# Project Status Overview: Optical Design Optimization

## LSST Telescope Final Design
## October 3, 2005

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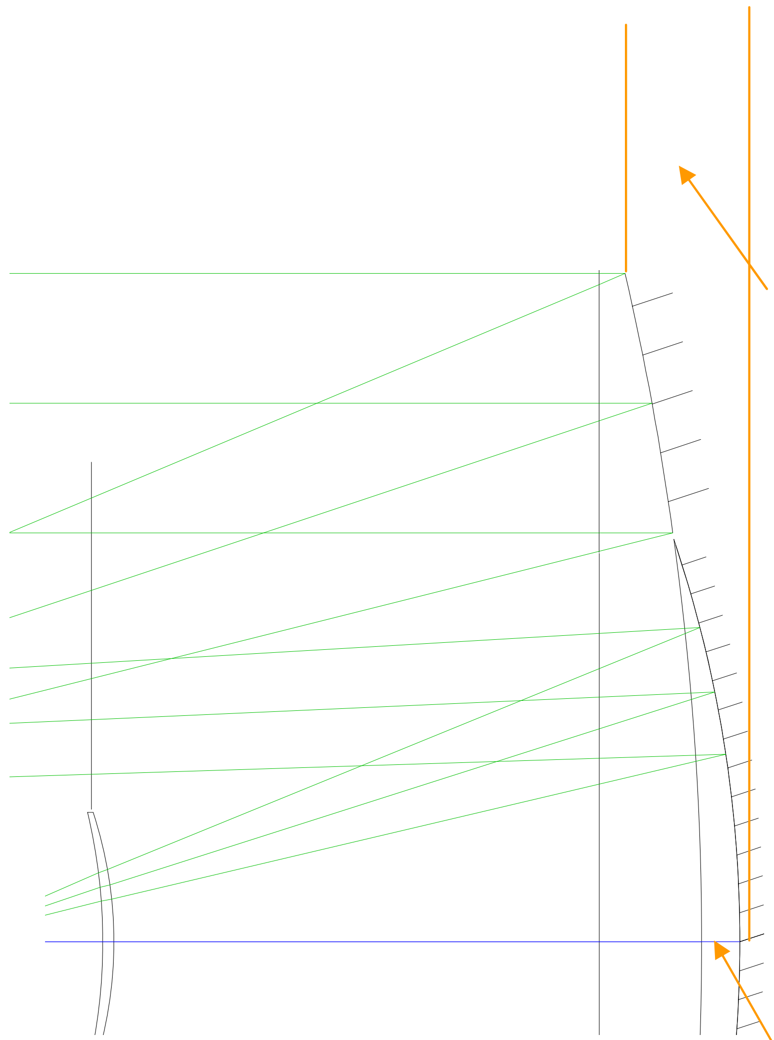
# Summary of accumulated changes to baseline

- The CA ID of the secondary is 1.8 m to facilitate installation of the camera through the hole in the secondary.
- Space of 5.0 cm (down from 8.0 cm) between clear apertures of the primary and tertiary mirrors.
  - The CA ID of the primary, joint line and the CA OD of the tertiary are respectively: 5116, 5066 and 5016 mm.
  - The overall sag of the M1 / M3 monolith is 680 mm.
- Warren Davison suggests reducing the diameter of the hole in the tertiary to 1054.7 mm, from 1160 mm.



# LSST baseline design specifications: updated

- **8.36 m diameter beam**
- **Full field of view of 3.5 degrees**
- **Etendue of 318 $m^2$ $deg^2$**
- **Focal ratio f/1.25**
  - **EFL: 10.45 m**
  - **Plate scale: 50.7 $\mu$m/arc-sec**
- **Flat focal plane**
- **Five photometric filters**
  - **g-r-i-z-y pass bands, 410 nm -1028 nm**
  - **Images calculated for 5 equally spaced and weighted wavelengths spanning the pass band**
- Primary and tertiary mirror :
  - monolithic
  - 5 cm between beams on each mirror
- Camera
  - 3 cm between beams at L1 input surface
  - Camera can be inserted in hole of secondary: 1.8 m diameter CA ID
- Telescope by itself is corrected on-axis
- No ADC

Three fused spherical silica lenses

- L1
  - Maximum diameter, :1.62 m
  - Edge thickness at CA diameter is 3.4 cm
- L2
  - Central thickness of 3.0 cm
  - Minimum space to filter at least 30 cm
    - Accommodate filter change mechanism
- L3
  - Vacuum barrier
    - >2.5 cm space to focal plane
  - Central thickness sufficient to provide “bullet-proof” design for fracture safety
    - Diameter/thickness ratio of 12.17 yields 6.0 cm thickness for 73 cm lens

Fused silica filters

- First surface concentric about chief ray
- CT and $2^{nd}$ surface curvature optimized for image quality
- Minimum center thickness of 1.35 cm

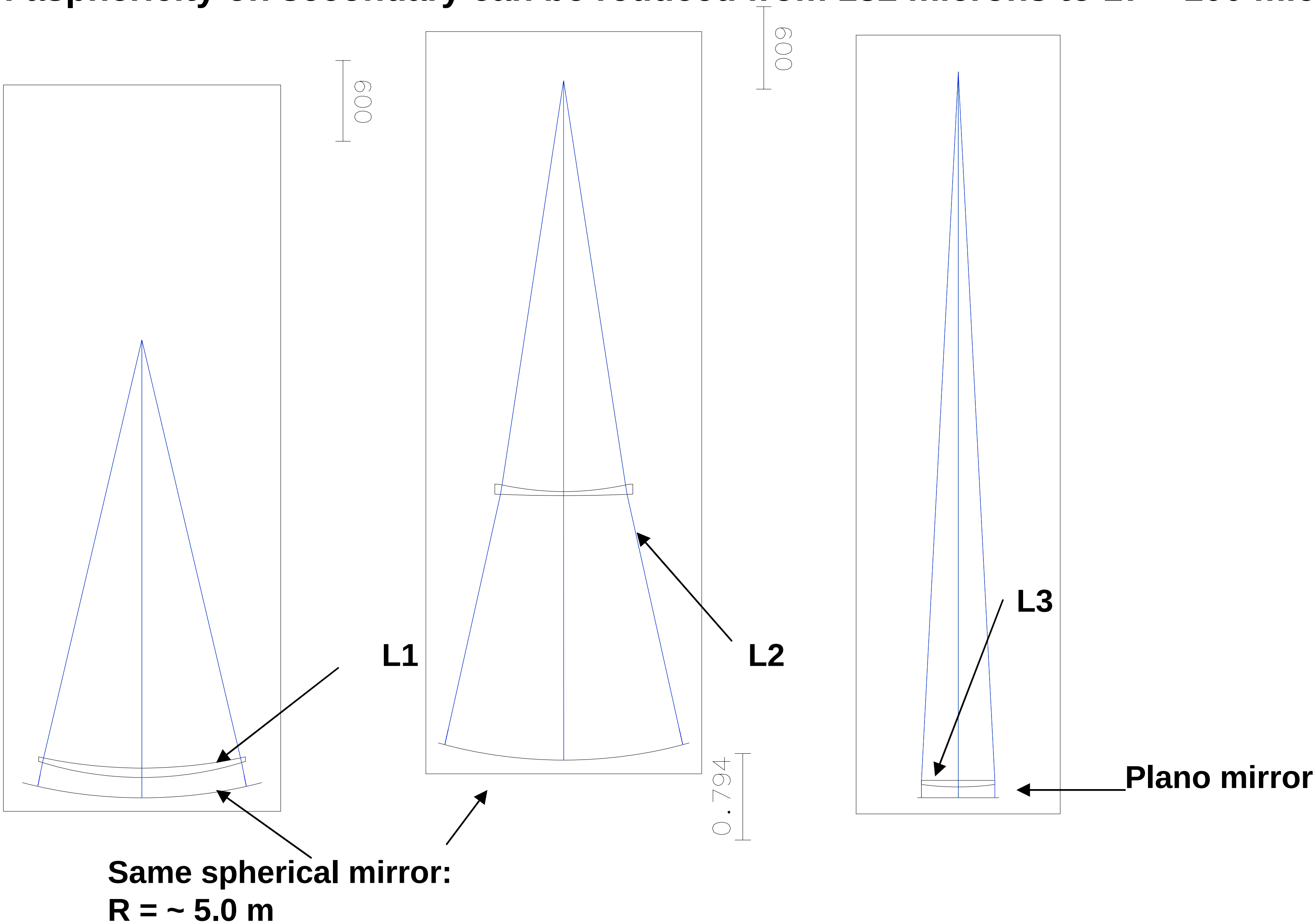
# Current work

Refine design regarding throughput, camera location, secondary asphericity while maintaining imaging performance

1. Add small amounts of asphericity on $L_2$ and $L_3$ to:
   - Reduce asphericity on secondary mirror
   - Improve null testing for $L_2$ and $L_3$
   - $L_2$ is now fixed; no imaging advantage for moving $L_2$
2. Study small changes in focal ratio: f/1.25 to f/1.20
   - Further reduce asphericity on secondary
   - $L_2$ cantilever and/or secondary diameter increase slightly

# Null tests can be simplified by adding small amounts of asphericity on L2 and L3

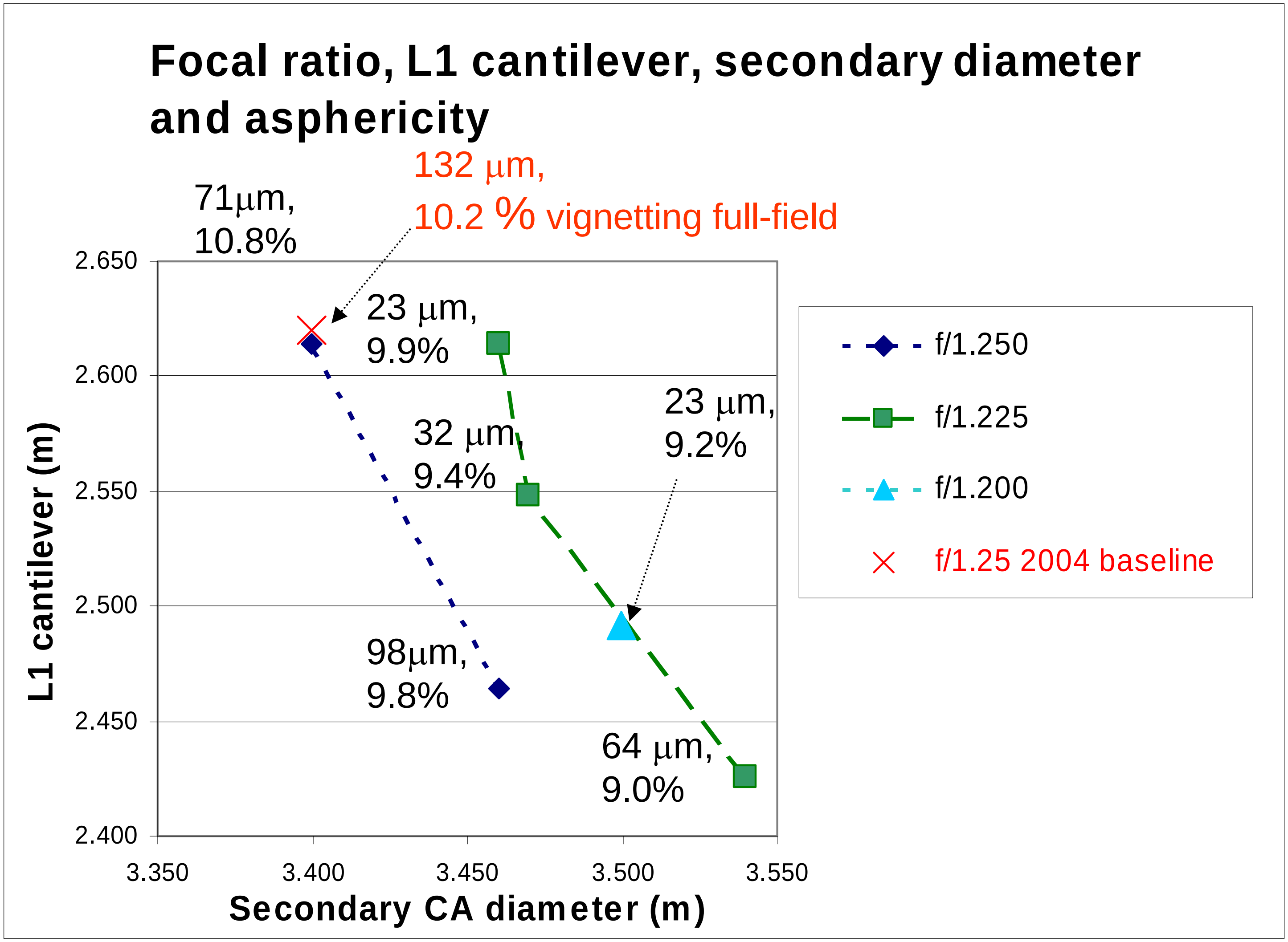
**Bonus: asphericity on secondary can be reduced from 132 microns to 17 – 100 microns**



# Trade studies maintaining constant image quality, for designs with aspheric lenses

- Decreasing the $L_1$ cantilever can:
  - increase the diameter of the secondary
    - decrease the vignetting
  - increase the asphericity of the secondary
- Decreasing the focal ratio of the telescope can:
  - decrease the asphericity of the secondary
    - Either the $L_1$ cantilever or secondary diameter will increase

# Vignetting at full-field added; vignetting decreases as secondary diameter increases



# Continuing work

- **Look at designs with secondary asphericity 17- 34 microns**
  - **There are relatively small increases of the L1-FP vertex distance**
    - increase from 2.63 to 2.75 – 2.81 m should be acceptable
  - **The potential advantages for fabricating and testing the secondary mirror are more significant**
- **Ranges**
  - **f/1.25 to f/1.2236 (plate scale 50.66 to 50.00 microns/arc-sec)**
  - **Primary radius 19.6 to 19.9 m**
  - **L1 cantilever 2.7 to 2.8 m**
  - **M2 CA diameter 3.37 to 3.44 m**
  - **Telescope length 6.32 to 6.45 m**

# Continuing work

- **Comments on next slide [slide 10]**
  - **Designs A-H increase the L1 cantilever from 2.6 m to 2.7 m**
  - **Designs A-C with biconcave L2 have 21 to 25 microns asphericity**
    - Long radius on 1st surface of L2 leads to testing difficulties since radius must be within + /- 50 mm or so
  - **Designs D-H have a plano-concave L2**
    - Ideal for fabrication and testing
    - Asphericity increases to 30 to 34 microns
  - **Decreasing the focal ratio**
    - Decreases the vignetting as it increases the diameter of M2
    - Slightly improves the image sizes
- Designs D-H are reasonable but look at what is required to further reduce asphericity on secondary

# L1 cantilever increased to 2.7 meters; f/1.25, f/1.24 and f/1.2236

## A-C, L2 is biconcave; D-H, L2 is plano-concave

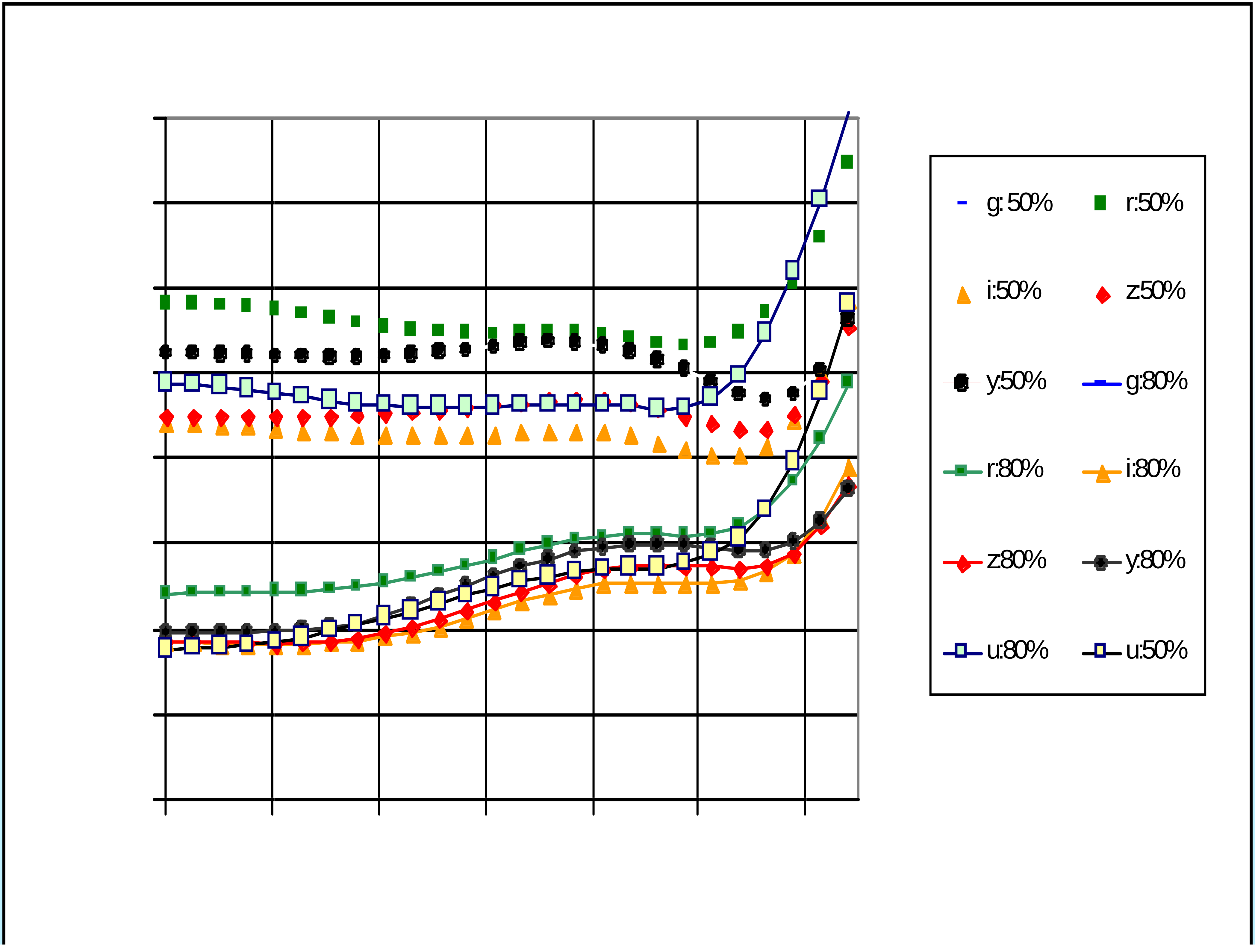
| LSST : Sept 30,2005 | | Units | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|---|---|
| **FNBR** | | --- | 1.2500 | 1.2400 | 1.2336 | 1.2500 | 1.2500 | 1.2400 | 1.2336 | 1.2336 |
| | Plate scale | µm/sec | 50.66 | 50.26 | 50.00 | 50.66 | 50.66 | 50.26 | 50.00 | 50.00 |
| **Casting** | Required depth: M1M3 | mm | 676 | 676 | 676 | 676 | 671 | 672 | 676 | 674 |
| **M1** | Radius | m | -19.681 | -19.695 | -19.688 | -19.681 | -19.832 | -19.811 | -19.685 | -19.795 |
| **M1** | Max. Dep.: BF parabola | µm | 109 | 113 | 116 | 114 | 117 | 119 | 120 | 123 |
| **M2** | Diameter (Optical CA) | m | 3.40 | 3.41 | 3.42 | 3.40 | 3.41 | 3.43 | 3.42 | 3.44 |
| **M2** | Max. Dep.: BSF | µm | 25 | 21 | 21 | 32 | 34 | 31 | 30 | 31 |
| **M3** | Max. Dep.: BSF | µm | 411 | 409 | 406 | 407 | 394 | 391 | 394 | 388 |
| **L1** | Diameter (Optical CA) | m | 1.58 | 158 | 1.58 | 1.58 | 1.58 | 1.58 | 1.58 | 1.58 |
| **L1** | Center Thickness | mm | -72.13 | -70.18 | -69.99 | -72.67 | -71.95 | -70.70 | -69.76 | -72.63 |
| **L2** | Diameter (Optical CA) | m | 1.056 | 1.042 | 1.046 | 1.058 | 1.048 | 1.048 | 1.044 | 1.064 |
| **L2** | Surface1: Radius | m | 29.93 | 39.78 | 54.53 | **plano** | **plano** | **plano** | **plano** | **plano** |
| **L2** | Surface2: Radius | m | -2.914 | -2.954 | -2.95 | -2.651 | -2.727 | -2.796 | -2.864 | -2.789 |
| **L2** | Max. Dep.: BSF | µm | 260 | 253 | 268 | **213** | **230** | **245** | **233** | **244** |
| **L2-filter** | L2 to Filter space | mm | -300 | -300 | -300 | -300 | -300 | -300 | -300 | -318.7 |
| **Filter** | Surface1&2:RD i-filter | m | -6.403 | -6.223 | -6.122 | -6.3 | -6.306 | -6.174 | -6.104 | -6.066 |
| **Camera** | L1 1st vertex to M2 | m | 2.710 | 2.709 | 2.708 | 2.711 | 2.690 | 2.691 | 2.706 | 2.694 |
| | Overall System Length[1] | m | 6.352 | 6.331 | 6.317 | 6.35 | 6.37 | 6.35 | 6.32 | 6.33 |
| | Integrated Etendue(AΩ) | $m^2deg^2$ | 318.9 | 319.2 | 319.7 | 318.9 | 319.5 | 319.9 | 319.7 | 320.3 |
| | on-axis | % | 62.55 | 62.55 | 62.55 | 62.55 | 62.55 | 62.55 | 62.55 | 62.55 |
| | full-field | % | 55.47 | 55.67 | 55.72 | 55.58 | 56.01 | 56.19 | 55.80 | 56.37 |
| | Integrated | % | 60.39 | 60.45 | 60.54 | 60.39 | 60.49 | 60.57 | 60.54 | 60.65 |
| | Vignetting (% from center) | % | 11.32 | 11.01 | 10.93 | 11.14 | 10.46 | 10.17 | 10.79 | 9.89 |
| **Image Size (Worst case 80% Diffraction Encircled energy Dia.)** | | | | | | | | | | |
| | g: 410 - 552 nm | sec | 0.305 | 0.300 | 0.299 | 0.328 | 0.307 | 0.298 | 0.303 | **0.280** |
| | r : 550 -694 nm | sec | 0.273 | 0.259 | 0.250 | 0.280 | 0.248 | 0.234 | 0.257 | **0.236** |
| | i: 694 - 847 nm | sec | 0.265 | 0.252 | 0.242 | 0.267 | 0.236 | 0.222 | 0.248 | **0.215** |
| | y: 847 - 930 nm | sec | 0.278 | 0.261 | 0.247 | 0.274 | 0.239 | 0.225 | 0.252 | **0.219** |
| | z: 960 - 1028 nm | sec | 0.290 | 0.274 | 0.260 | 0.282 | 0.245 | 0.234 | 0.259 | **0.231** |

# Look at larger L1 cantilever distance of ~2.8 m

- Designs I – M: Minimum asphericity of 17 microns achieved for L1 cantilever of ~2.8 m
- All designs I – M should be acceptable
- Designs K-M look at reducing L1 CA size from 1.58 m to 1.55 m
  - Powers of L1 and L2 increase slightly ( and weight, thickness)
  - Reducing the focal ratio increases the space between L2 and the filter; could be helpful for filter interchange
    - Size of L2 increases slightly
- **Recommendation: Designs K-M should be passed by small group to further discuss**

# Increasing L1 cantilever to 2.8 m reduces secondary asphericity to minimum possible values; K-M trades M2 diameter and vignetting vs. L1 size

| LSST : Sept 30,2005 | | Units | I | J | K | L | M |
|---|---|---|---|---|---|---|---|
| FNBR | | --- | 1.2500 | 1.2400 | 1.2500 | 1.2400 | 1.2336 |
| | Plate scale | μm/sec | 50.66 | 50.26 | 50.66 | 50.26 | 50.00 |
| Casting | Required depth: M1M3 | mm | 675 | 677 | 677 | 677 | 677 |
| M1 | Radius | m | -19.840 | -19.839 | -19.842 | -19.838 | -19.835 |
| M1 | Max. Dep.: BF parabola | μm | 102 | 104 | 100 | 105 | 111 |
| M2 | Diameter (Optical CA) | m | **3.39** | **3.40** | **3.37** | **3.40** | 3.42 |
| M2 | Max. Dep.: BSF | μm | **17** | **17** | **17** | **17** | **17** |
| M3 | Max. Dep.: BSF | μm | 400 | 393 | 400 | 401 | 403 |
| L1 | Diameter (Optical CA) | m | 1.56 | 1.58 | **1.550** | **1.550** | **1.550** |
| L1 | Center Thickness | mm | -74.410 | -74.220 | -78.400 | -79.14 | -81.60 |
| L2 | Diameter (Optical CA) | m | 1.058 | 1.060 | 1.078 | 1.084 | 1.098 |
| L2 | Surface1: Radius | m | **plano** | **plano** | **plano** | **plano** | **plano** |
| L2 | Surface2: Radius | m | -2.609 | -2.660 | -2.508 | -2.545 | -2.541 |
| L2 | Max. Dep.: BSF | μm | **230** | **253** | **224** | **235** | **233** |
| L2-filter | L2 to Filter space | mm | -305.3 | -312.2 | -300 | -323.9 | -355.8 |
| Filter | Surface1&2:RD i-filter | m | -5.899 | -5.731 | -5.744 | -5.69 | -5.628 |
| Camera | L1 1st vertex to M2 | m | 2.777 | 2.811 | 2.804 | 2.780 | 2.762 |
| | Overall System Length[1] | m | 6.43 | 6.42 | 6.45 | 6.42 | 6.39 |
| | Integrated Etendue(AΩ) | $m^2deg^2$ | 318.3 | 318.2 | 317.6 | 318.8 | 319.5 |
| | on-axis | % | 62.55 | 62.55 | 62.55 | 62.55 | 62.55 |
| | full-field | % | 55.72 | 55.53 | 55.59 | 55.80 | 56.12 |
| | Integrated | % | 60.27 | 60.26 | 60.13 | 60.37 | 60.50 |
| | Vignetting (% from center) | % | 10.92 | 11.22 | 11.13 | 10.79 | 10.28 |
| | | | | | | | |
| | g: 410 - 552 nm | sec | 0.276 | **0.264** | 0.274 | **0.267** | 0.264 |
| | r : 550 -694 nm | sec | 0.228 | **0.209** | 0.232 | **0.216** | 0.209 |
| | i: 694 - 847 nm | sec | 0.226 | **0.202** | 0.225 | **0.208** | 0.201 |
| | y: 847 - 930 nm | sec | 0.233 | **0.207** | 0.232 | **0.215** | 0.209 |
| | z: 960 - 1028 nm | sec | 0.247 | **0.215** | 0.237 | **0.218** | 0.209 |


g: 50%
r:50%
i:50%
z:50%
y:50%
g:80%
r:80%
i:80%
z:80%
y:80%
u:80%
u:50%

# Current baseline Detector/WFS Layout