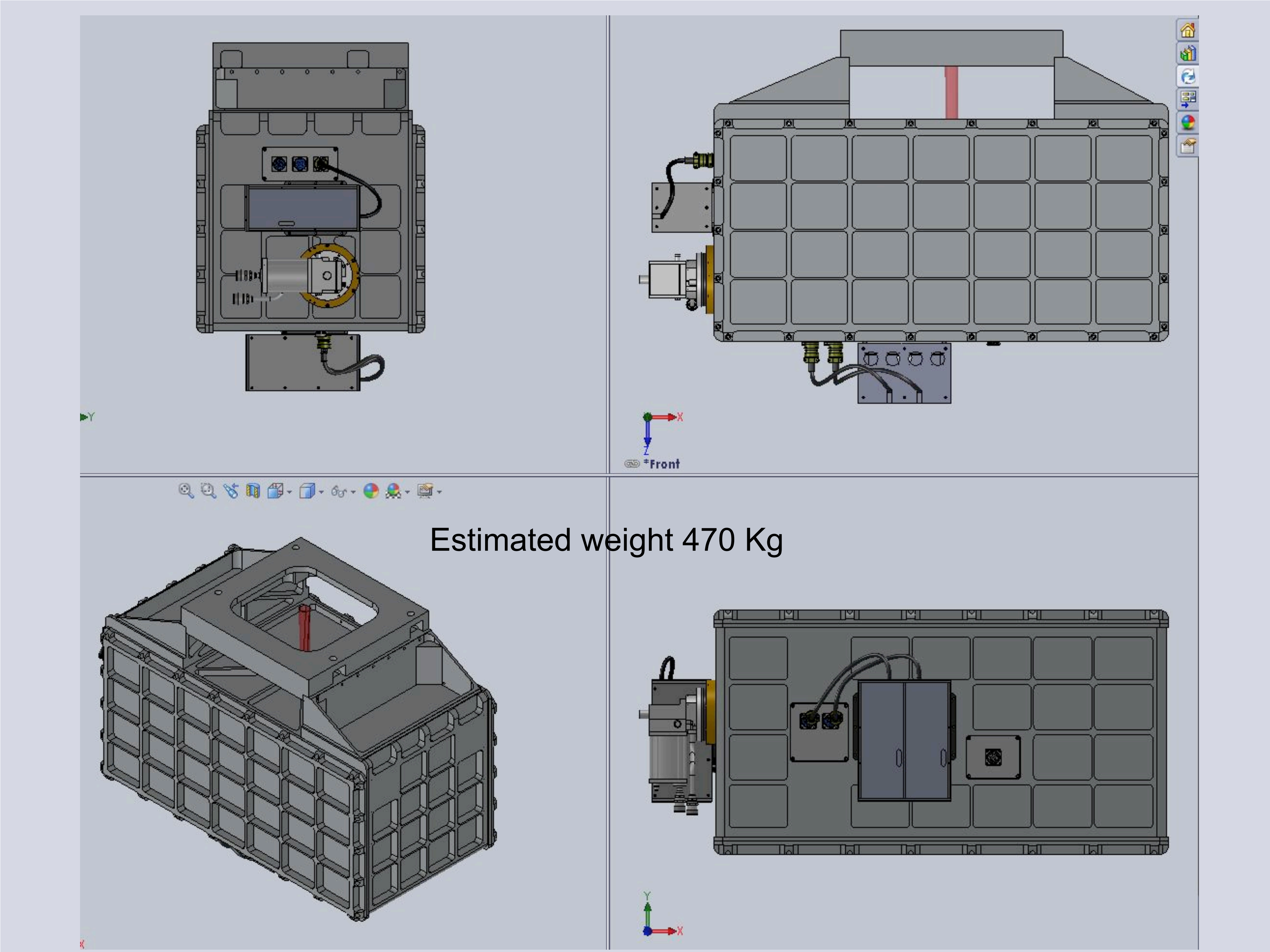
2 µm QE





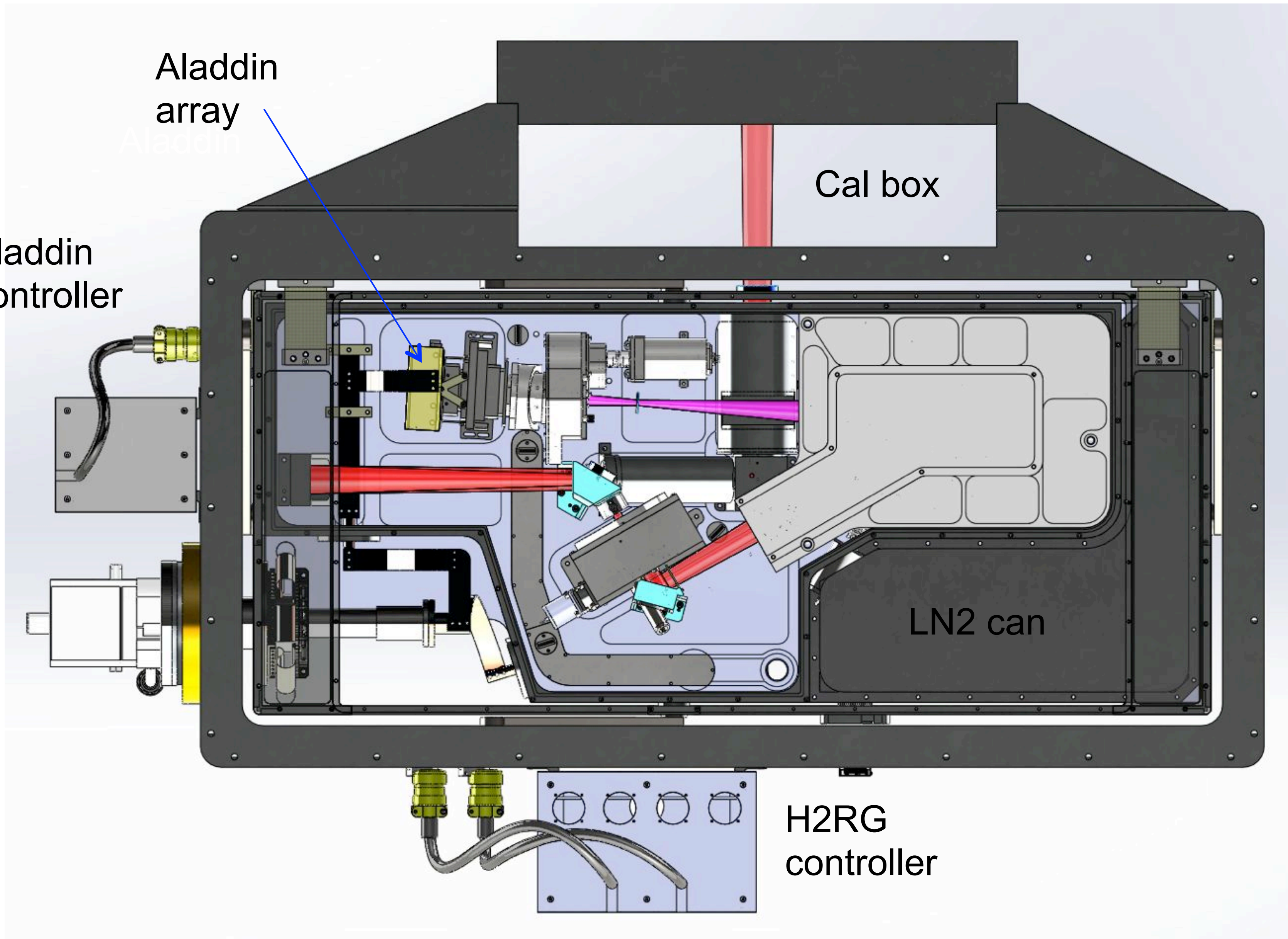
iSHELL Science Array: H2RG - 17311



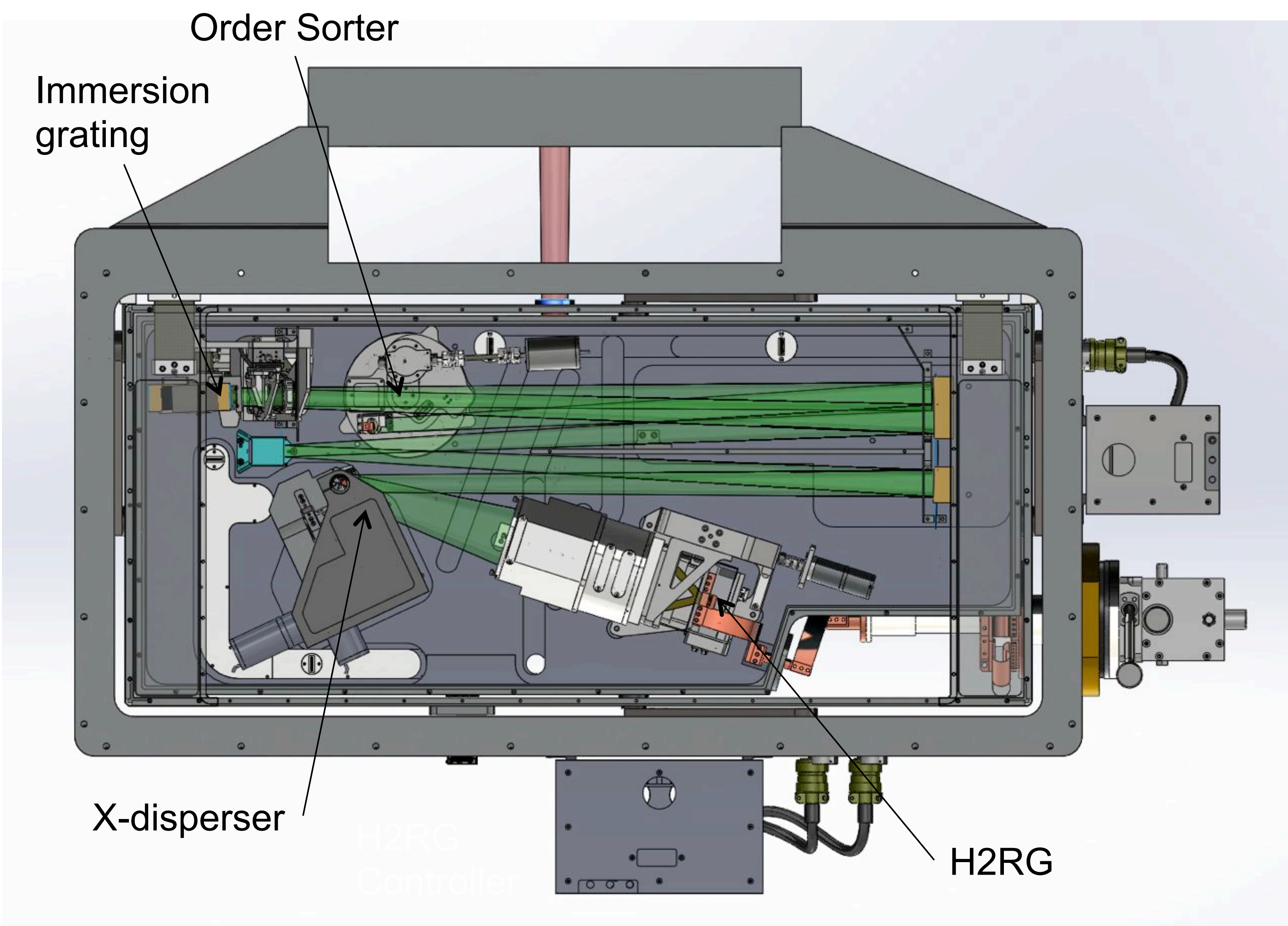


Estimated weight 470 Kg

Fore-optics

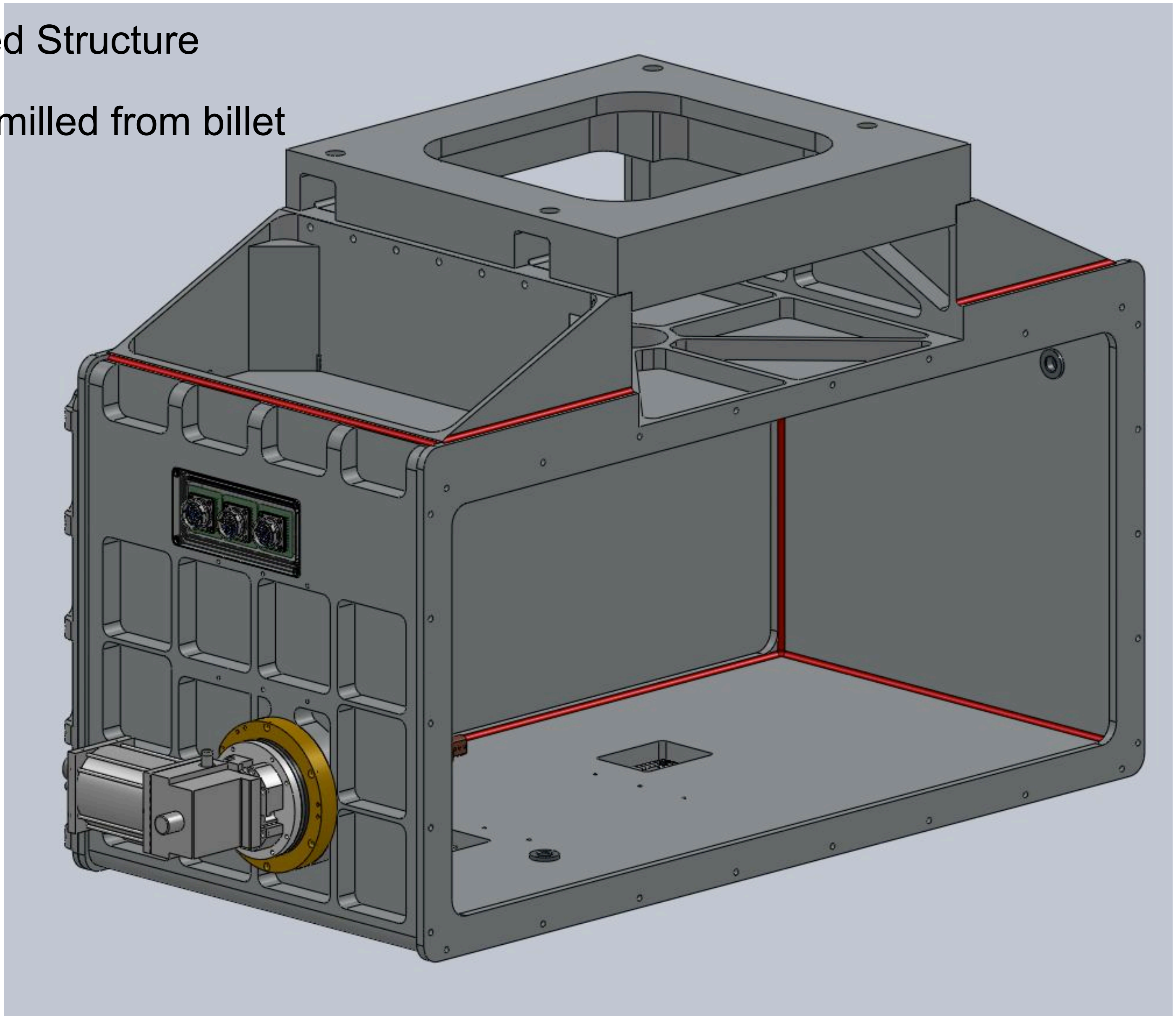

Aladdin
array
Cal box
Aladdin
controller
LN2 can
H2RG
controller

Spectrograph



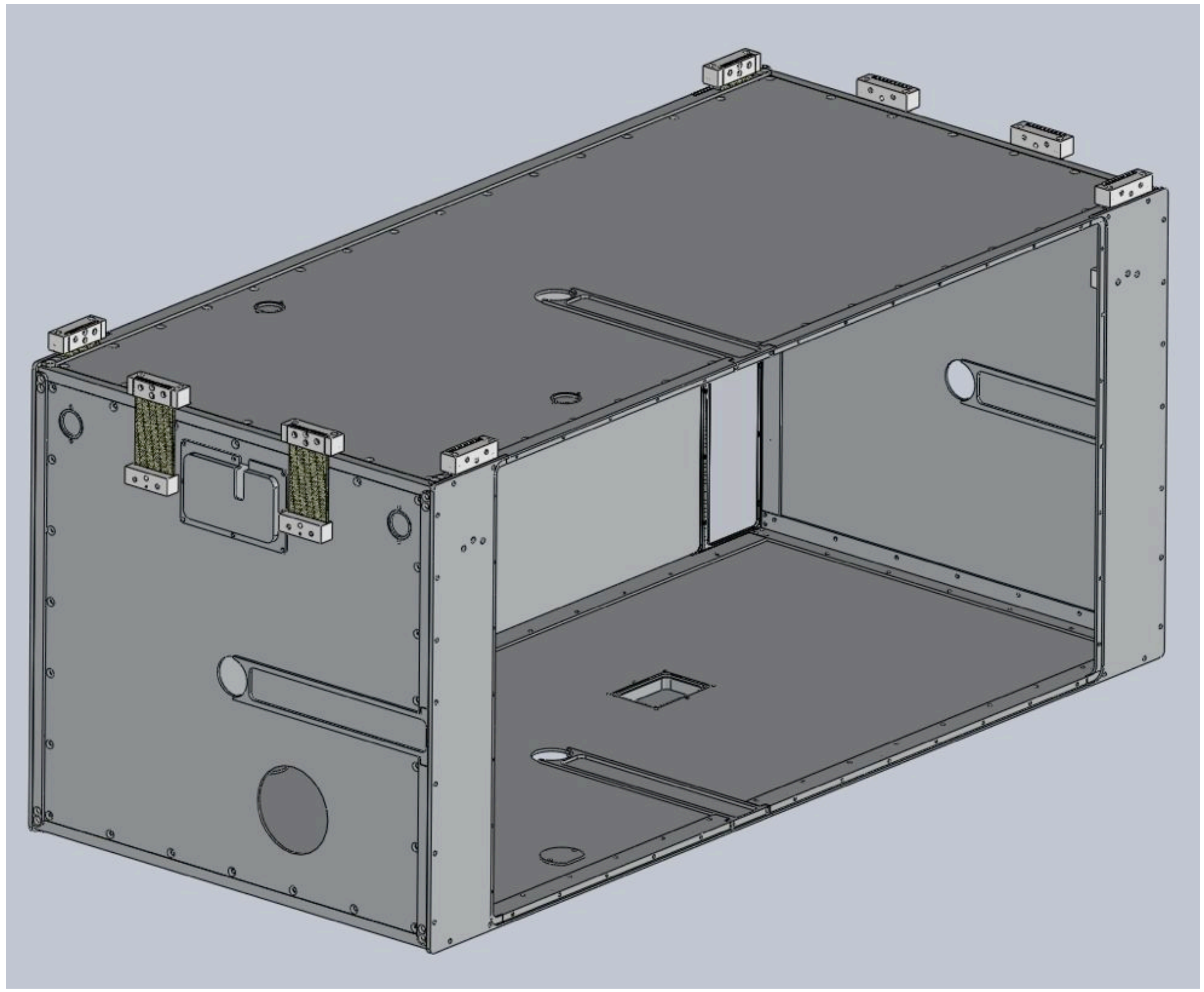
Cryostat vacuum jacket

- Welded Structure
- Parts milled from billet

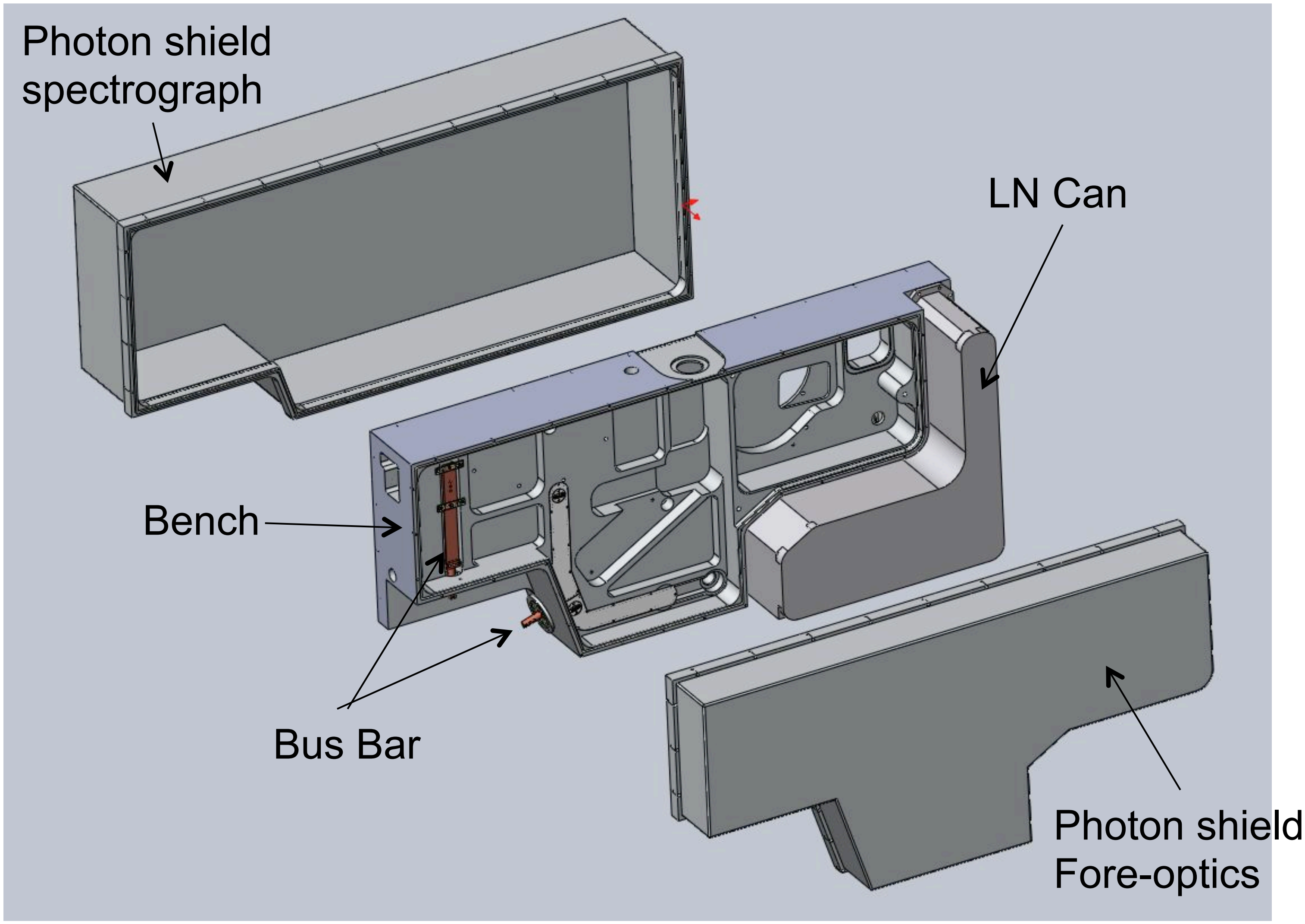


Cryostat radiation shield

- Eight G-10 Mount tabs (1.9W heat load)
- Pre-polished panels
- Access panels for wire harness installation
- Slots for truss clearance during installation
- Covers for access to truss mount bolts

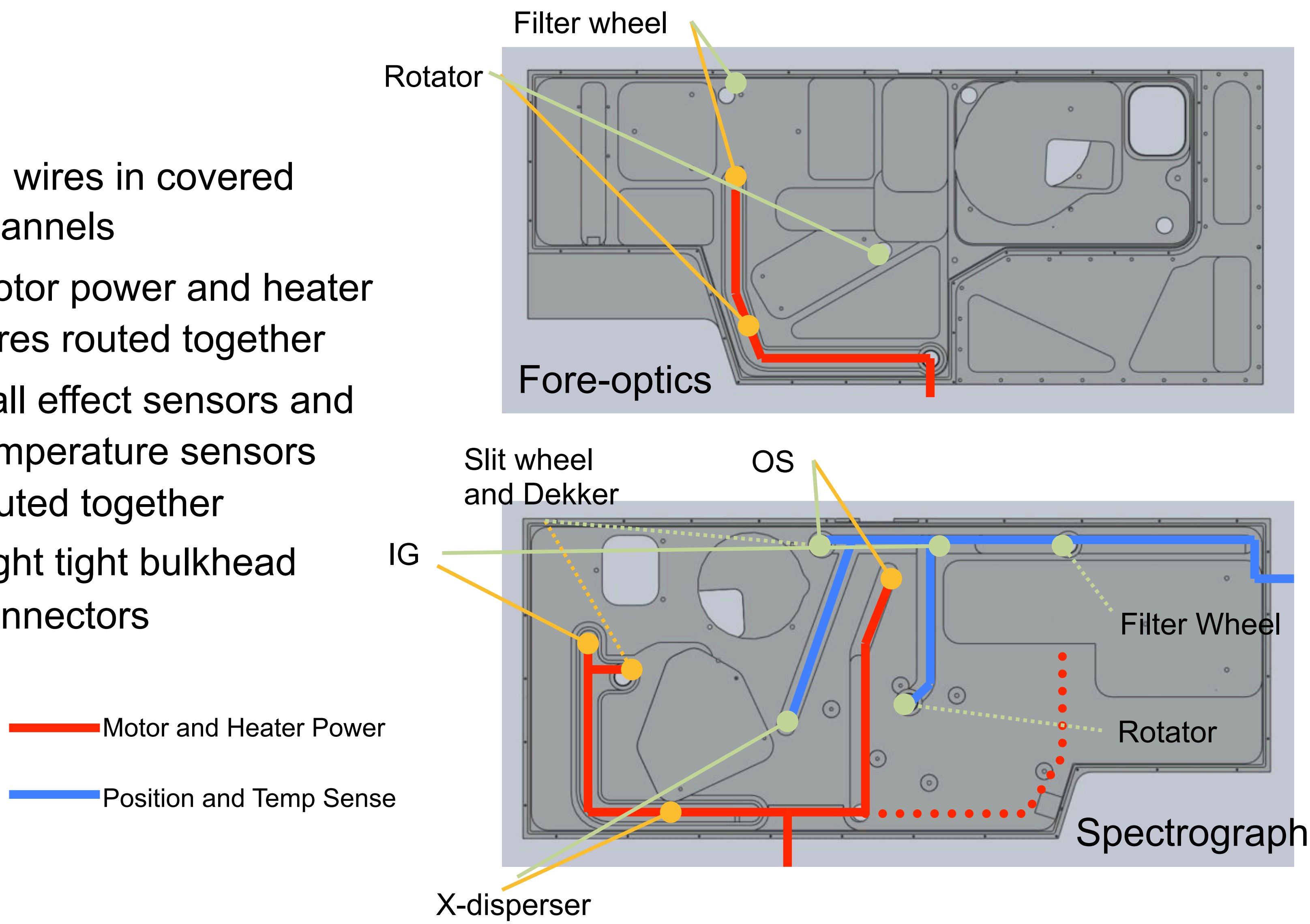


Optics Bench

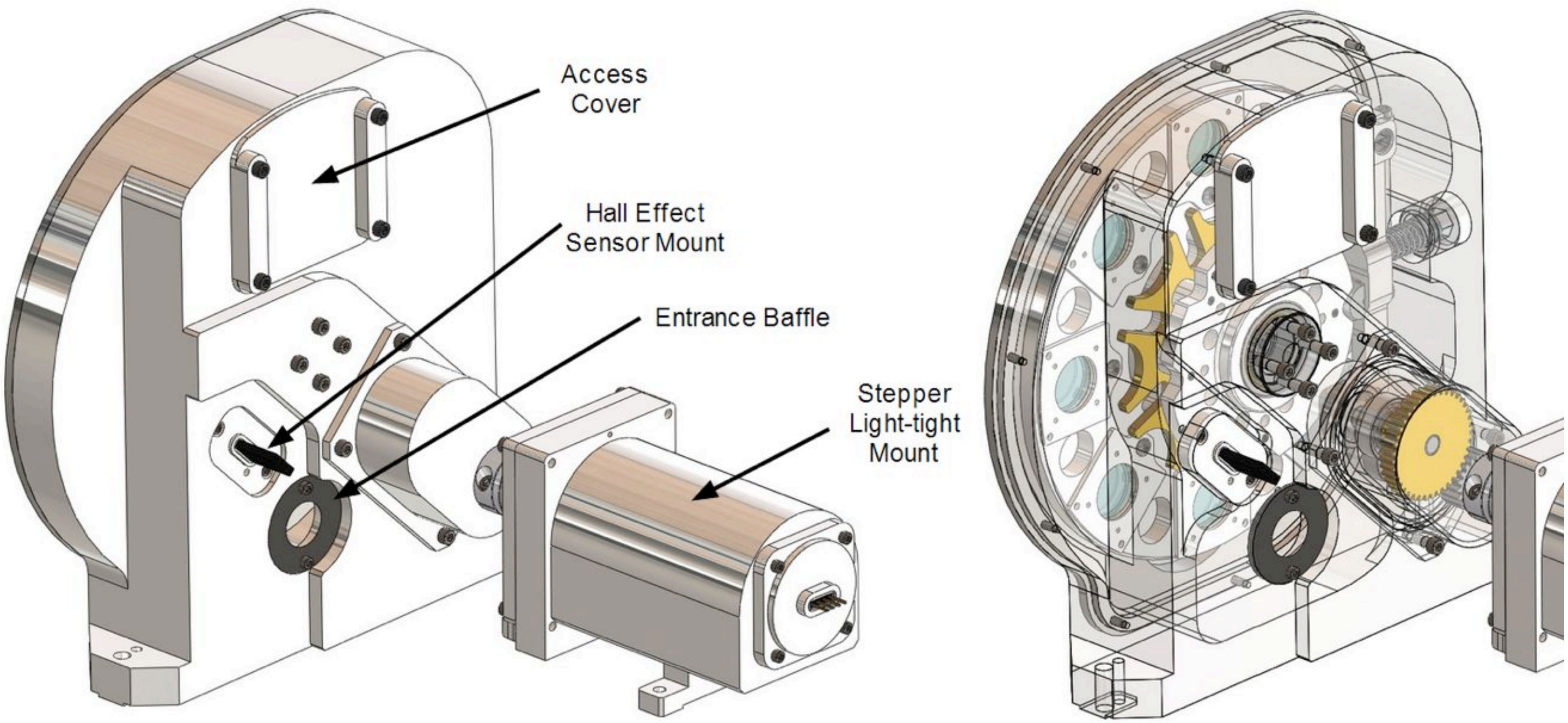


Internal wiring

- All wires in covered channels
- Motor power and heater wires routed together
- Hall effect sensors and temperature sensors routed together
- Light tight bulkhead connectors

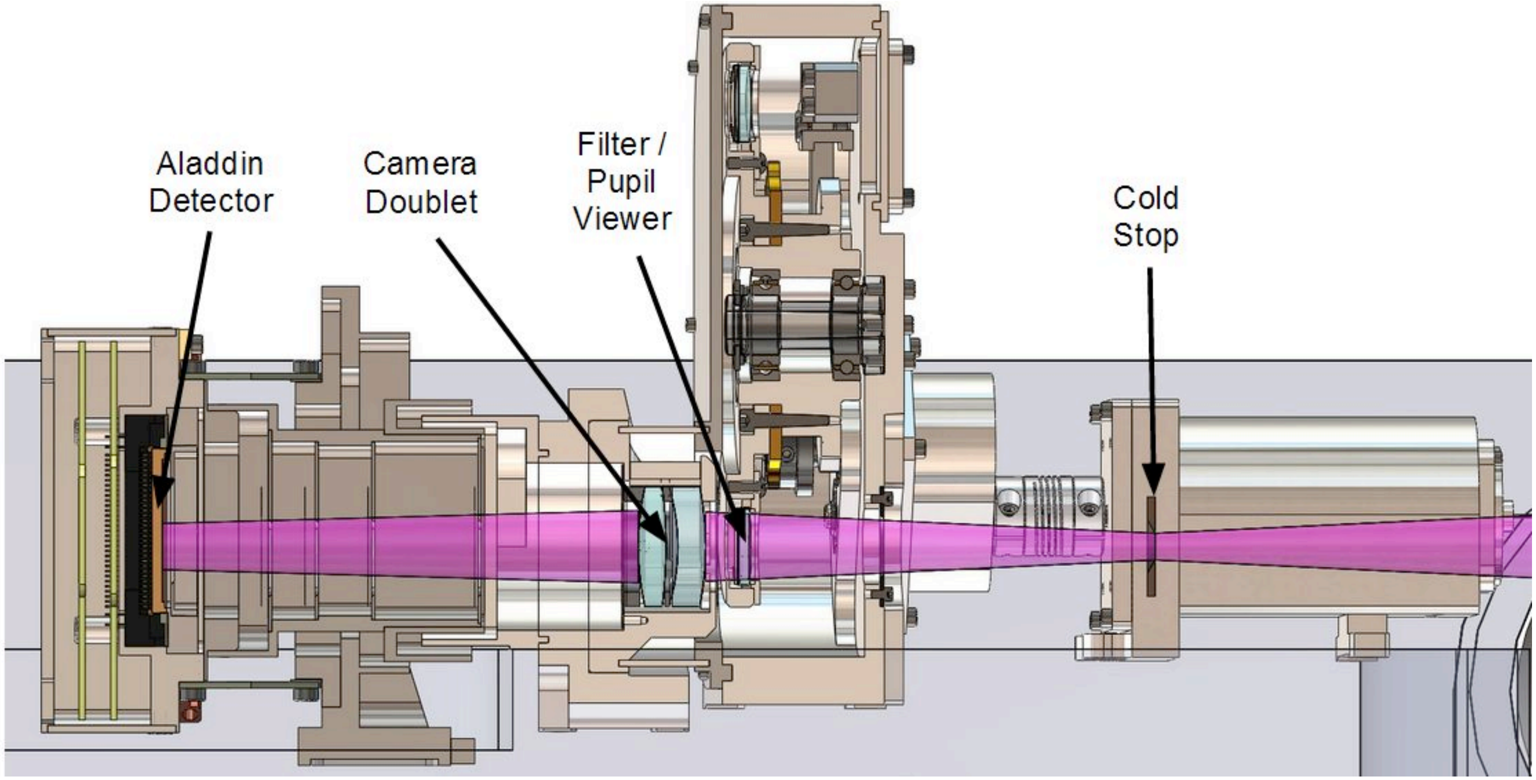


Slit Viewer Filter Wheel



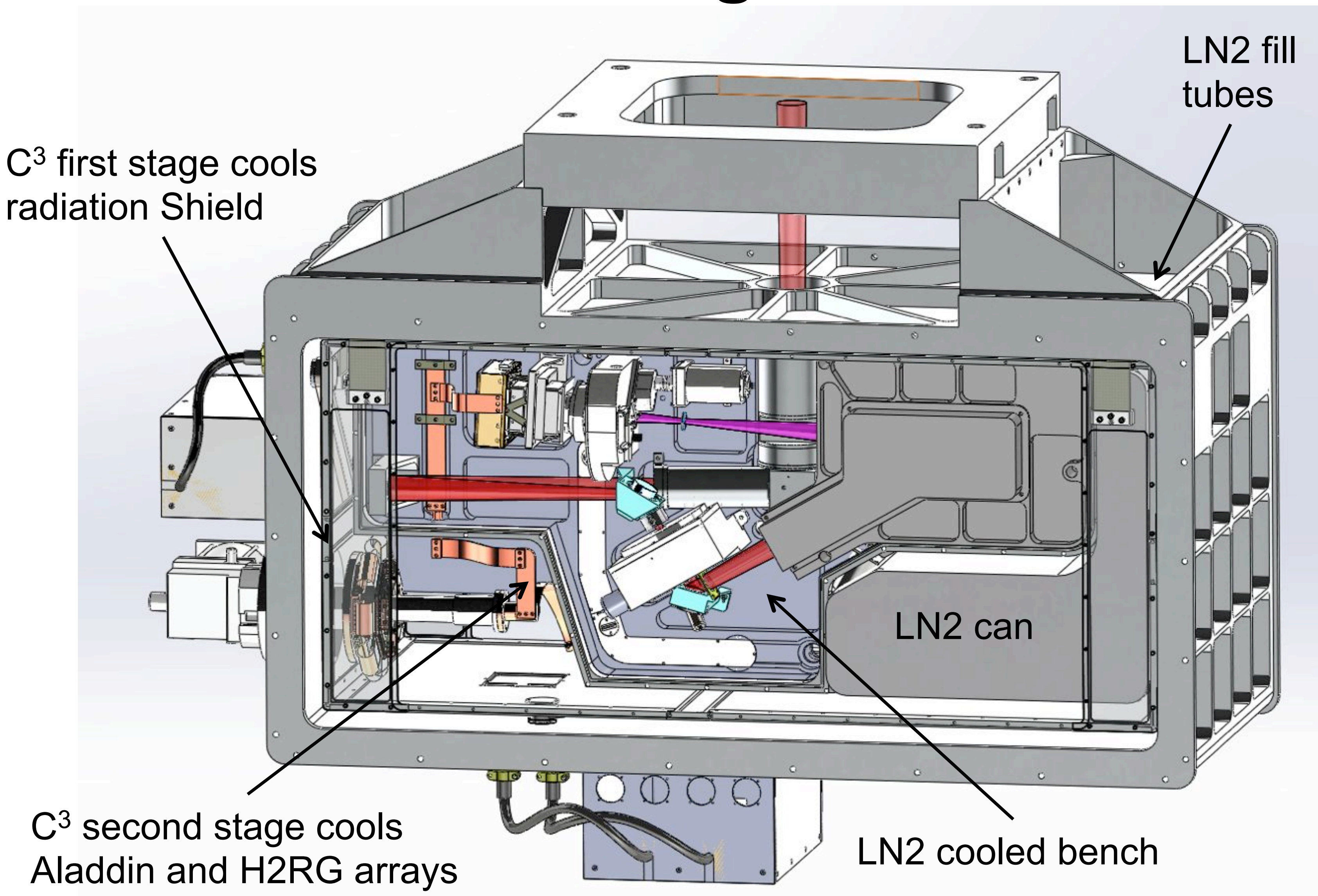
- De-scope: 8 positions instead of 15, easier to implement
- Now same as order sorter filter wheel
- Light-tight motor mount

Slit Viewer Assembly

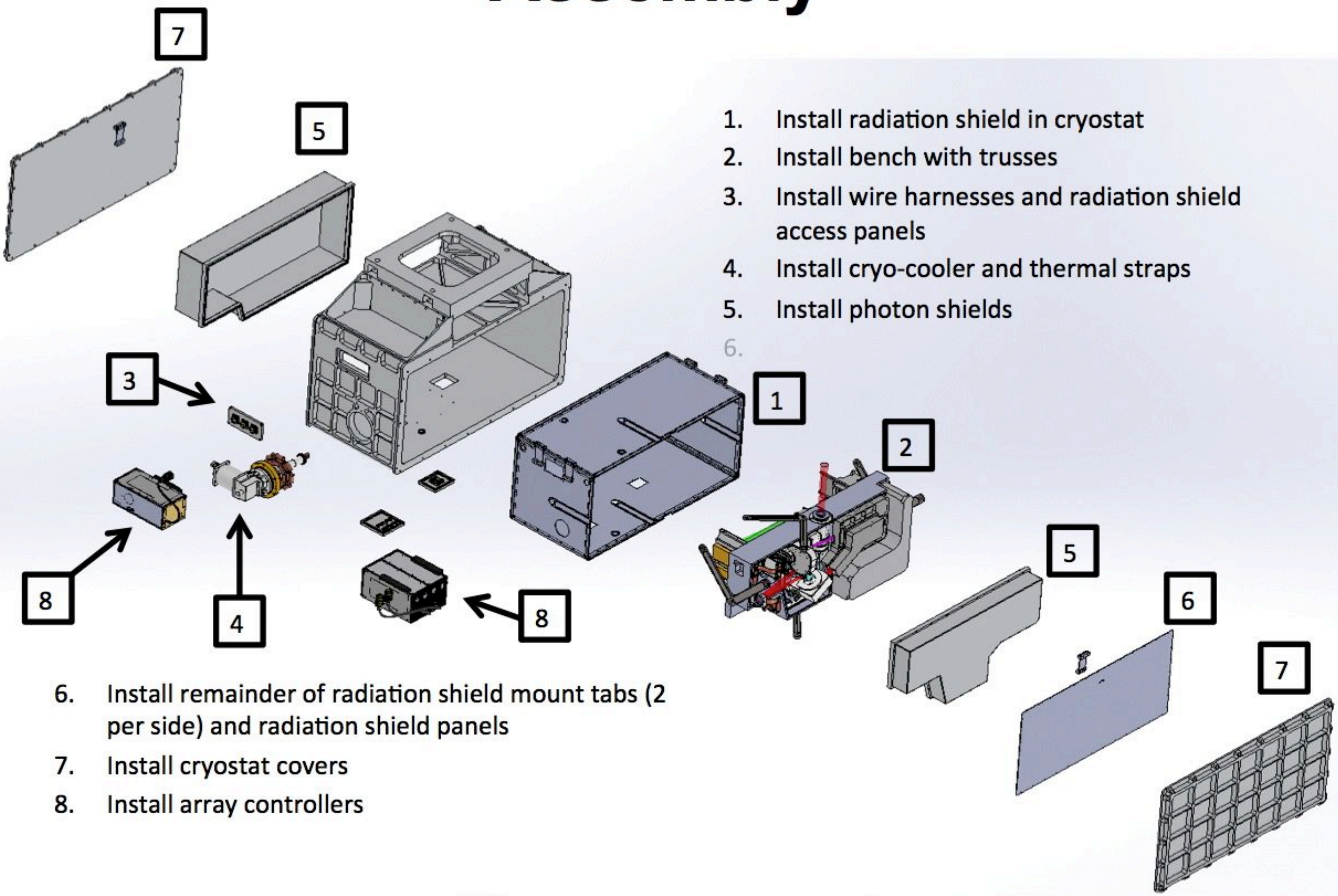


- Light tight from filter wheel to Aladdin array
- Reusing the array mount and baffle tube “as is”. Only the baffles are re-designed to accommodate ISHELL’s optical layout
- The doublet mount is used as a light-tight interface between the filter wheel and array mount

Cooling


LN2 fill tubes
C³ first stage cools radiation Shield
LN2 can
C³ second stage cools Aladdin and H2RG arrays
LN2 cooled bench

Assembly



1. Install radiation shield in cryostat
2. Install bench with trusses
3. Install wire harnesses and radiation shield access panels
4. Install cryo-cooler and thermal straps
5. Install photon shields
6. Install remainder of radiation shield mount tabs (2 per side) and radiation shield panels
7. Install cryostat covers
8. Install array controllers

Data Reduction

- iSHELL requires DR tool similar to Spextool
- Not included in original NSF iSHELL proposal
- We will propose (1 Nov 2013) to NSF/ATI to fund this work :
  - Based on Spextool algorithms and GUI
  - Consultant Mike Cushing and a programmer
  - Estimate 26 weeks of effort, $100k
  - Schedule: first six months of 2015 starting when lab data is first available

iSHELL Budget and Schedule

Budget

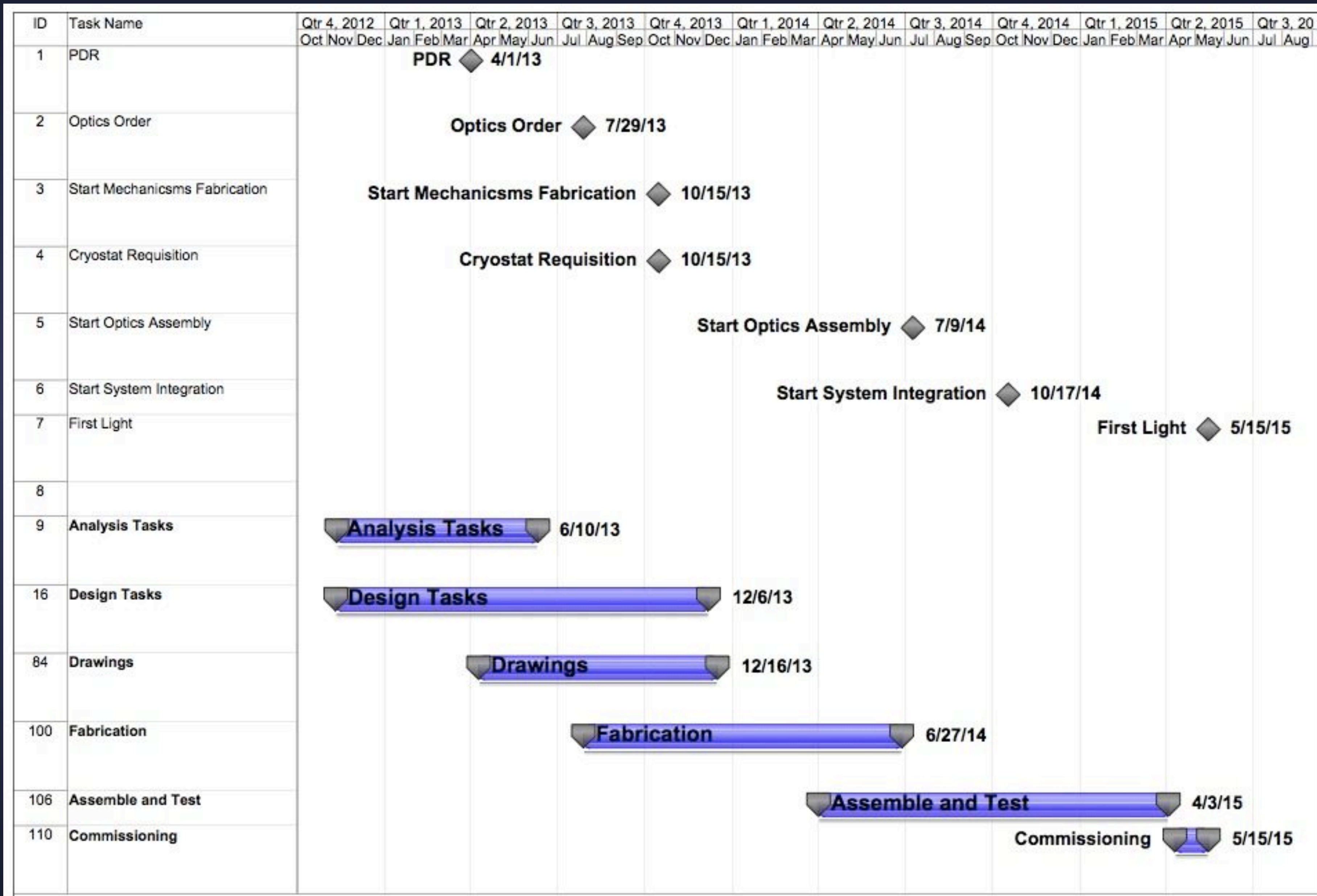
Funding needed to complete (not including IRTF manpower):

Oceanit	$390K
Machine shop	$550K
Equipment	$250K
Optics	$120K
Materials; Supplies	$100K
Total	$1,390K

Funding available:

Remaining NSF funds	$1,292K
IRTF operations	$ 120K

Top-level schedule



Teledyne H2RG Procurement

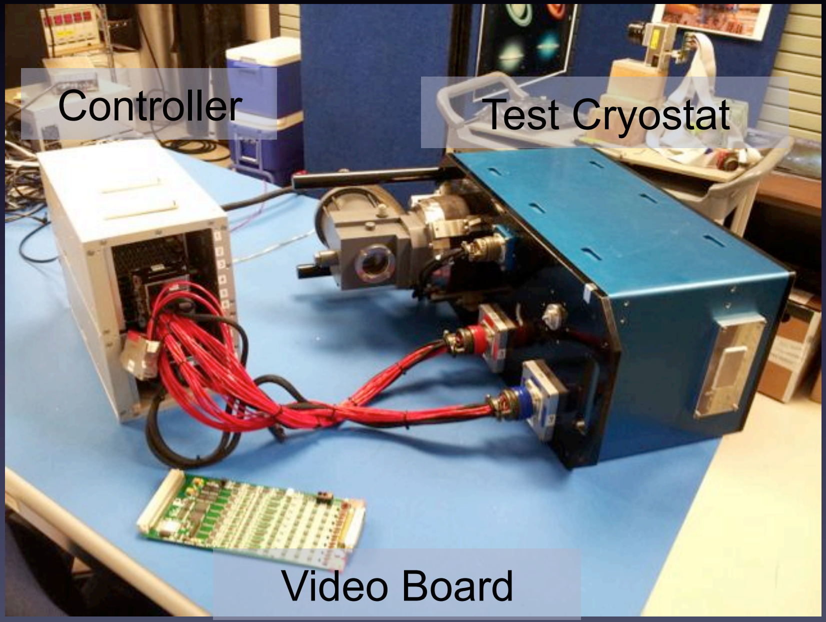
- IRTF paid $0.8m for two science grade arrays and two MUXes. Teledyne also agreed to supply two good eng. grade arrays
- All four arrays suffered from the indium migration problem discovered in 2010
- Teledyne agreed to replace the science grade arrays and replace an eng. grade array if foundry run yields allowed
- New science grade arrays for iSHELL and SpeX are now in hand
- Teledyne was not able to provide a new eng. grade array for NSFCAM
- Procurement is now complete

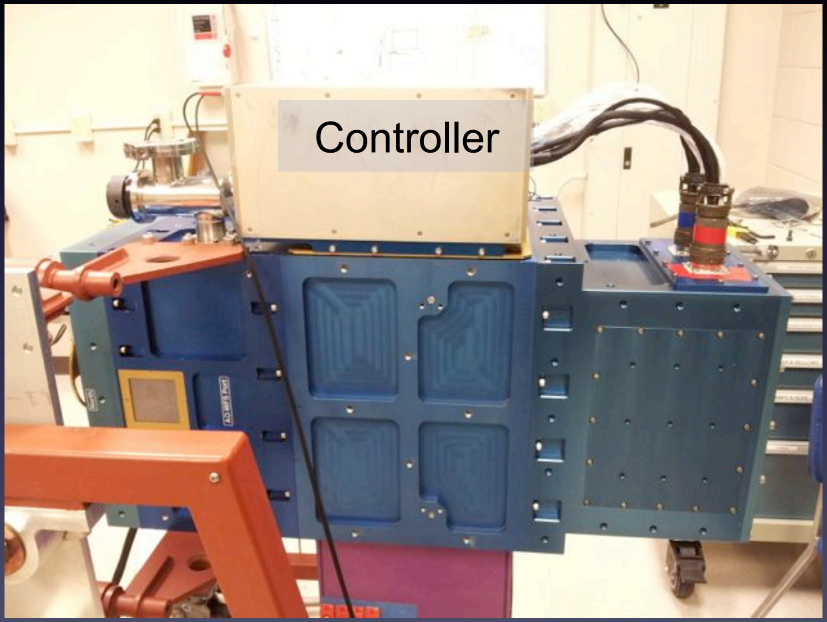
Teledyne H2RG Procurement

1. New (fixed) science grade array for SpeX
2. New (fixed) science grade array for iSHELL
3. Original science grade array (5% bad pixels) is in NSFCAM. No further degradation expected if array is stored cold
4. Original engineering grade array (20% bad pixels) is being used for testing

IARC Controller Background

IRTF is using the Astronomical Research Cameras (ARC) Generation III controller for both H2RG and Aladdin arrays





NSFCAM2
(Upgraded & In Use April 2013)

H2RG Noise Results

Readout Mode	Noise Requirement	Current Noise	Conditions
Cryostat Standard	<=15e-	11e-	COAD=1, NDR=1
NSFCAM Standard	<=15e-	15e-	COAD=1, NDR=1
Cryostat Slow (30s)	<=5e-	3.1e-	COAD=1, NDR=16, 30s
NSFCAM Slow (30s)	<=5e-	4.4e-	COAD=1, NDR=16, 30s

- Used original science grade H2RG (degraded by indium migration – about 5% bad pixels)
- Results obtained by selecting a 40 pixel by 40 pixel area in the array that was free of defective pixels
- Slow readout using NDRs is dominated by pattern noise since it is the change in value of a pixel over a long series of readouts
- Currently working to optimize this fixed pattern noise

iARC past semester milestones

- February 2013
  - H2RG controller deployed with NSFCAM
  - NSFCAM first light
- March 2013
  - New cryogenic configuration (cable interface) board
  - New flex cable
  - Separate clock and bias signals cabling to optimize noise
- April 2013
  - Receive new array mounts for SpeX and iSHELL
  - Incorporate 100-pin mil-spec connector for SpeX and iSHELL
- July 2013
  - Clocking Aladdin MUX with ARC Aladdin controller
  - New ANU board ready (stable biases)
  - Sub-array clocking with H2RG
- August 2013
  - Aladdin controller working

iARC Schedule

- September 2013
  - Install Aladdin PAIDAI array in lab dewar and test
- October 2013
  - H2RG eng. Array test with new mount and SpeX H2RG controller
  - Install and test SpeX science array in lab test dewar
- November 2013
  - Run cold H2RG together with warm Aladdin MUX to simulate science integrations and IR guiding
- December 2013
  - SpeX H2RG and Aladdin controllers ready for deployment
- February 2013
  - SpeX in Hilo lab ready for upgrade