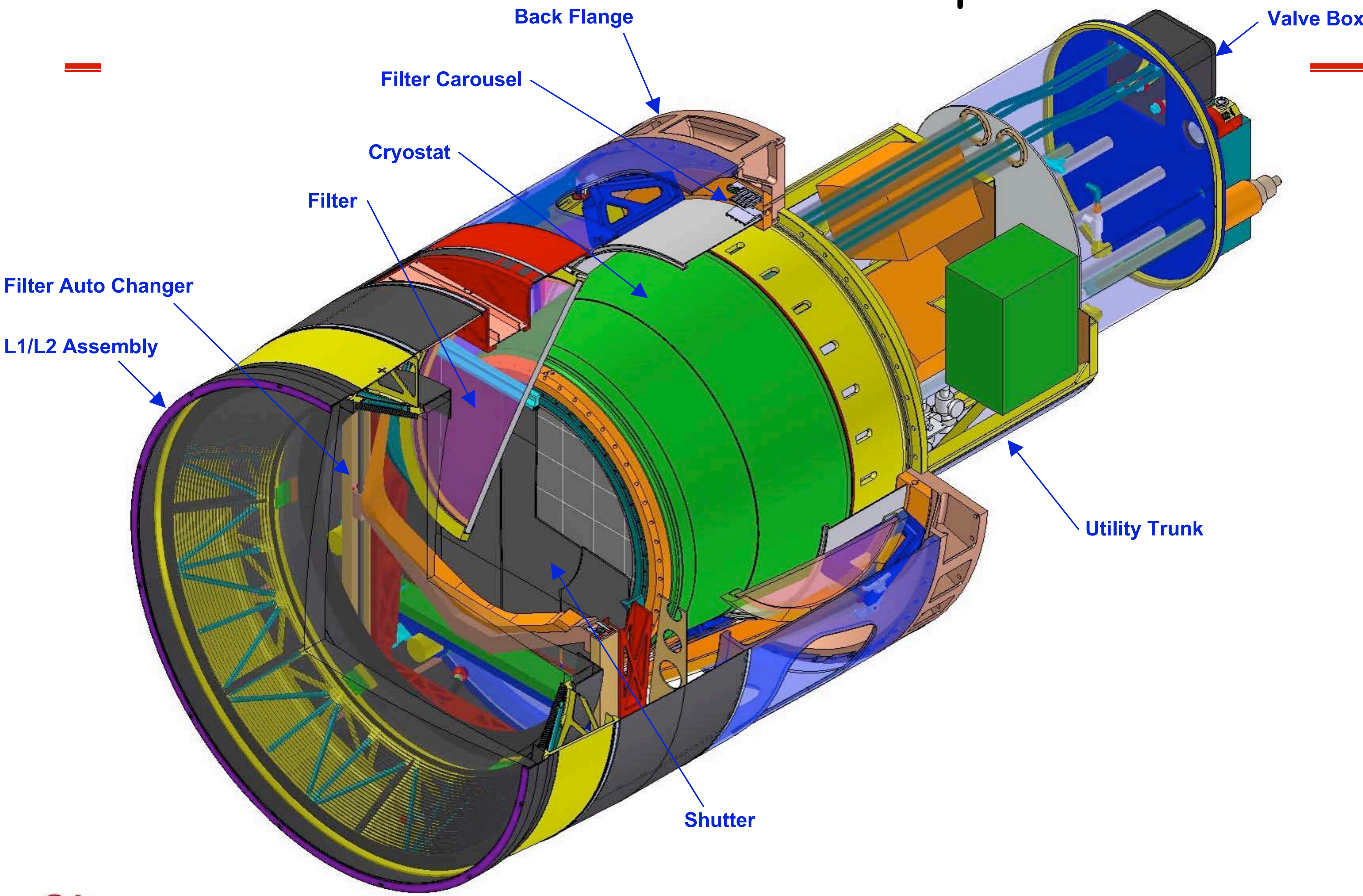
LSST Camera Status

Kirk Gilmore
SLAC/KIPAC/LSST

LSST camera concept



LSST CAMERA AT SLAC

* SLAC Manages the Development of the Camera For LSST
  - The major areas of engineering work at SLAC include:
    - Mechanical / Thermal engineering –
      - “Everything” except Sensors & Raft-Towers & Optics
    - Integration, Assembly and Test (SLAC Bldg 33)
      - Includes contamination control, focal plane metrology & in-situ calibrations
    - Camera Utilities (thermal, vacuum, gas)
    - Sensors & Electronics → Camera Interfaces
    - Telescope → Camera Interfaces
* Close collaboration on sensor development, filter development and CMOS guiders in corner rafts (Gilmore,Kahn,Simms)
* SLAC manages camera/telescope calibration effort (Burke)
* Collaborates with UC Santa Cruz on Camera DAQ /Control System (Huffer and Marshall)

LSST CAMERA R&D AT SLAC

* MECHANICAL & SYSTEM ENGINEERING

  – SLAC is the lead institution developing /coordinating a consistent design for the camera and its interfaces to the rest of the project – effectively leading the "systems engineering" effort

    - Developing all the camera interfaces (telescope/electronics etc.)

  – Design work and finite element analysis conducted on elements of the:

    - Camera Body
    - L1/L2 Assembly
    - Shutter
    - Filter Changer Mechanisms
    - Cryostat & L3 Mount
    - Utilities (Vacuum and Cryogenics)

  – Thermal Analysis for Cryostat & Camera (starting up as design has matured)

  – SLAC also coordinates the Integration and Test planning

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LSST CAMERA R&D AT SLAC

* The Cryostat Subsystem in the near term:

  - The cryostat milestones for R&D this year are to try to retire some of the major risks we are concerned with:
    - Contamination in cryostat
    - Raft-GRID Kinematic interface
    - Focal plane metrology through L3

* Outstanding issues:
  - Contamination Test Chamber
    - Chamber is in final stages of re-assembly on campus. (add cryo elements)
    - Move into “production mode” ASAP for testing materials deemed critical
    - Assembly of a database of materials in the cryostat to estimate outgassing levels and vac. pumping requirements
  - Raft-GRID Kinematic Interface
    - Demonstrate sub-micron stability and reproducibility through choice of V-block and ball materials, their preparation and their mounting.

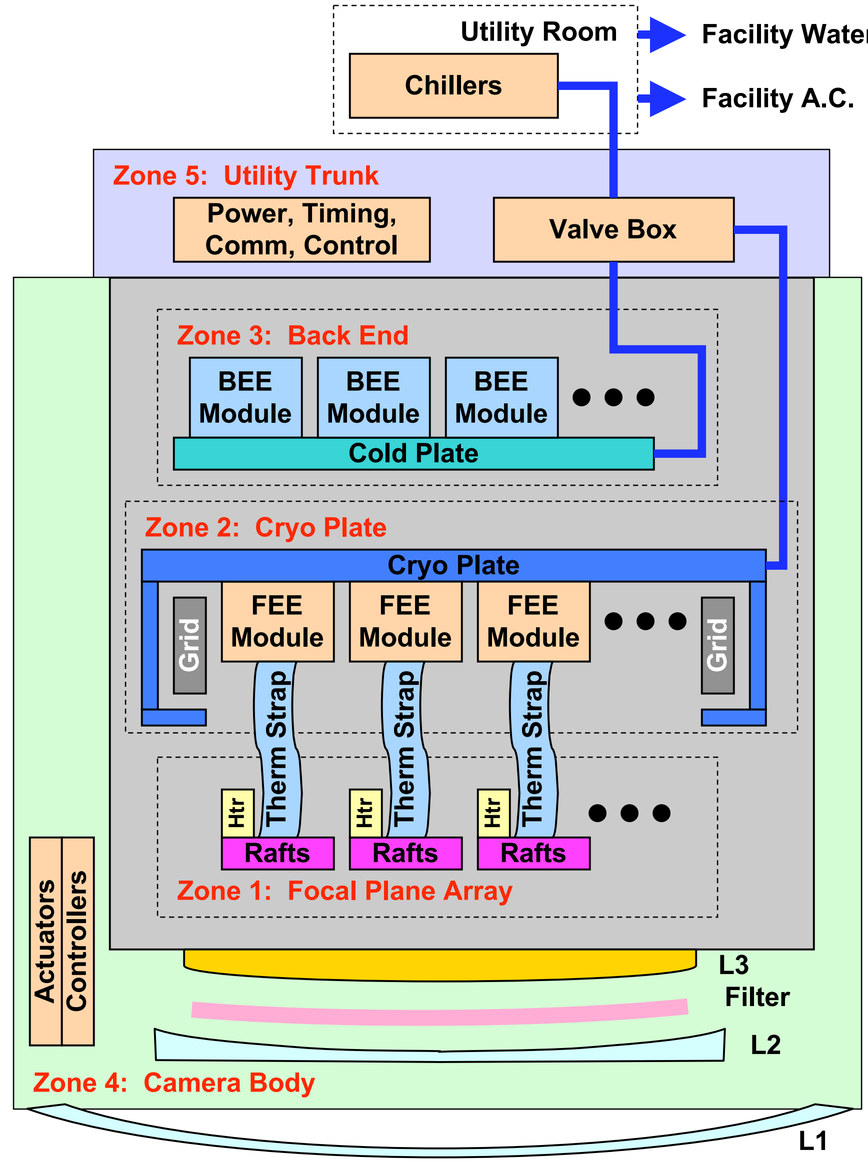
  - Focal plane metrology
    - Demonstrate that the large area of the focal plane can be stitched together through a real vacuum wall (L3) at the <1 micron level. We have already shown this to be possible with no window.

Thermal control engineering model being developed

- **Design approach**
  - **Create isolated zones for controlling the camera environments**
  - **Control zones independently to produce the environments needed**
  - **Allow for on-telescope cool-down/warm-up**

- **Thermal zones: 5 thermal zones in the camera**

1. **Focal plane array**
   - Cooled by Cryo plate
2. **Cryo Plate**
   - Cools Cryo plate, shroud, FEE modules
3. **Back end**
   - Cools Cold plate, BEE modules
   - No temperature stability requirements
4. **Camera body**
   - Actively controlled to match ambient temp
5. **Utility trunk**
   - Actively controlled to match ambient temp

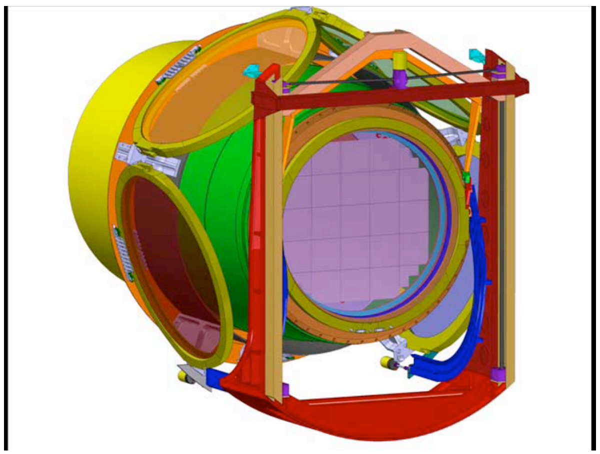


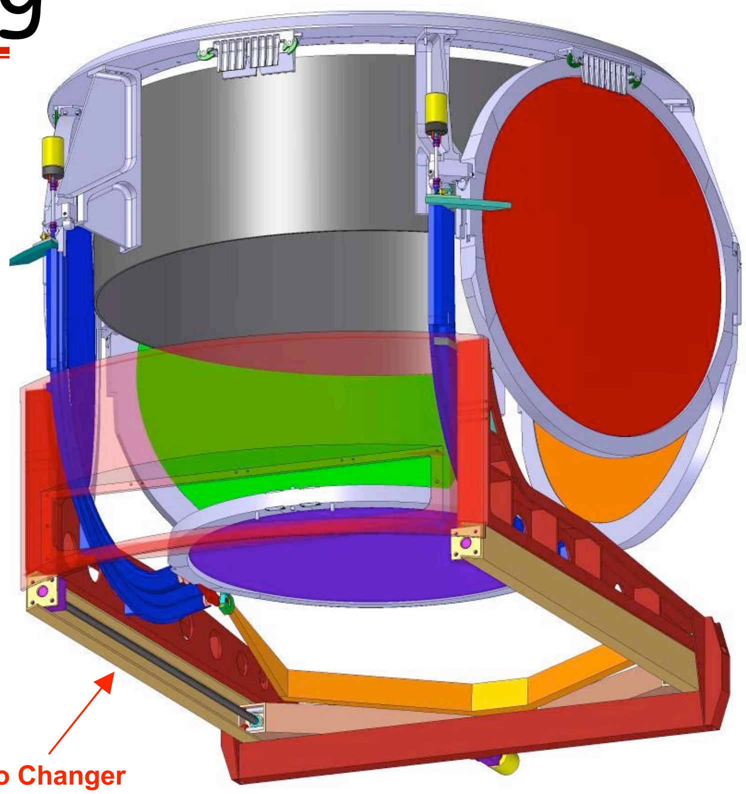
Filter exchange mechanism in prototyping

Filter exchange time = 120s

Filter exchange consists of 3 assemblies

- Carousel
  - Stores up to five filters out of the field of view
  - Moves chosen filter into exchange position
- Auto Changer
  - Supports filter in the field of view
  - Moves filter from storage position into field of view
- Manual Changer
  - Used for filter exchange from outside the





Requirement	Value	Unit
Number of filters housed in the Camera at one time	5	
Max time between two visits in different filters	2	min
Minimum operational life of filter changer	40,000	cycles
Minimum operational life of filter carousel	20,000	rev
Minimum time between preventative maintenance	4,000	cycles

Filter prototype RFP going out to vendors

* Discussions initiated with multiple vendors
  – JDS Uniphase
  – Infinite Optics
  – SAGEM
  – Barr
  – Goodrich
  – Asahi Spectra

* Substantial industrial base exists to coat large, thin filters
* Industry estimates of cost and schedule to coat these large, thin optics have been used as input for LSST camera optics schedule and budget

  – **These estimates include a risk reduction study during the R&D phase**

300cm coating chamber

NOVA Laser Fusion Optics

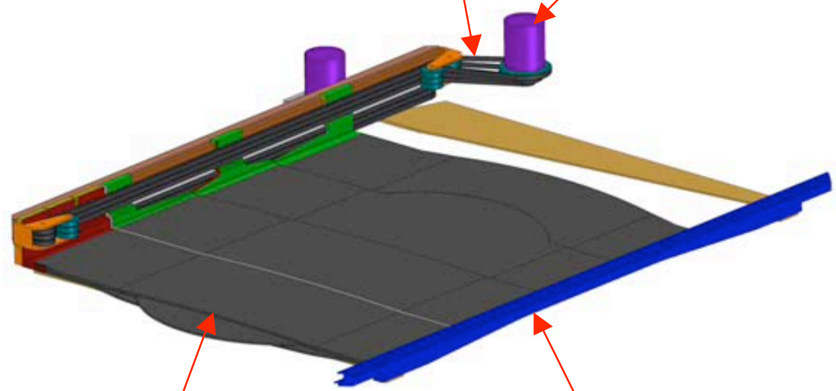
Shutter design being prototyped in 08

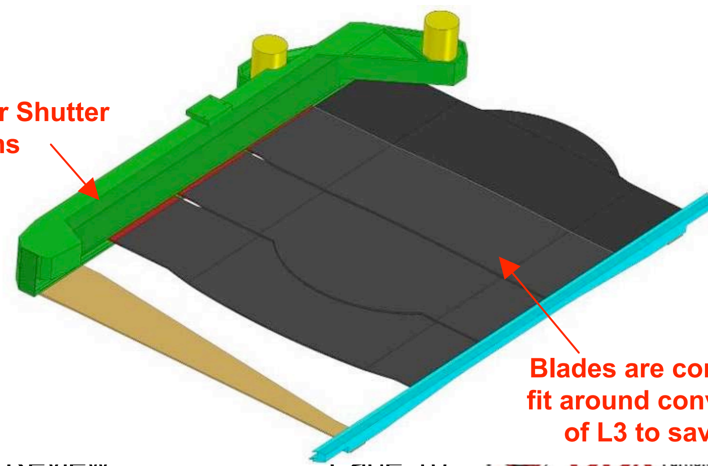
* Shutter is comprised of two stacks of 3 blades each
  – One stack retracts to start an exposure, and the second stack extends to stop it

This ensures uniform exposure time for all pixels

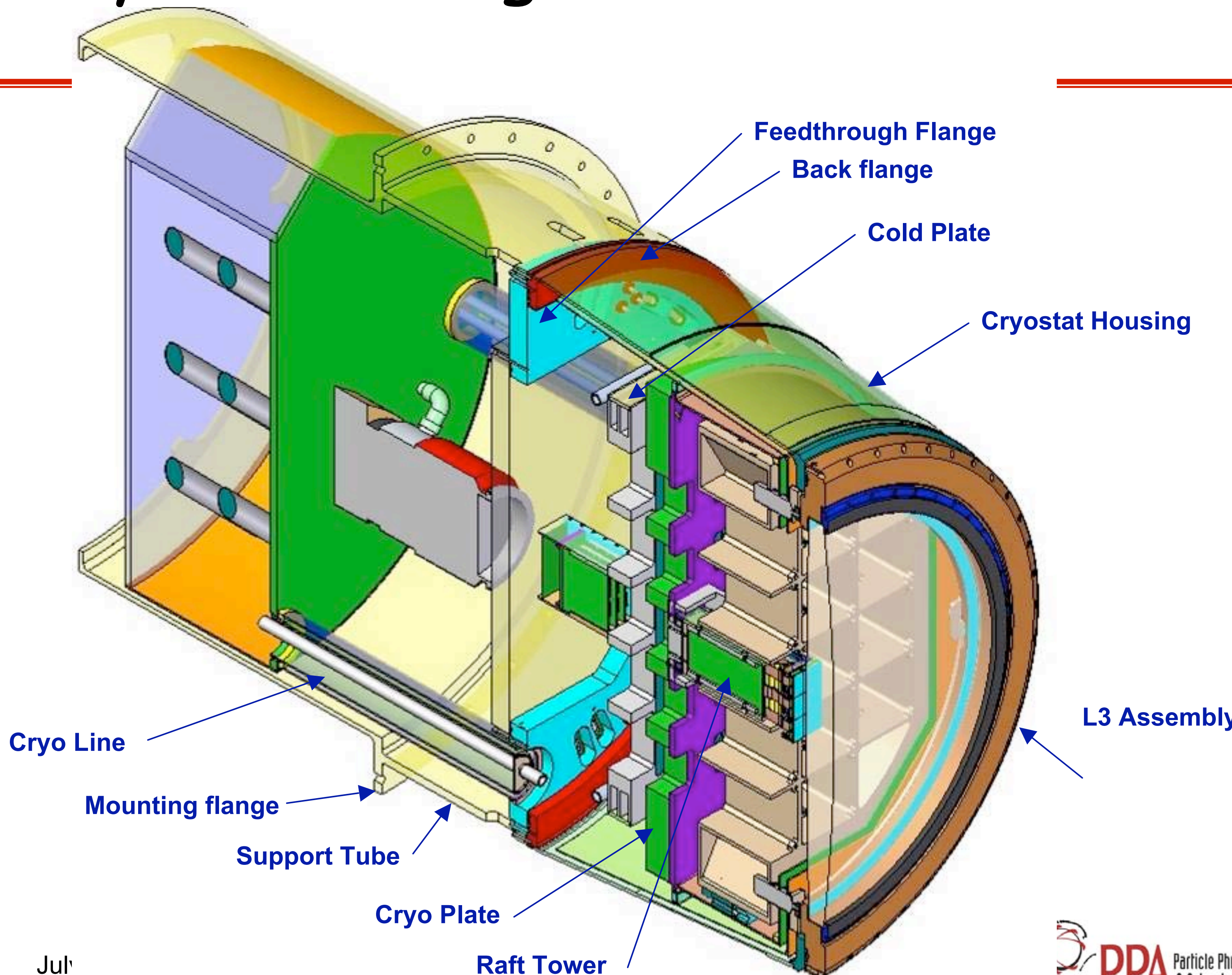
1s close to open time

1s open to close time

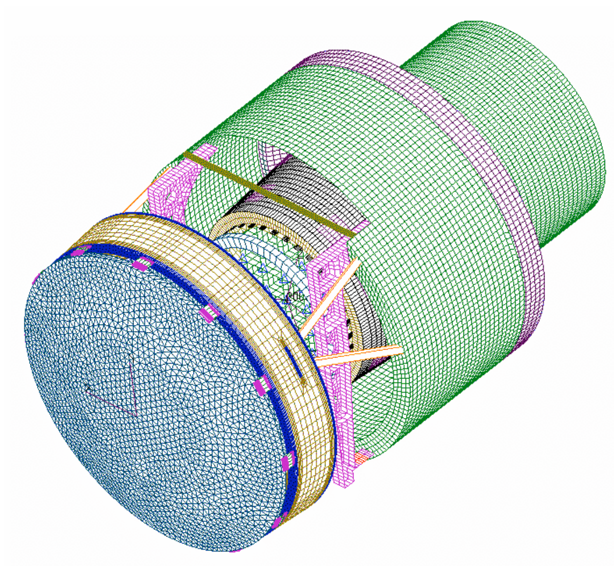


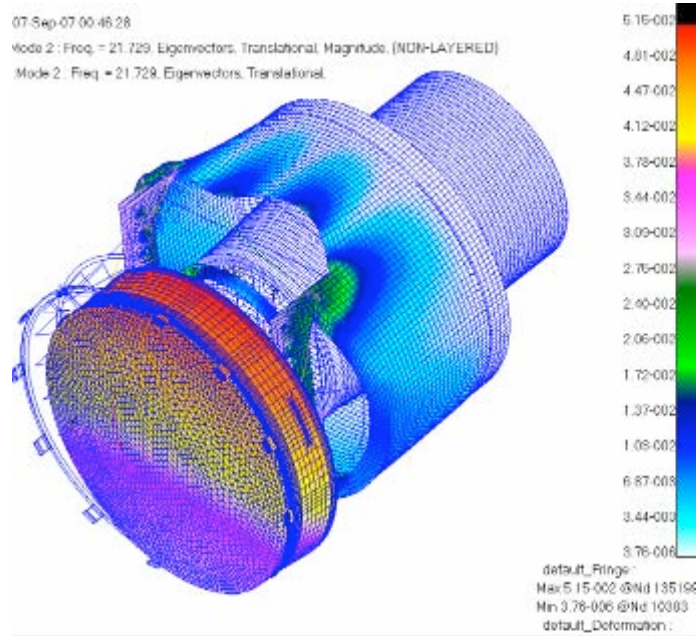


Cryostat design



A complete camera structural FEA model has been assembled

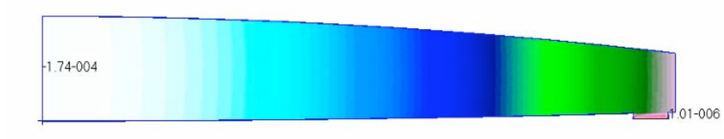




* Structural FEA results to date
  - Mass optimization
  - Improving structural efficiency:
  - Interfacing to the telescope: F_2 = 21.73Hz
  - Sensitivity analyses
  - Distortion analysis
  - Stress analysis

L3 lens distortion and stress analysis indicates working design

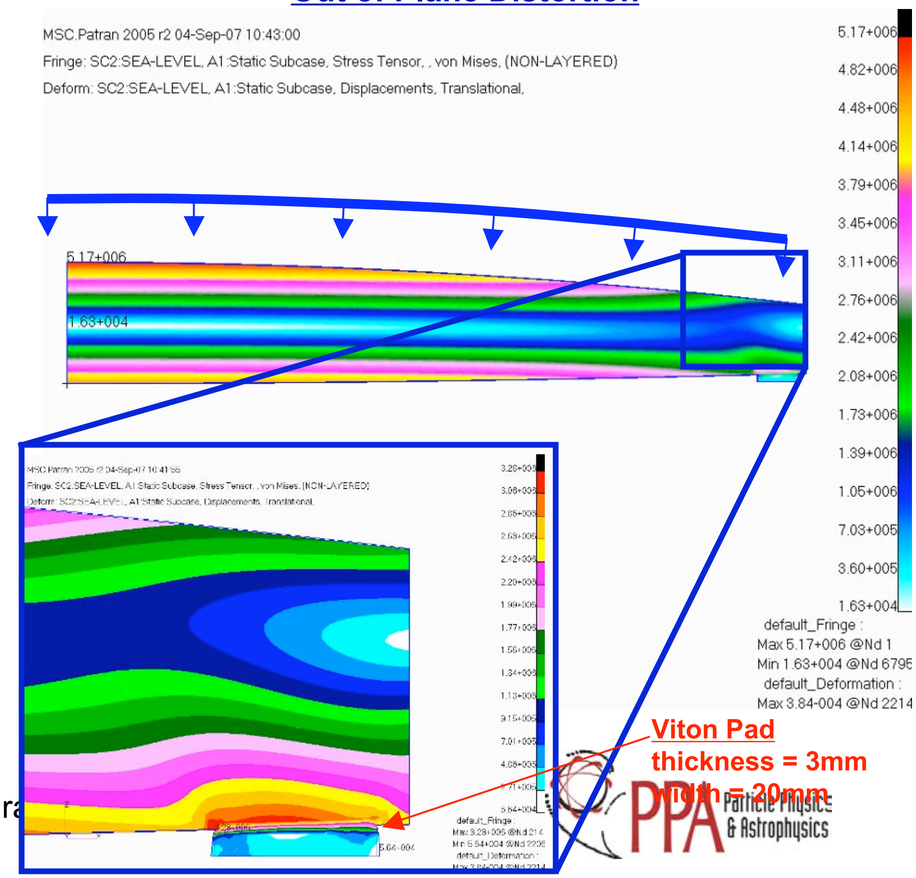
* CTRIAX6 2-D 6-noded Axisymmetric triangular elements used
  – FEA Mass = 43.25 kg; CAD Mass = 43.29 kg
* Vacuum loading on lens (at sea level)
  – Generally accepted maximum safe working stress for fused silica is 7.0 MPa, which corresponds to a safety factor of 7.5
  – Lens design carries an adequate margin of safety
* Fracture analysis
  – Critical flaw size = 0.73 mm (SF = 2)



Umax = 174 μm

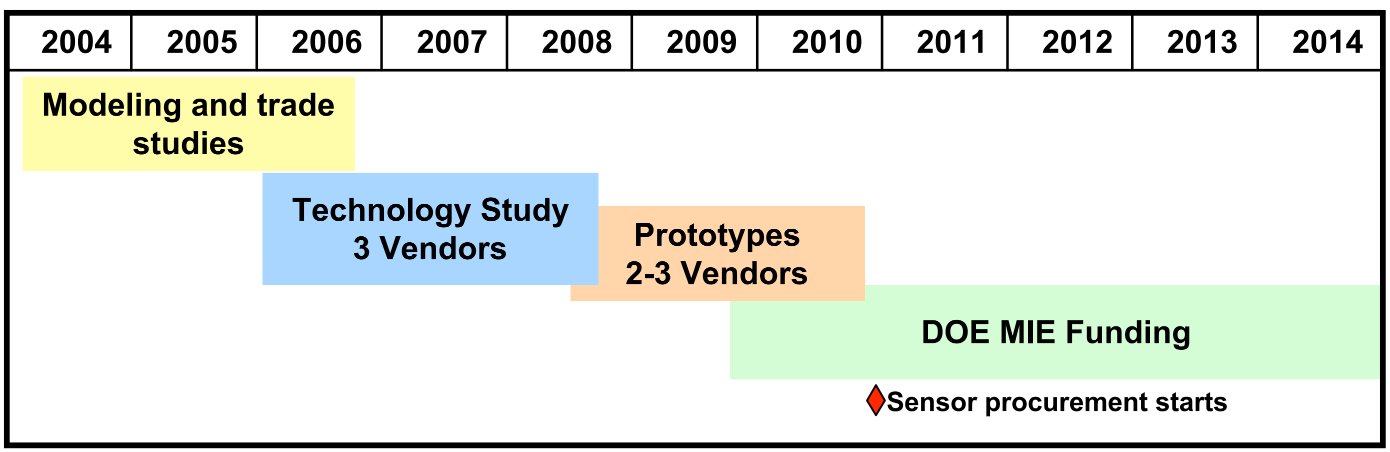
Through-thickness uniformity indicates no change in thickness

Out of Plane Distortion

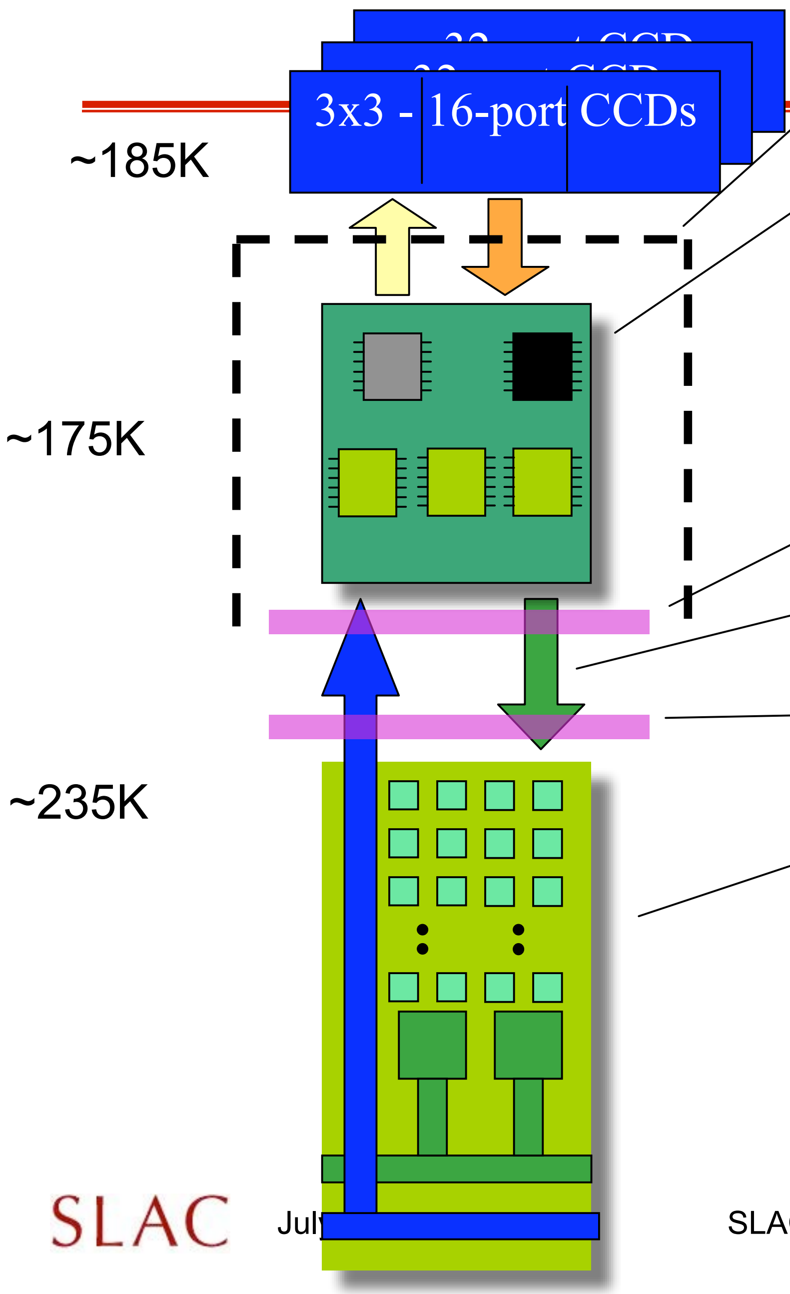


Sensor development plan

- **Technology study**
  - understand and model device characteristics
  - engage qualified vendors
  - address the most pressing technical challenges early
  - establish test lab at BNL
- **Prototype**
  - multivendor competition
  - fabricate sensor meeting all LSST specifications
  - demonstrate yield and quality control
  - ramp up test capability within LSST collaborating institutions
- **Production**
  - manufacture, test, and deliver 200+ science-grade sensors
  - 24-month production period
  - single- or dual-source

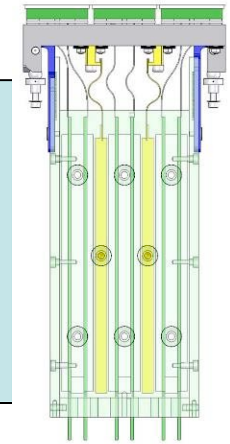


Raft tower electronics partitioning



Molecular Flow Barrier

Front End Boards (6 per raft):
- 144-channels of video signal chain through CDS processing
- clock and bias drive
- ASIC-based (ASPIC/SCC)



Cryo Plate (~170k)

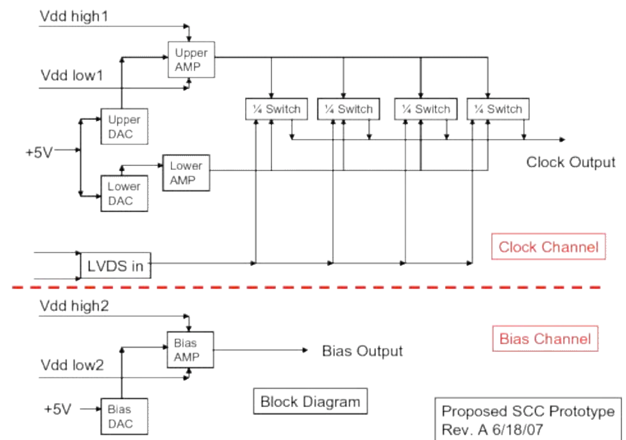
Flex cables (~ 500 signals)

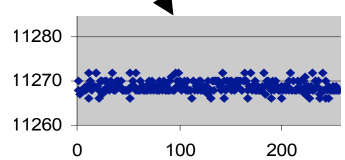
Cold Plate (~230k)

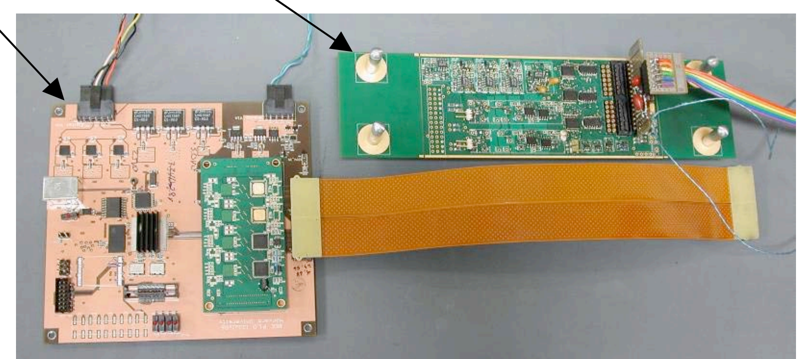
BEE motherboard and backplane:
- differential receiver
- signal chain ADC (16+ bits)
- buffers
- data transport to optical fiber
- clock pattern generation
- clock and bias DACs
- temperature monitor / control

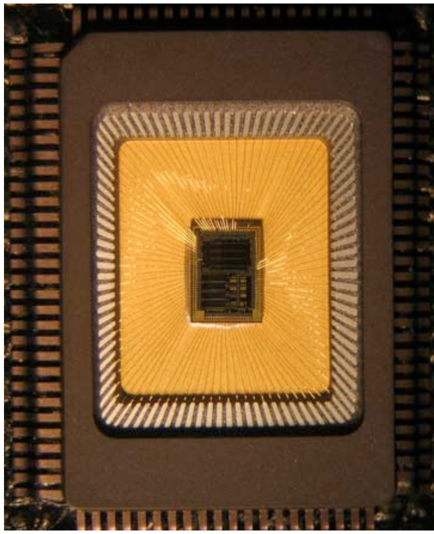
Electronics Prototyping

- * Noise < 5 e- r.m.s.
- * Nonlinearity < 5% from 100e- to full well
- * Crosstalk < 0.01%
- * ASIC Developments
  - – ASPIC – IN2P3 - CMOS - P/A, CDS, Driver - submitted 7/25/07
  - – SCC – ORNL - CMOS – Bias Generator, Clock Driver – submitted 8/30/07
- * Discrete Prototypes
  - – FEE – Penn – Commercial parts – P/A, CDS, Driver, Bias, Clock, Cold capable
  - – BEE – Harvard – Commercial parts – ADC, Timing Gen, Data Out
  - – Now in joint test – Present noise result is 1.3 ADC Units (~3 e-) rms - no sensor
  - – Add charge injection
  - – Add real CCD
  - – Go to ASIC versions





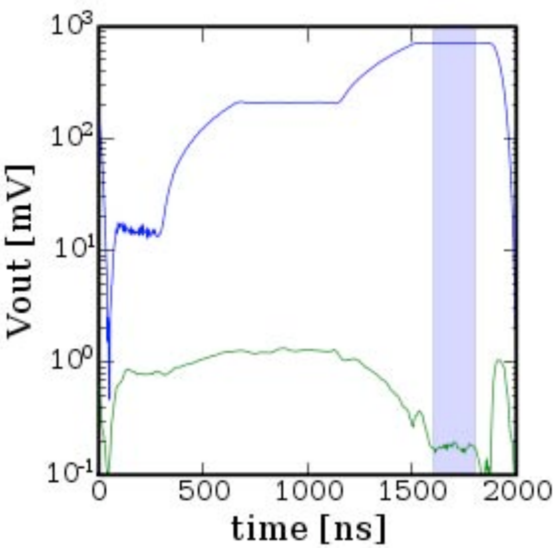




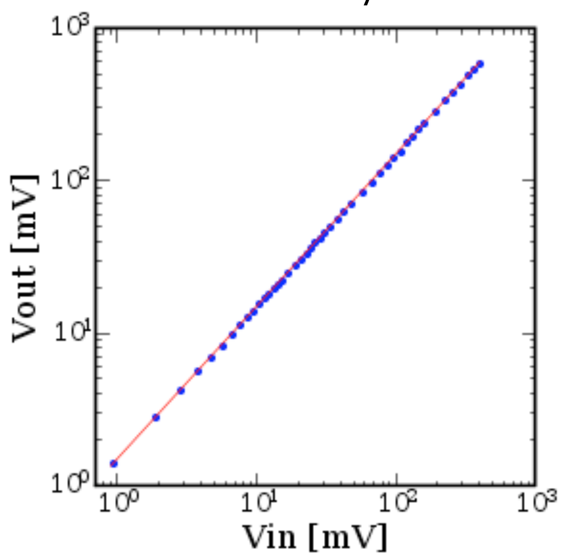
ASPIC - Analog Signal processer

- 8-channel CCD readout ASIC developed in France (LAL/LPNHE)
  - Dual-Slope Integration and Clamp & Sample implemented for comparison
- Channel cross talk < 0.01% (hardest requirement fulfilled)
- Linearity better than 0.5% from 1 - 400 mV input (require 1%)
- Noise properties under study

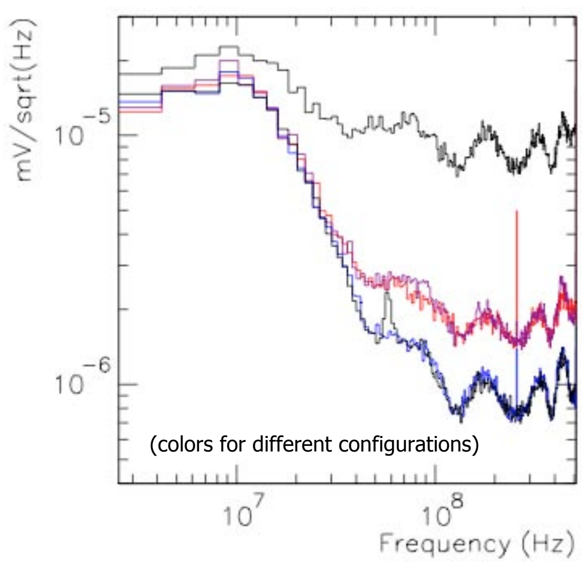
Crosstalk



Linearity

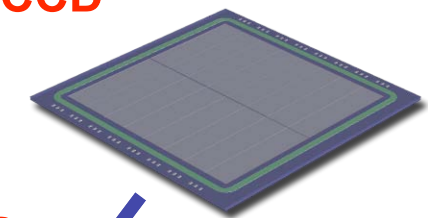


Noise

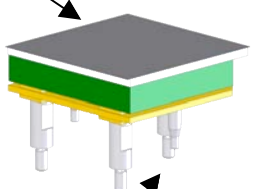


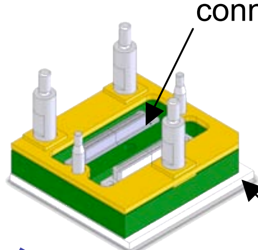
From sensors to rafts to raft/towers - All being prototyped in 08-09

CCD

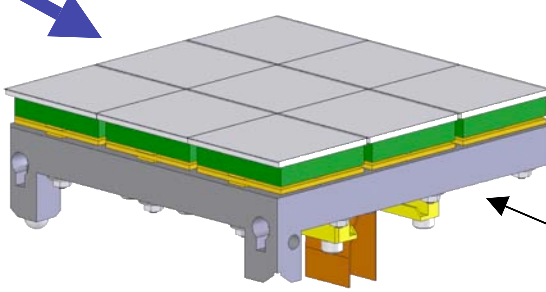


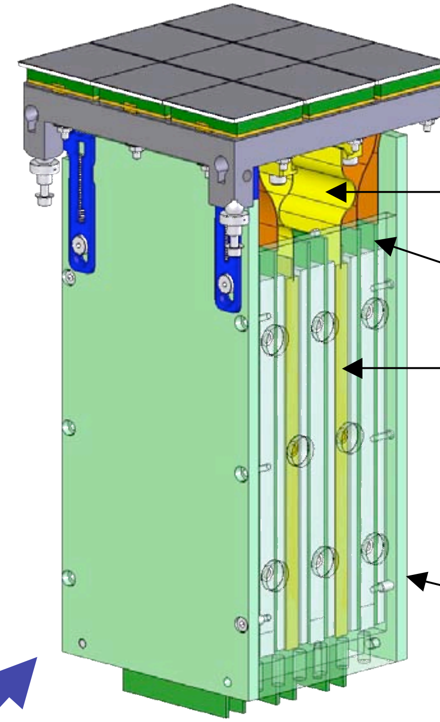
PACKAGED CCD





RAFT



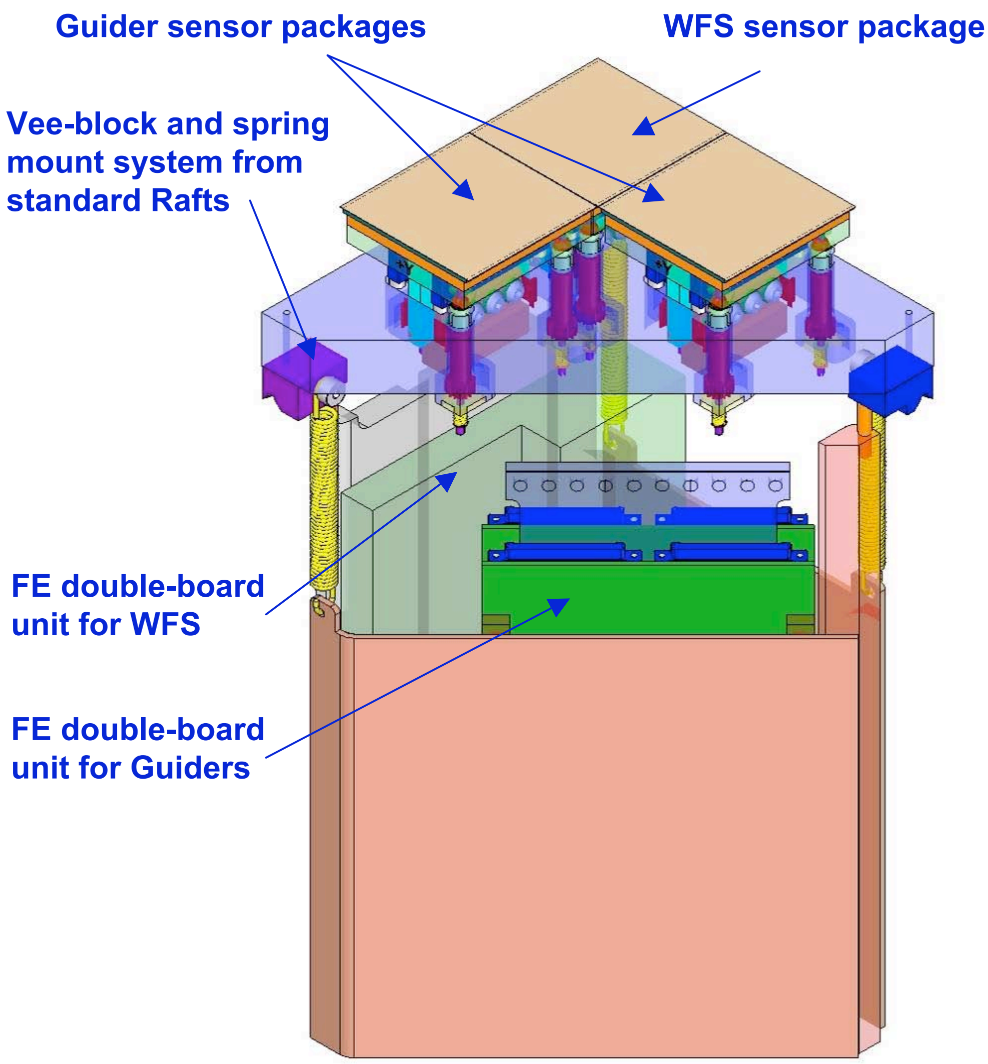


TOWER

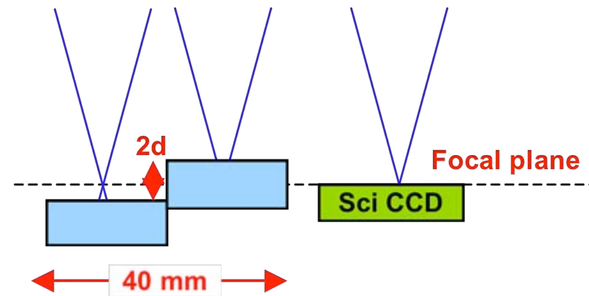
- *3 x 3 submosaic of CCDs*
- *front end electronics*
- *thermal management components*

- Tower is an autonomous, fully-testable 144 Mpixel camera

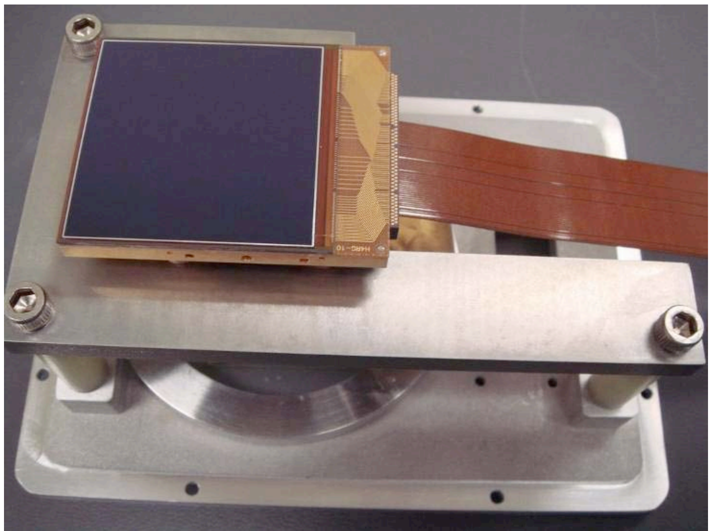
Corner raft tower - Prototype in 09 at Purdue



CCD Curvature Sensor



CMOS Guide Sensor

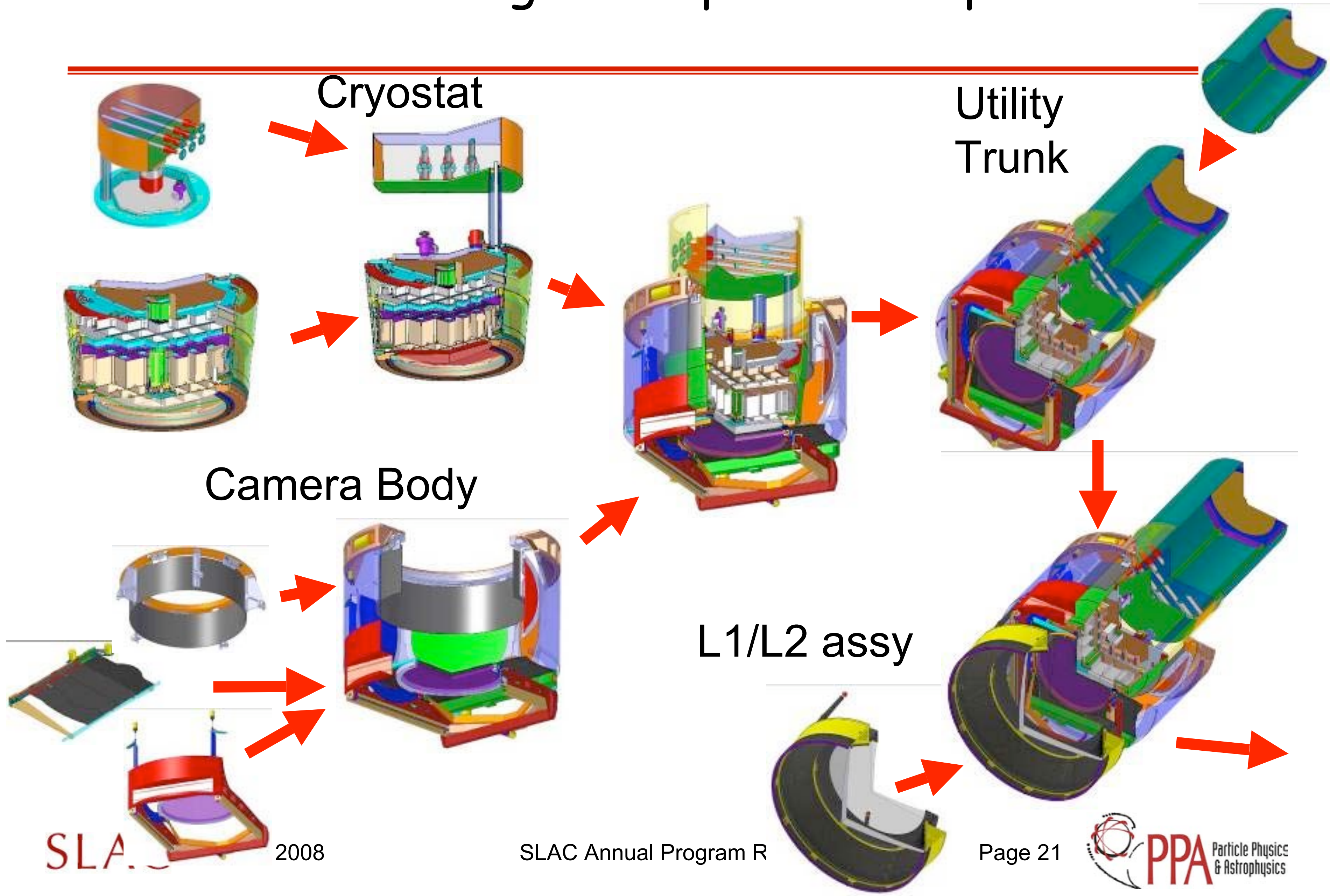


08-09 French activities that support camera R&D

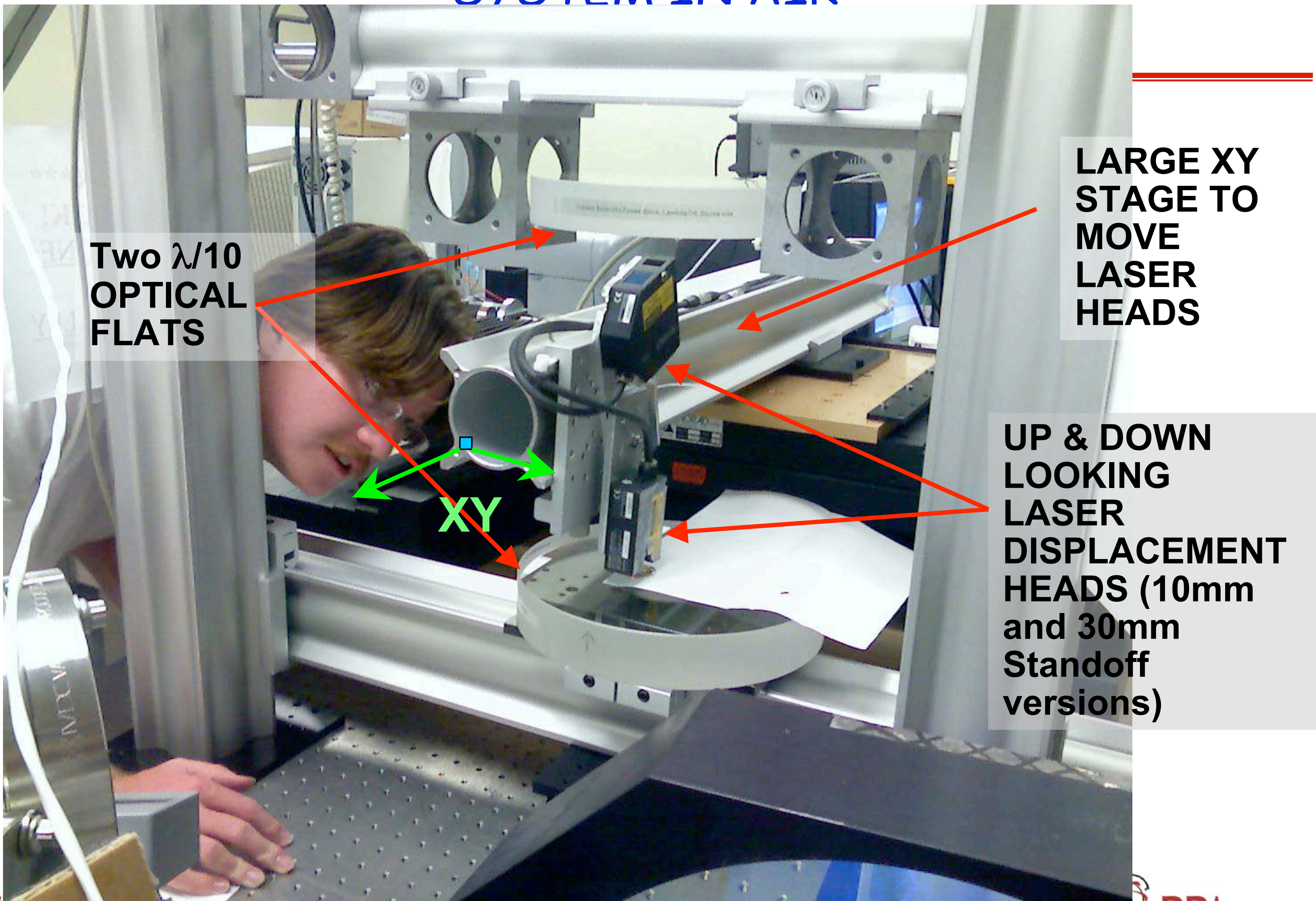
- **CCD test stand (LPNHE , Paris):**
  - Setup started in January 2008. First version scheduled to be operational before the end of spring.
  - Test Stand will be used in to contribute to the LSST CCD prototyping characterization.
  - Short-term goal, before September 2008, will be to begin a detailed study of the ASPIC chip readout with an LSST CCD.

- **Calibration test stand (LPSC, Grenoble):**
  - The goal of this test stand will be to characterize the LSST camera after integration at SLAC.
  - Studies on the optical requirements for this test stand started in March 2008.

A camera integration plan is complete



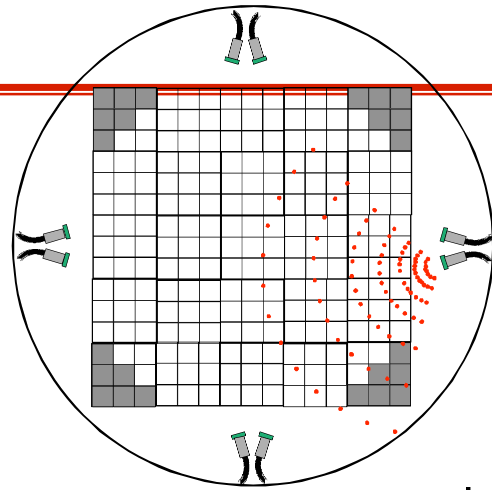
DIFFERENTIAL NON-CONTACT METROLOGY SYSTEM IN AIR



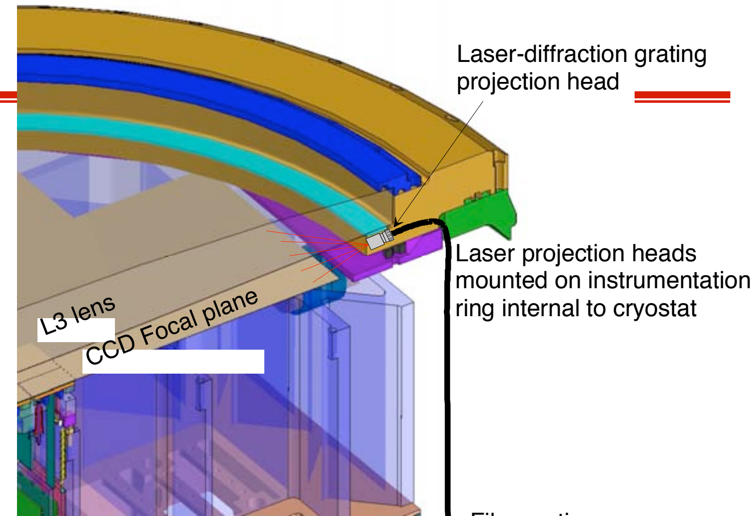
IN-SITU METROLOGY - DIFFRACTION PATTERN GENERATOR

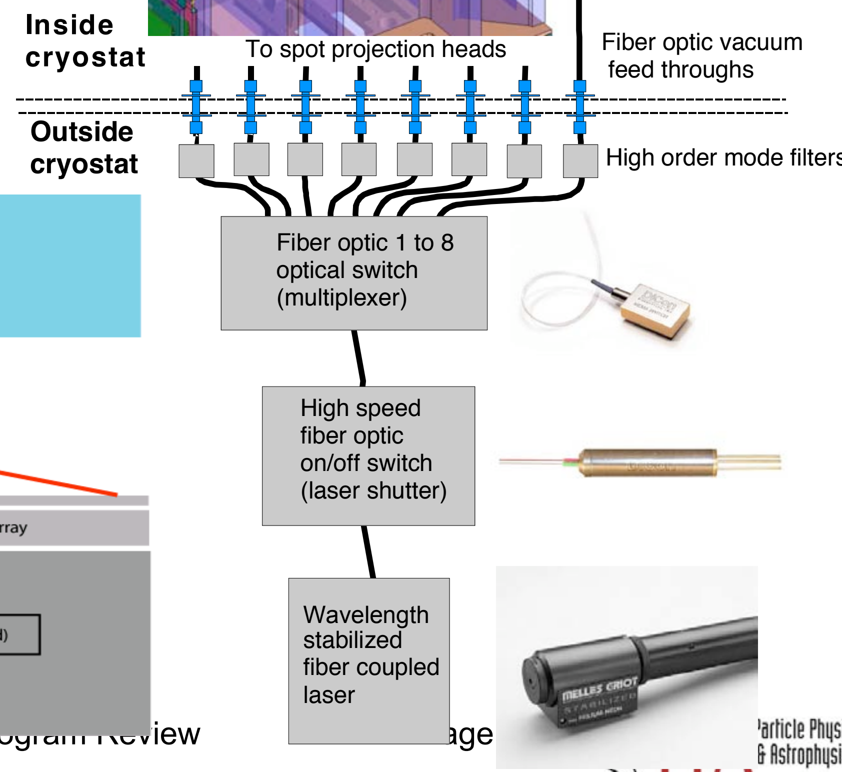
Sequentially Project & Reconstruct Precisely Known Patterns of Ellipses at Shallow Angles Onto FPA

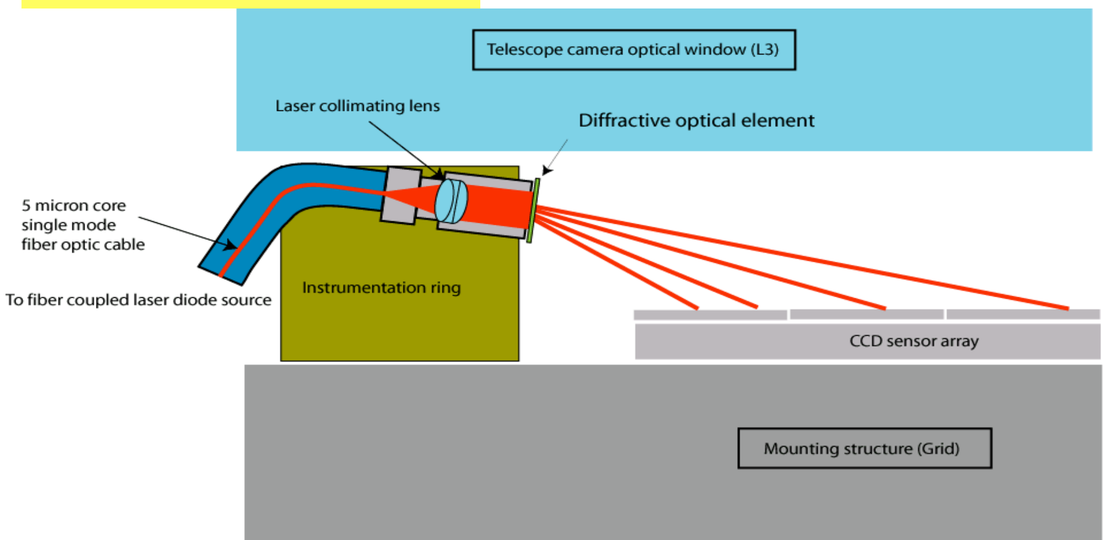
Fit Centroids Thru Full CCD System and Reconstruct Δ Patterns To Find



8 OVERLAPPING PATTERNS COVER FOCAL PLANE







Summary of sub-system risk mitigation activities

Mechanical

#	Activity	Description of Activity/Risk Mitigation	Risk Needing Mitigation
1A	Kinematic coupling prototype	Prototype kinematic coupling design concept; evaluate material/coating options; test over full temp range	Kinematic coupling is not suitably stable and repeatable to keep CCD's in flatness spec
1B	Grid thermal-mech analysis	Develop Grid/Cryo Plate thermal and structural model (steady-state)	Grid thermal-mech motion could move CCD's beyond their allowable position envelope

Contamination

#	Activity	Description of Activity/Risk Mitigation	Risk Needing Mitigation
1A	Contamination Study Chamber Construction	Complete Construction and Commissioning of Contamination Study Chamber and Move to Campus Lab	Materials in Cryostat will outgas and degrade the performance of the CCD's. All potential materials in cryostat will need to be examined.
1B	Contamination Testing	Purchase material samples and commercial coatings. Student labor (10hrs/weekx26wks)	Demonstrate that the most serious potential contaminents can be controlled without changing design of the cryostat

Metrology

#	Activity	Description of Activity/Risk Mitigation	Risk Needing Mitigation
1	Raft Kinematic Coupling Prototype (testing)	Fit-up of metrology facility for testing;	Budget environmental, surface & materials related effects to K.C. Mechanical properties, or wear-in. Testing required to isolate individual effects.
2	Raft Kinematic Coupling Testing follow-up & Specification	Evaluate results of testing and repeat tests (using other materials and surface finishes indicative of superior performance) as necessary. Contingent on testing results described above.	Nominal kinematic coupling materials/finish/coating choices may not provide required stability and reproducibility.

Summary of sub-system risk mitigation activities

Optics

#	Activity	Description of Activity/Risk Mitigation	Risk Needing Mitigation
1A	Optical Coating Evaluation	Evaluate results of vendor studies on optical coatings	Camera optical coatings won't meet specifications
1B	Optical Tolerance Analysis	Incorporate FEA structural and thermal analysis into camera optics tolerance analysis	Camera optics structural and thermal environment will prevent camera optics from meeting image quality spec.
1C	Wavefront Sensing and Guiding Analysis	Validate conceptual analysis through comparison with lab and sky data	Wavefront sensing and guiding won't meet image quality specifications

CCS

#	Activity	Description of Activity/Risk Mitigation	Risk Needing Mitigation
1	CCS control system	Prototype an instance of the control system	We need an instance of the controls system to deliver on a test bed
1A		graduate student developer @ UI	a person to actually write code

CCD

#	Activity	Description of Activity/Risk Mitigation	Risk Needing Mitigation
1A	CCD characterization test stands	This category includes new Dewar extensions, vacuum equipment, optics, and measurement systems for characterization of CCDs from study contract and prototype contract vendors. The goal for this year is to complete the construction and commissioning of two	Development of overdepleted, multi-output back-illuminated CCDs is the number one technical and schedule risk to the LSST camera. Maturity of prototype sensors needs to be determined by testing at BNL. A facility for conducting tests in a reproducible man
1B	Electronics test interfaces	PCBs, components, connectors, and cables for interfacing new electronics to CCD sensors.	New front-end electronics modules produced by U. Penn, Harvard, and other LSST groups need vaildation with CCD inputs at -100C temperature.
1C	Raft prototypes	This category includes design and fabrication of silicon carbide raft prototype(s), fixturing, and measurement equipment for studying dimensional stability of rafts and sensor-raft assemblies. We plan the first demonstration of focal plane mosaic flatnes	Assembly procedure to ensure 6.5micron coplanarity of sensors on rafts requires experimental study. Failure to achieve required flatness would severely compromise image quality of the camera.

Electronics

Priority	Activity	Requesting institution	Notes:
All 1	Camera Electronics Project Management	Harvard	Technical and budgetary project management
	Design, Fabricate, and test Raft Control Crate with Version 2.0 BEE board, backplane, Raft Control Module	Harvard	Goal is full 144 channel readout electronics for one full raft of LSST science sensors.