Wide, near-IR, AO-corrected survey with LSST

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Science with the LSST-IR-AO

- Deep, wide, near-IR surveys not common
- Keenan et al. 2010 describe "one of the deepest wide-field surveys to date in the NIR": ~2.75 deg^2, JHK ~ 22-23
- Galaxy SEDs insensitive to galaxy type in NIR; galaxy counts can trace LSS without galaxy type assumptions
- Possibly constrain NIR cosmic IR background?
- Same fields as LSST: complement 6 LSST bands
- NIR transient sky – discovery space
- Observe redshifted rest-frame optical galaxies
- 2MASS: brown dwarfs, low mass star surveys, cataloging (300M point sources, 1M extended)

Sensitivity gains with AO

- Sky Backgrounds: ~16 (J), ~14 (H), ~15 (K)
- Resolution: ~0.7 arcsec, improved by factor of ~2

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In[45]:= Solve[SNR == ϵ R π r² t / Sqrt[ϵ R π r² t + ϵ B π r² t (0.35)² + σ²], t] /. R → 10^10 10^(-0.4 23) /. B → 10^9 10^(-0.4 {16.2,13.8,14.6}) /. r → 4 /.
    SNR → 10 /. σ → 5 /. ϵ → 0.5
Out[45]= {t → {4.70585, 37.6072, 18.3329}}}
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In[44]:= Solve[SNR == ϵ R π r² t / Sqrt[ϵ R π r² t + ϵ B π r² t (0.7)² + σ²], t] /. R → 10^10 10^(-0.4 23) /. B → 10^9 10^(-0.4 {16.2,13.8,14.6}) /. r → 4 /.
    SNR → 10 /. σ → 5 /. ϵ → 0.5
Out[44]= {t → {16.853, 148.527, 71.4194}}}
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$$\text{Solve}\left[\text{SNR} == \frac{\epsilon R \pi r^2 t}{\sqrt{\epsilon R \pi r^2 t + \epsilon B \pi r^2 t\,(0.35)^2 + \sigma^2}}, t\right]$$

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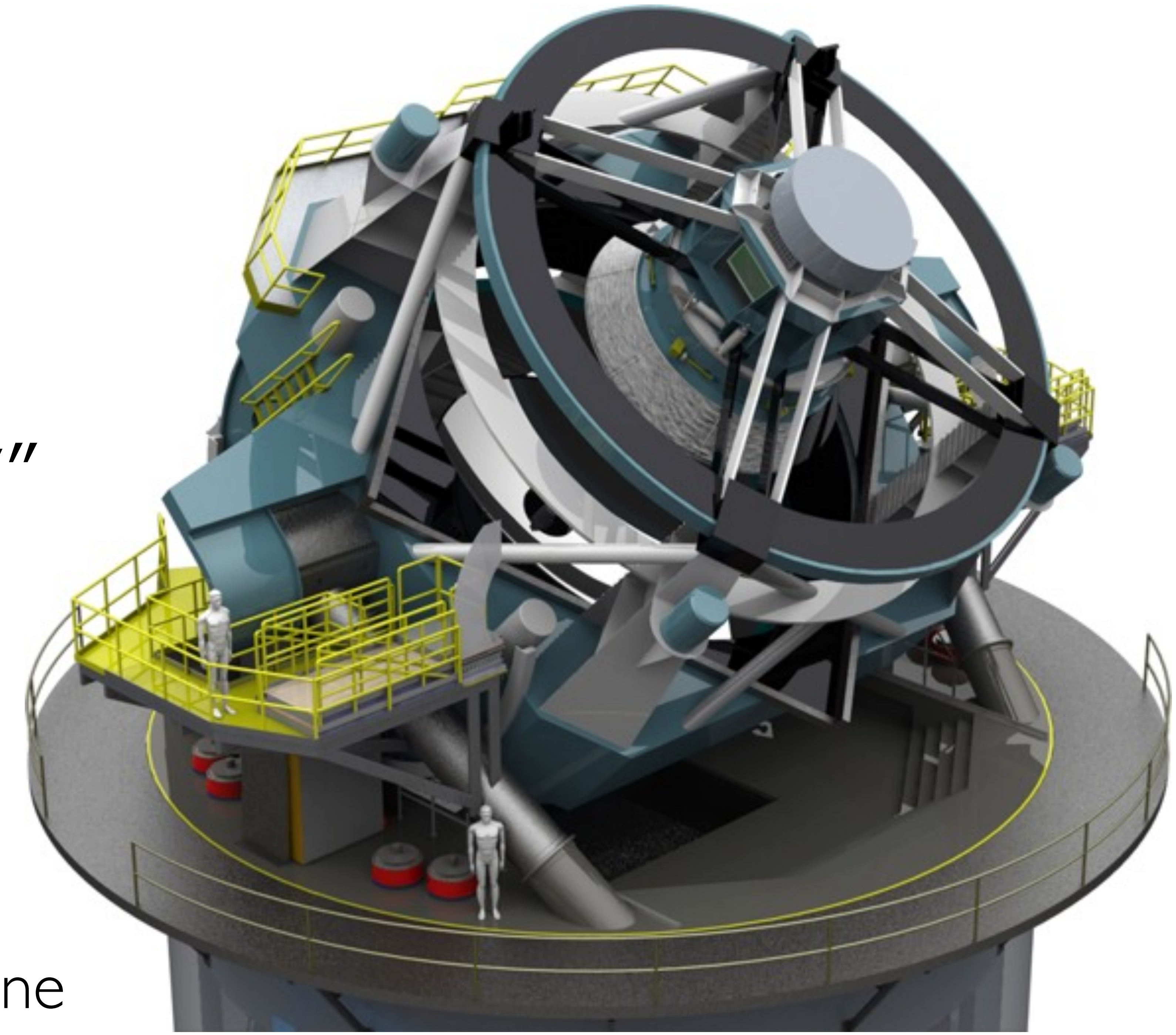
Survey capabilities

- LSST
  - 10,000 square degrees (15-sec exposures) every three nights
  - Typical depth r ~ 24.5
  - Databases of ten billion galaxies, stars
- LSST-IR-AO
  - JHK depth ~22-23
  - similar coverage

LSST – Baseline Design

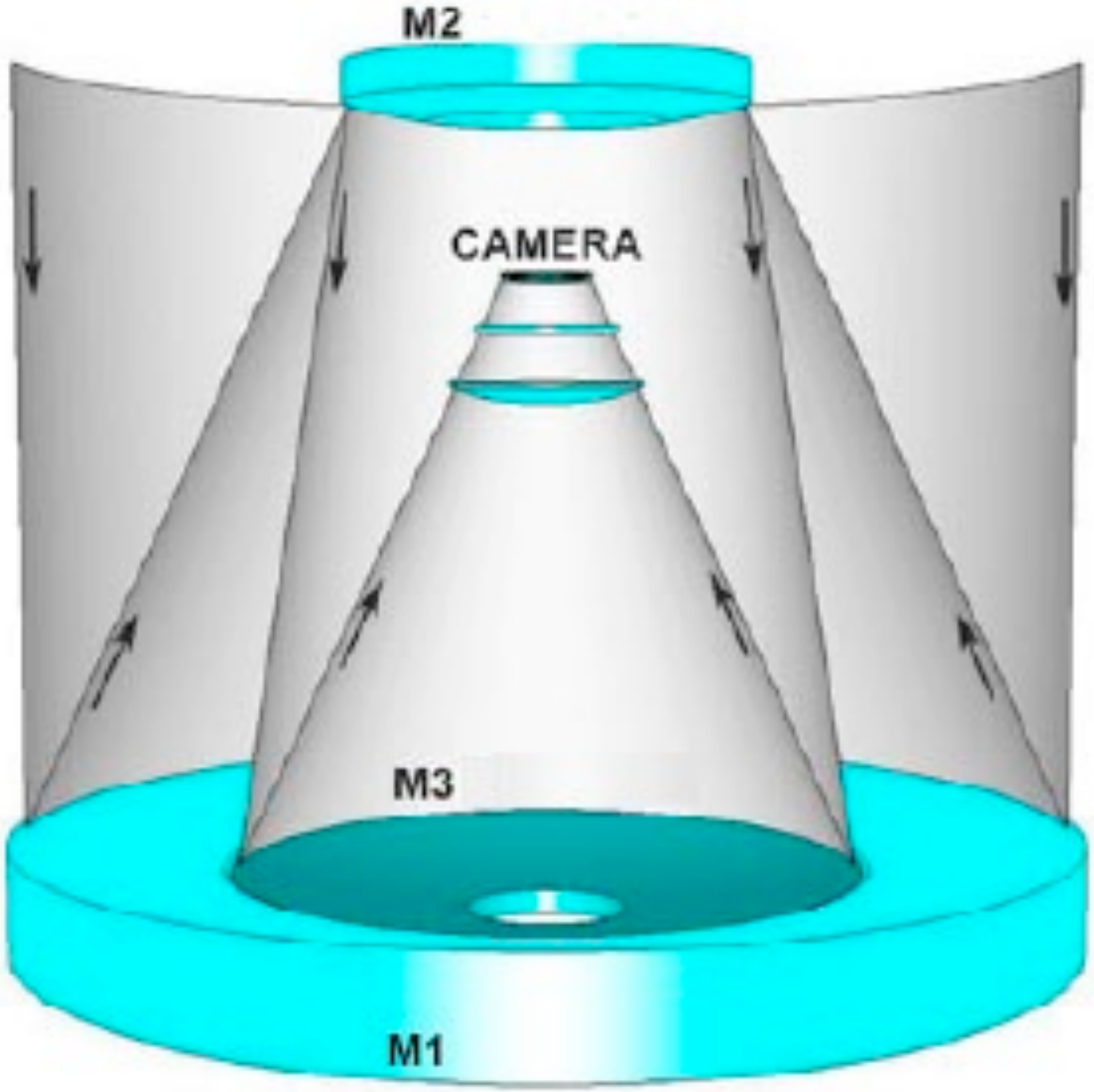
- Visible Waveband: 320–1060 nm
- First Light in Fall 2015
- Mirror Diameters:
  - Primary 8.4m
  - Secondary 3.4m
  - Tertiary 5.0m
- Angular resolution = 0.7″ (median seeing limit)
- 0.2″ pixel size
- 3.5° field of view
- Diameter of the flat image surface is 64 cm
- 3.2 gigapixels in focal plane

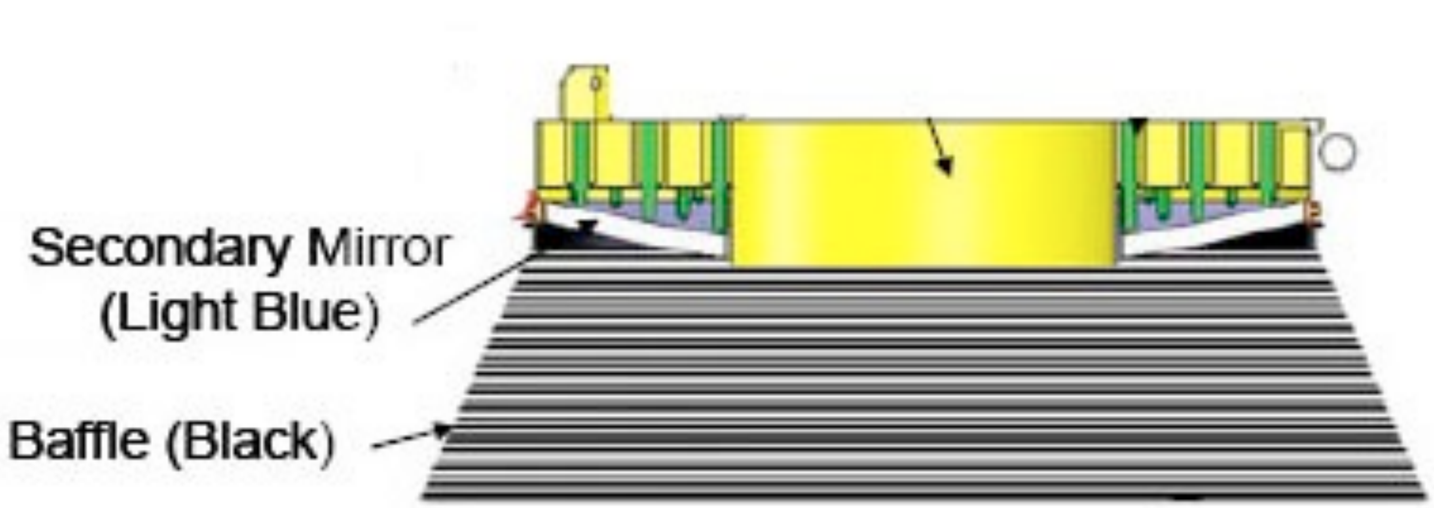


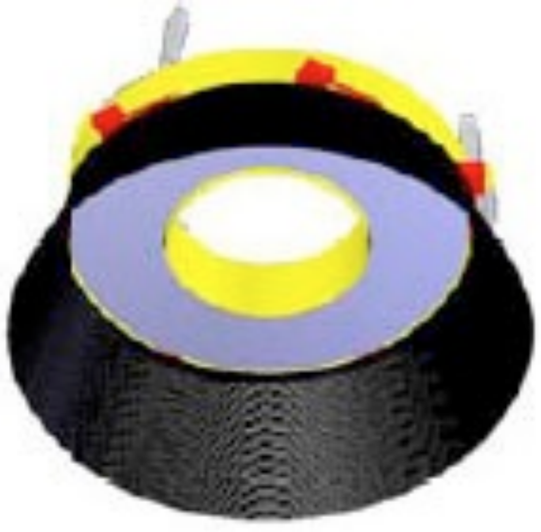
New IR Camera subsystem plus AO for the LSST

- Motivation:
  - An IR survey telescope with resolution twice the seeing limit gives rise to many very interesting science cases
- Implementation:
  - Visible to infrared (new waveband 0.8-2.5μm)
    - New camera subsystem with IR FPA and refractive optics
    - Pyramid wavefront sensors in the focal plane
    - Tip tilt correction done with refractive optics in front of FPA
  - Deformable mirrors in place of the secondary to provide ground layer *or* column AO correction

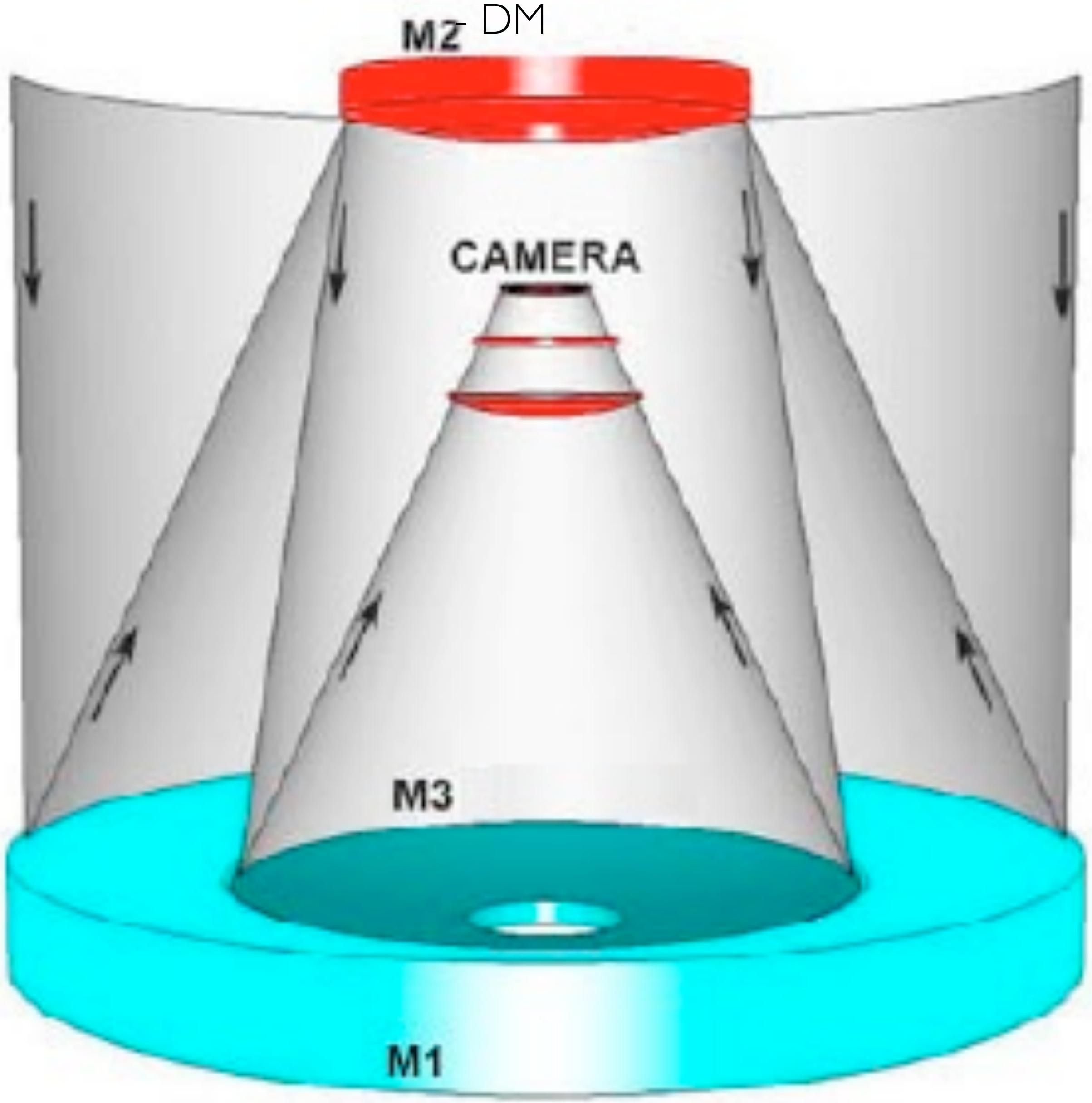
LSST Current Visible Optical Design



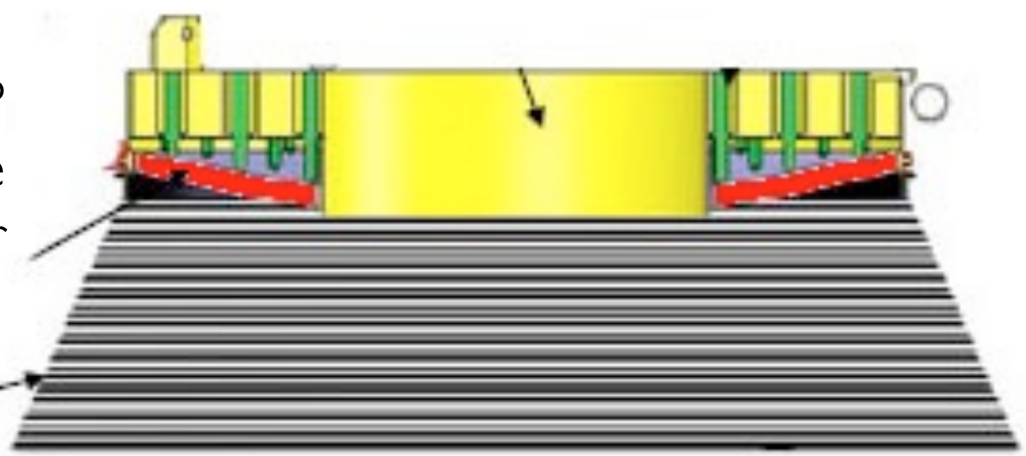




LSST Retrofitted IR Optical Design



CFRP Deformable Mirror

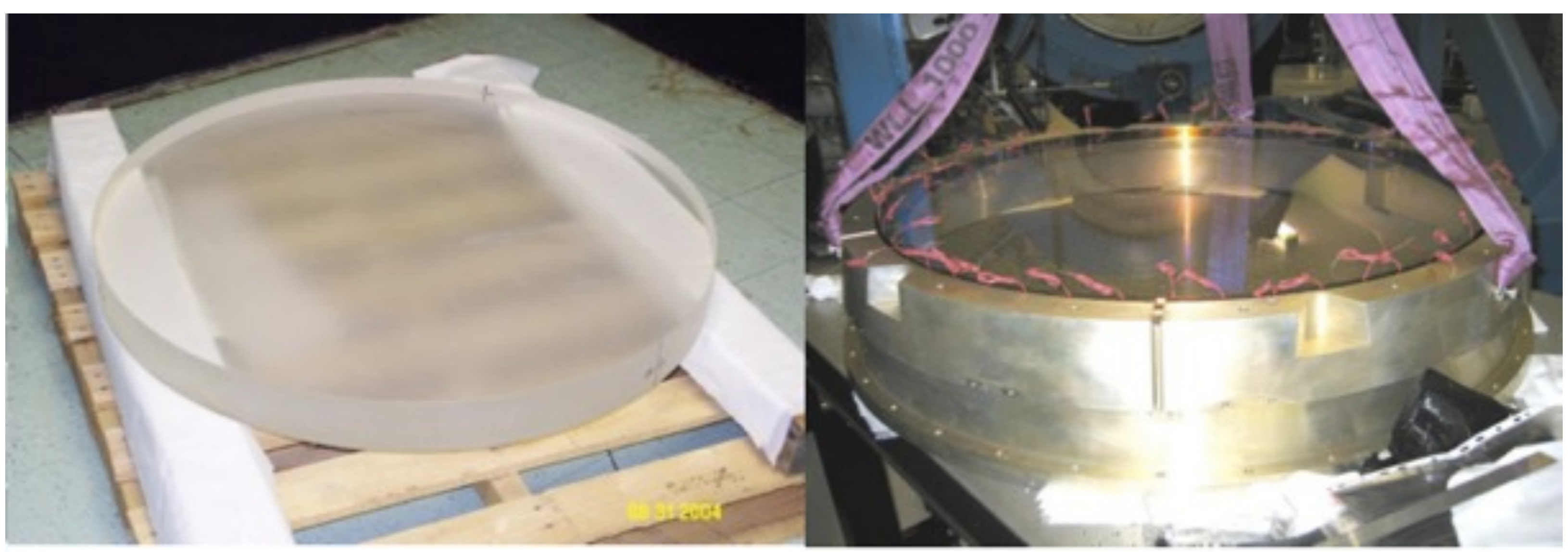


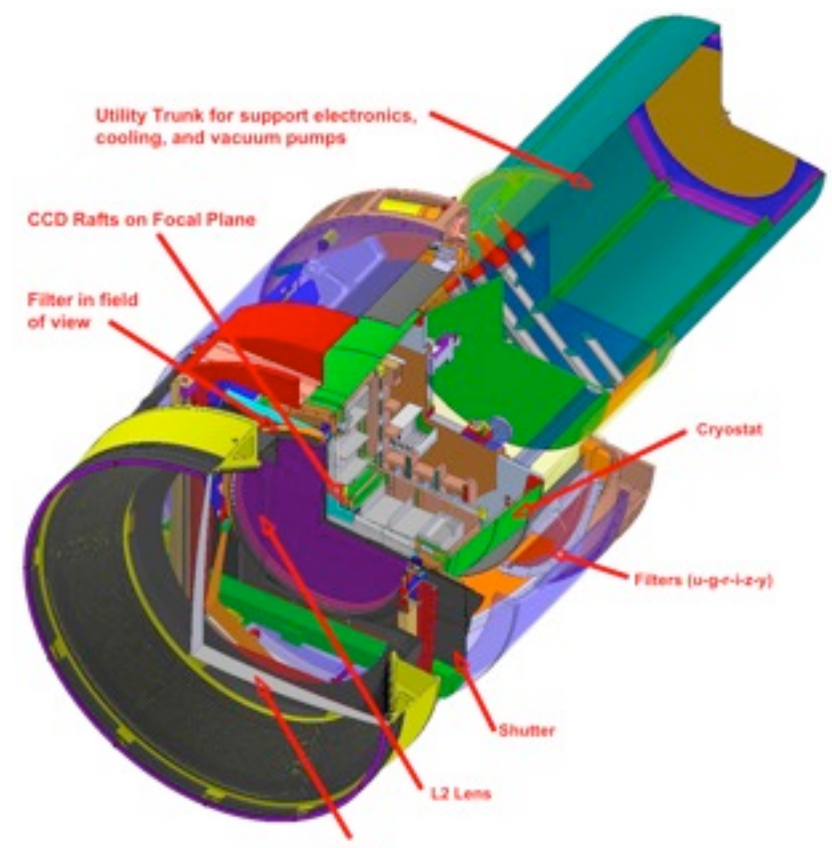
LSST Retrofitted IR Camera Design

Design considerations from VISTA IR Survey Telescope

Baffled Lens System for Cooling

Fused Silica Lenses for 0.8-2.5μm



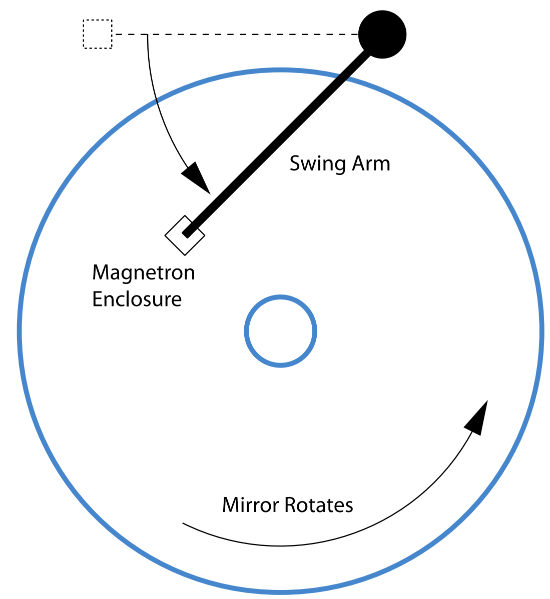


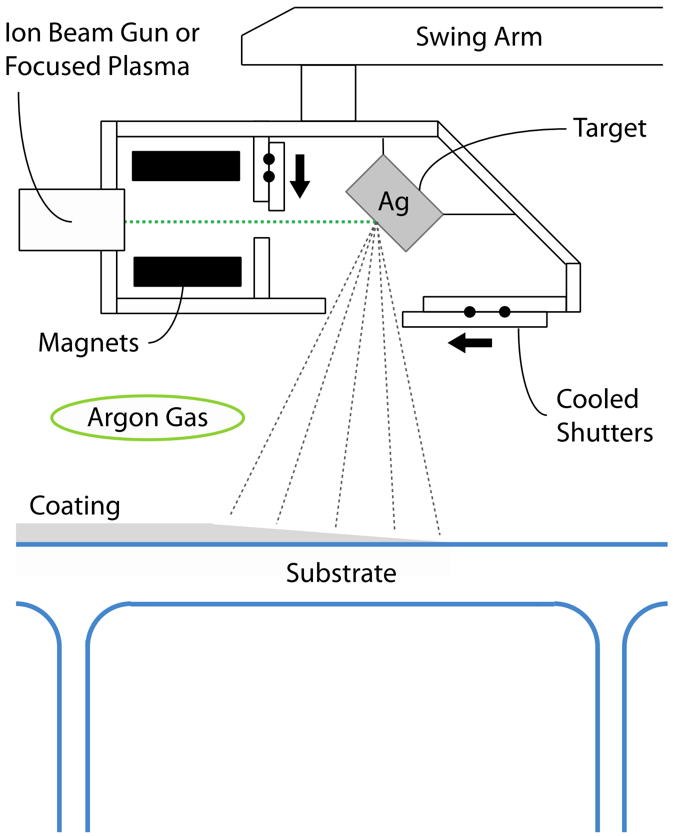
LSST Retrofitted IR Coatings

Design considerations from Gemini Observatory

Silver Sputtering

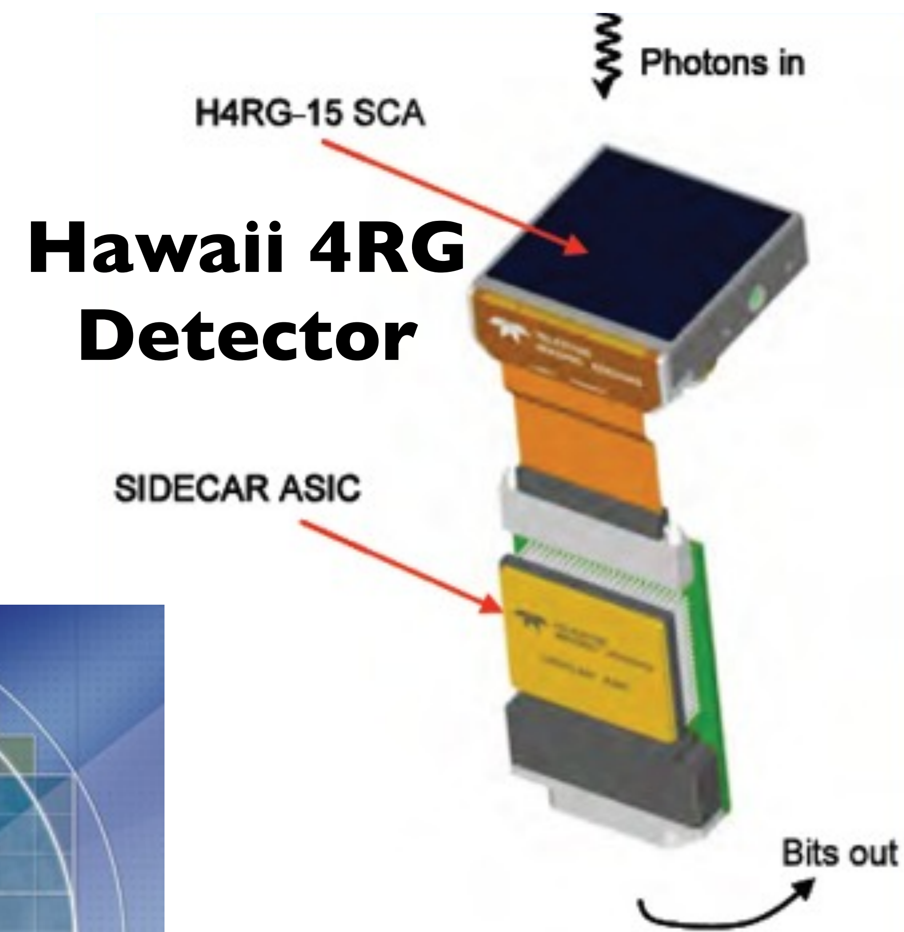
- Allows for Multi-Layered Coating with Thickness Control
- Recoated every 12 months
- High throughput for Visible-IR observations
- Low Absorption yields Low Thermal Background noise
- Recent paper showed monolithic borosilicate mirror could take thermal strain induced by coating process





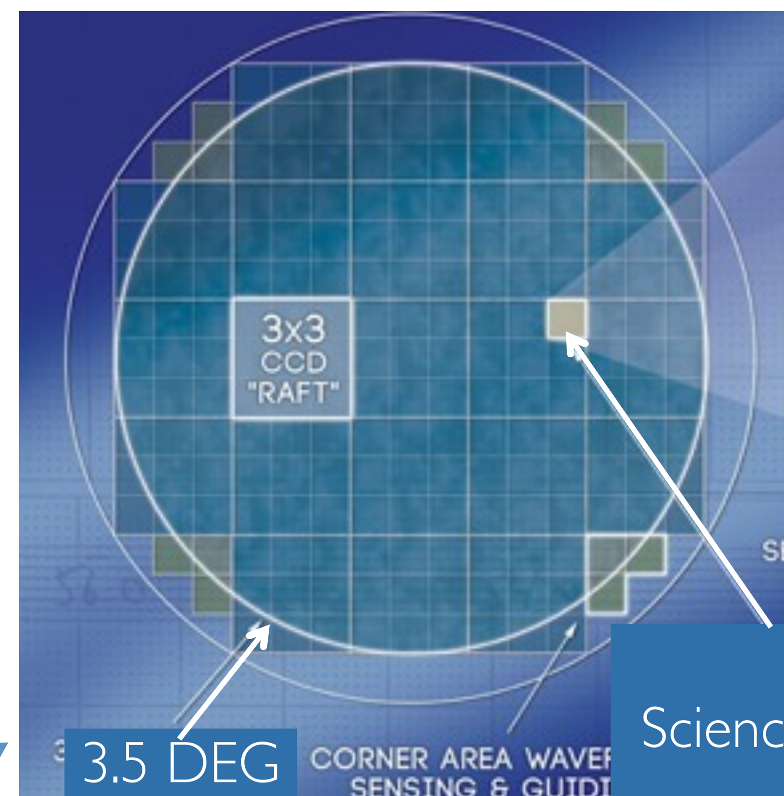
Hawaii 4RG IR Detector

- Teledyne HAWAII-2RG IR detector
  - 4096×4096 pixel array (same as visible detector
  - 10 μm pixel pitch (same as visible detector)
  - 41mm^2 area



- Current LSST image plane is 64cm^2
  - Requires 15x15 HAWAII-4RG IR detector

15x15
detector layout



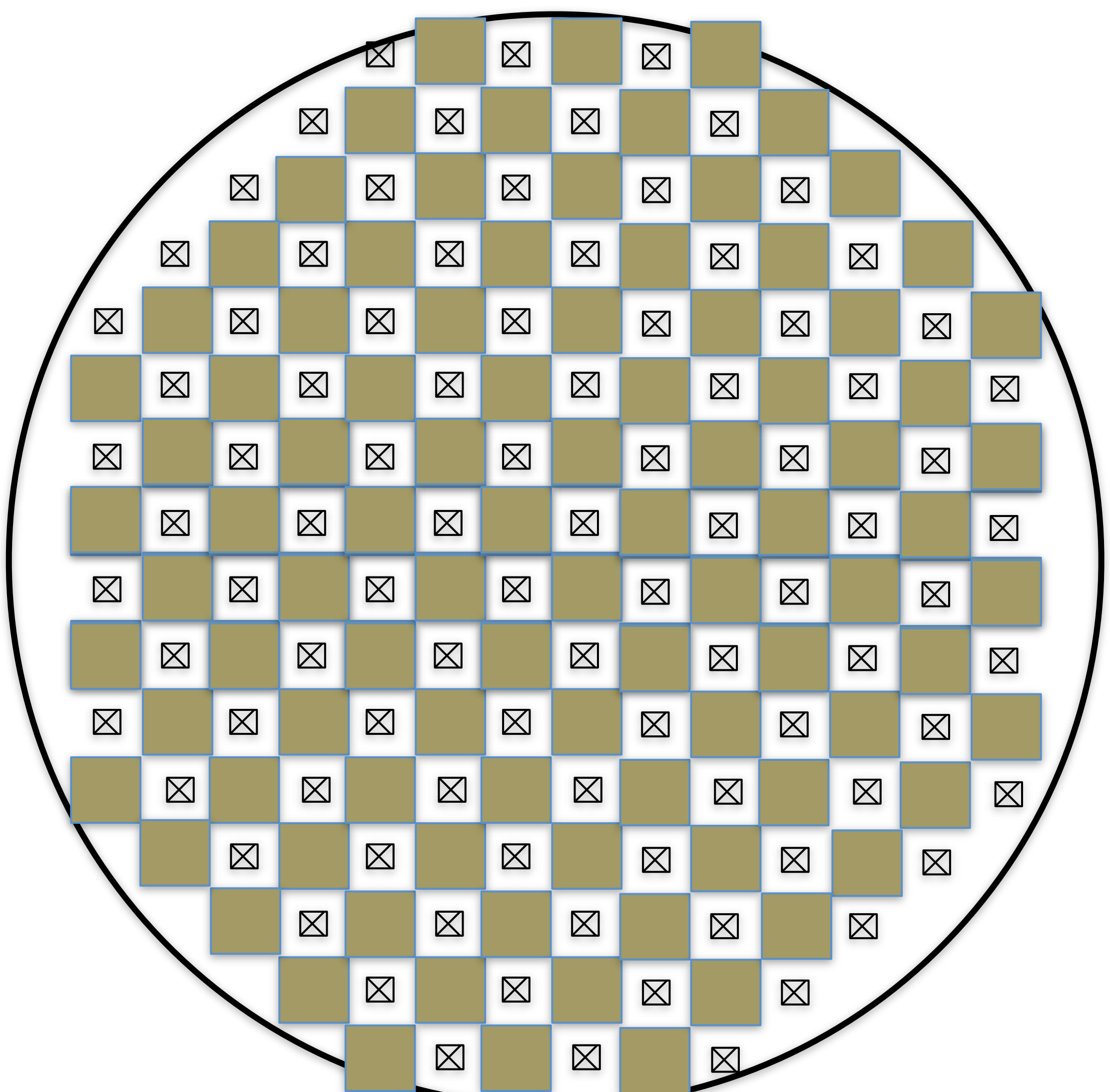
3.5 DEG
FOV

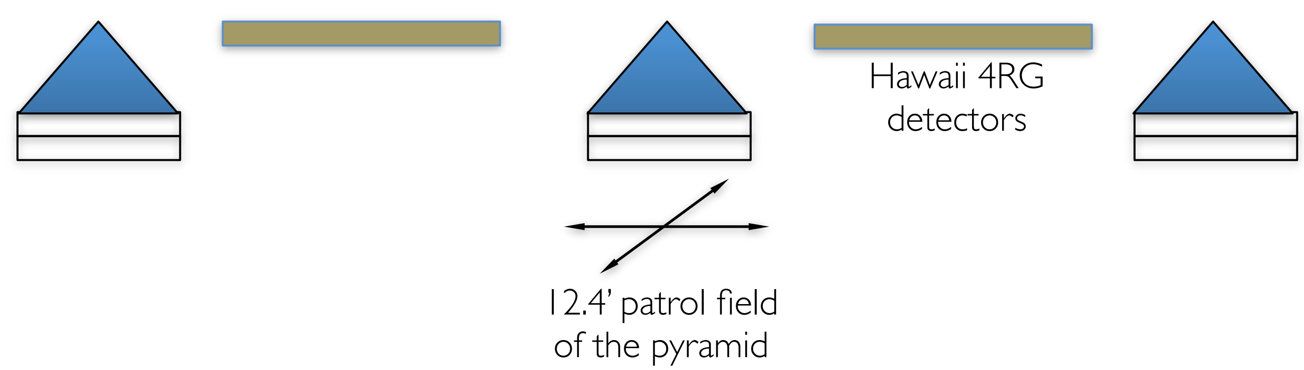
4kx4k
Science CCD 10μm
pixels

LSST super wide field WFS Concept

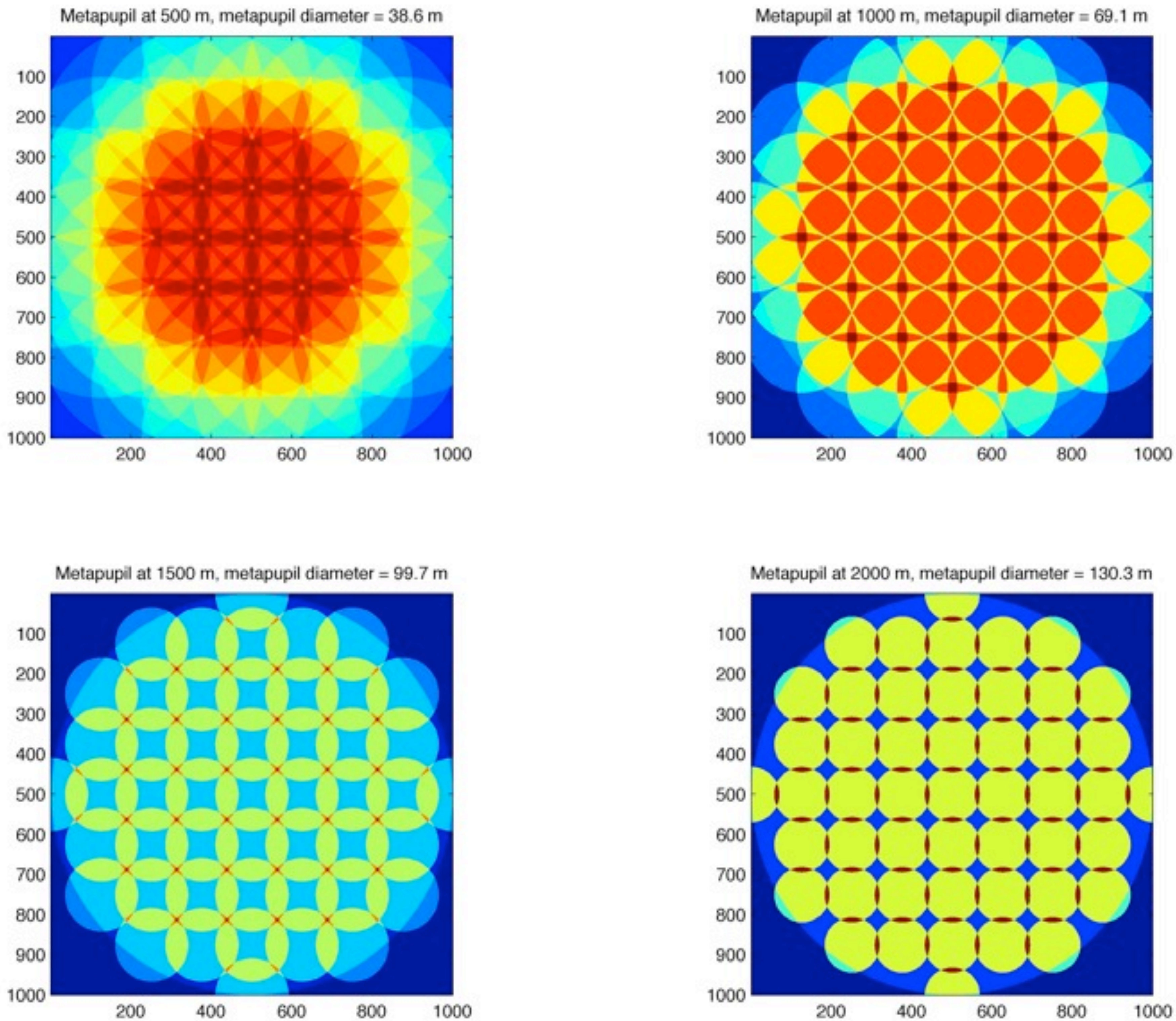
Take the Focal plane and install pyramid WFS in a checker board configuration.

- **Each detector covers 12.4' and the distance between each WFS is 24.8'**



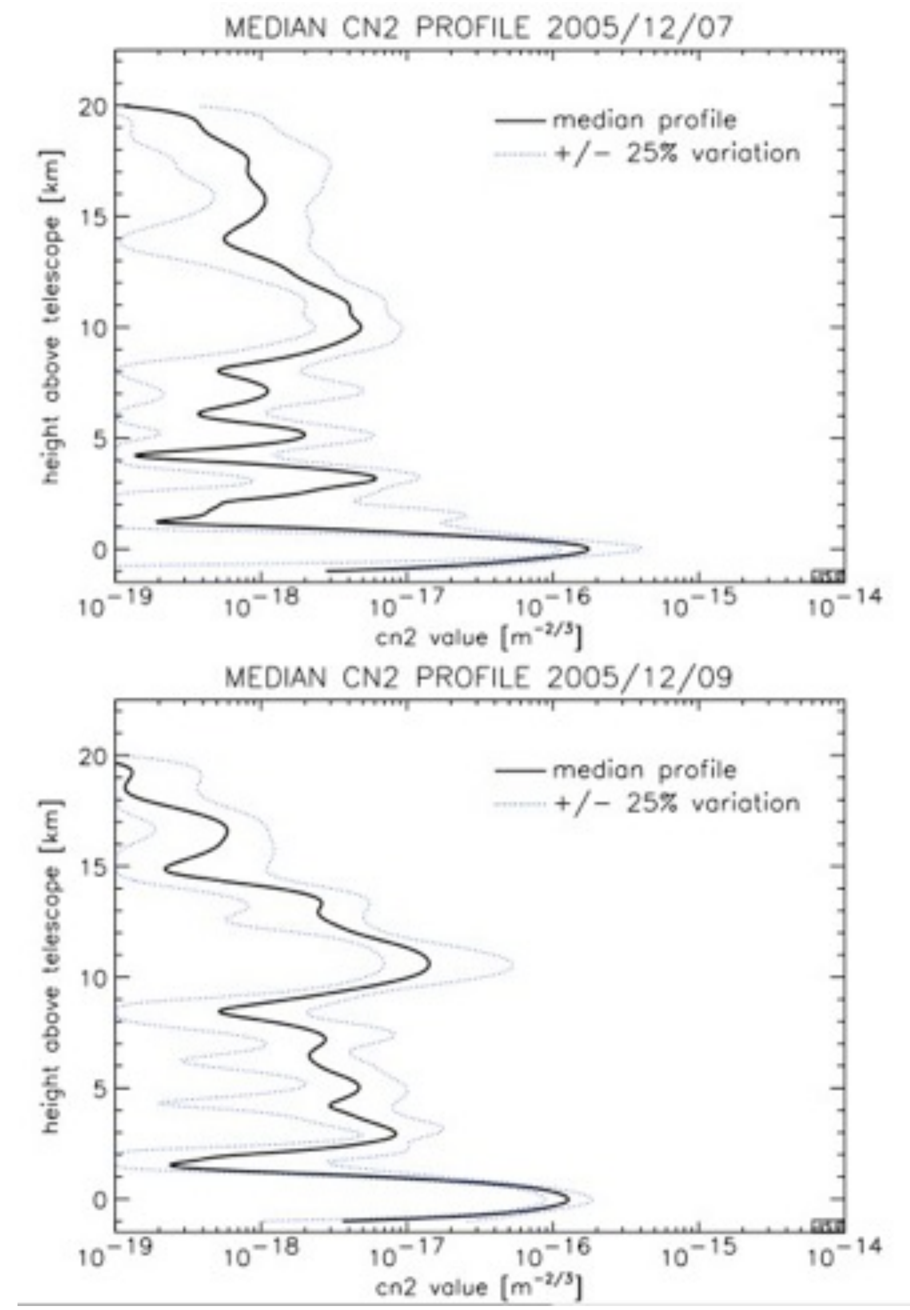


Simulation of LSST Metapupil fill



LSST AO modes

- **GLAO Mild correction of the ground layer.**
  - **DM is conjugated 17 m below the secondary.**
  - **Pupil get decorrelated by r_o at 27 m for FFOV=3.5 deg.**
  - **FFOV can be reduced to optimize performance.**
  - **Addition of local tip tilt correction will improve the performance. Very difficult to evaluate.**
  - **Expected a 1.5 to 2 reduction in FWHM**
- **NGS Tomography**
  - **Tomographic reconstruction is possible for the volume of the atmosphere < 2000 m.**
  - **Allows semi-diffraction limited single target performance.**



Mt Graham C_n^2, Egner 2006

Tip-Tilt Correction

- Tip-tilt correction will be Implemented in front of the detector will reduce the load/stroke required from the DM
- Tip-tilt correction will be done with two thin prisms in front of each detector
- The prisms will be rotated or rocked around to produce tip/tilt