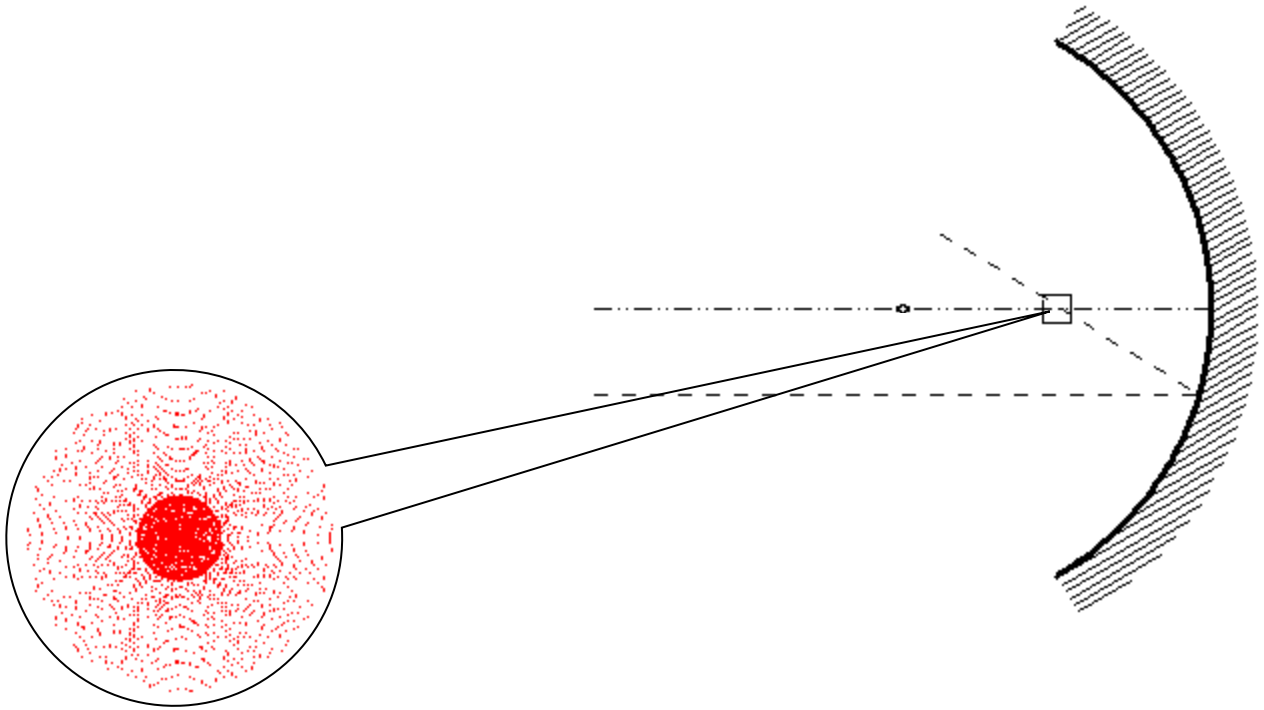
Observational Astrophysics II

TELESCOPES

Kitchin (5th edition) pp.51-113

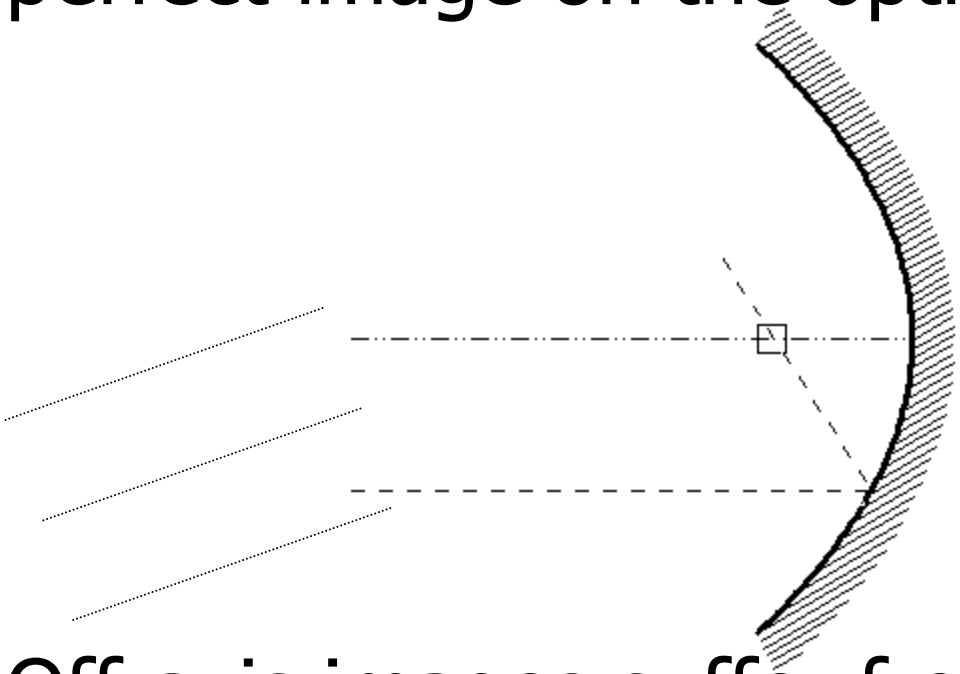
Optical Schemes

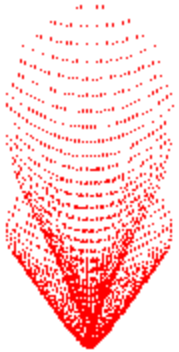
Spherical mirrors cannot focus light properly due to spherical aberrations:



Optical Schemes

… but a single parabola can produce perfect image on the optical axis:





Off-axis images suffer from coma.

Ritchey-Chrétien telescope

Parabolic primary and hyperbolic secondary solve main aberration problems (spherical and coma) in a rather large field of view (few arcminutes) in Cassegrain focus

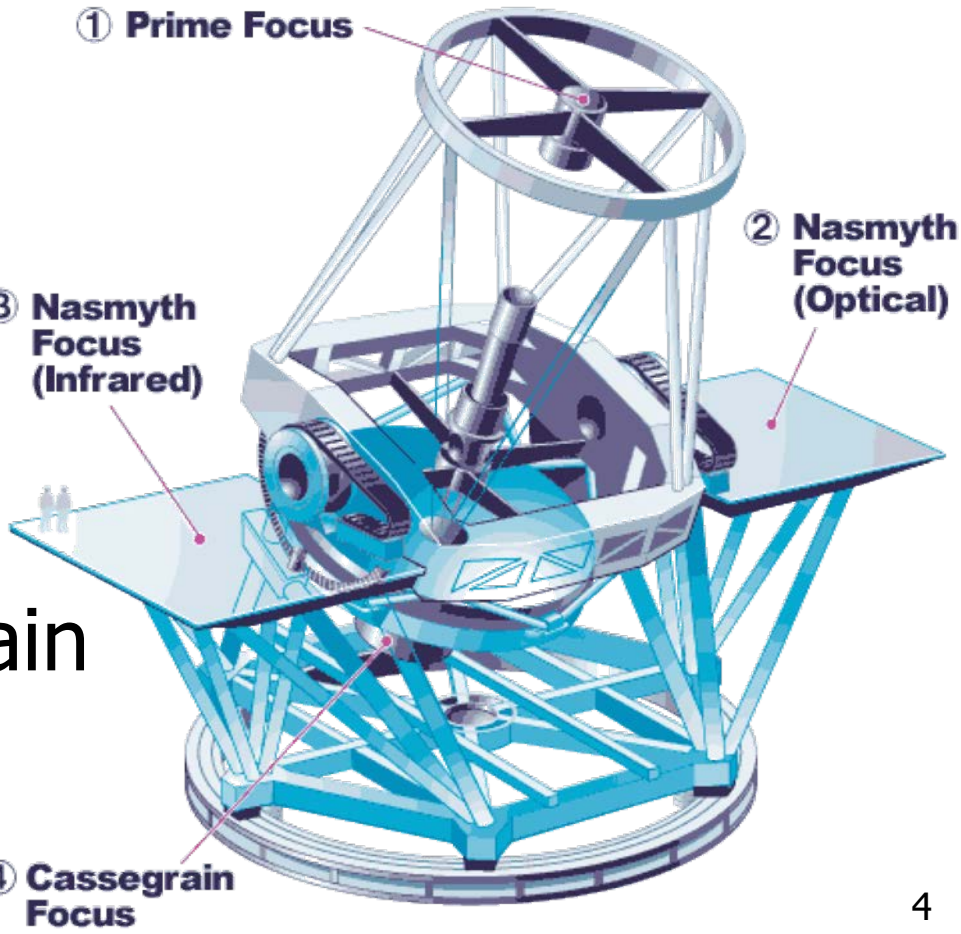


Illustration by Takaetsu Endo, taken from Nikkei Science 1996

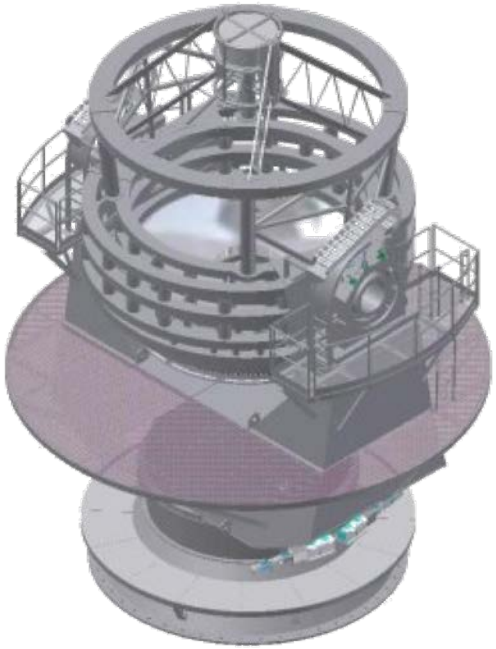
RC design: compromises & tools

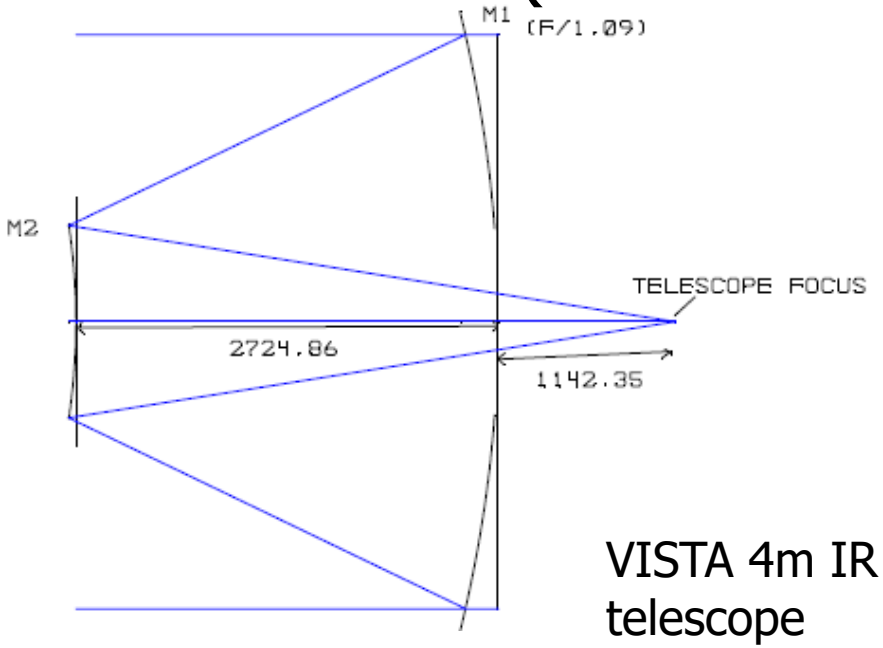
- Optical aberrations
- Curvature of the focal plane
- The size of field of view
- Detector pixel size and pixel number
- Additional corrections (e.g. atmospheric dispersion, flexure)

Paranal

RC design: compromises & tools

- Average image quality (match optical aberrations)
- Curvature of the focal plane (fit detectors)
- Field of View to match science (VISTA FoV 2º)

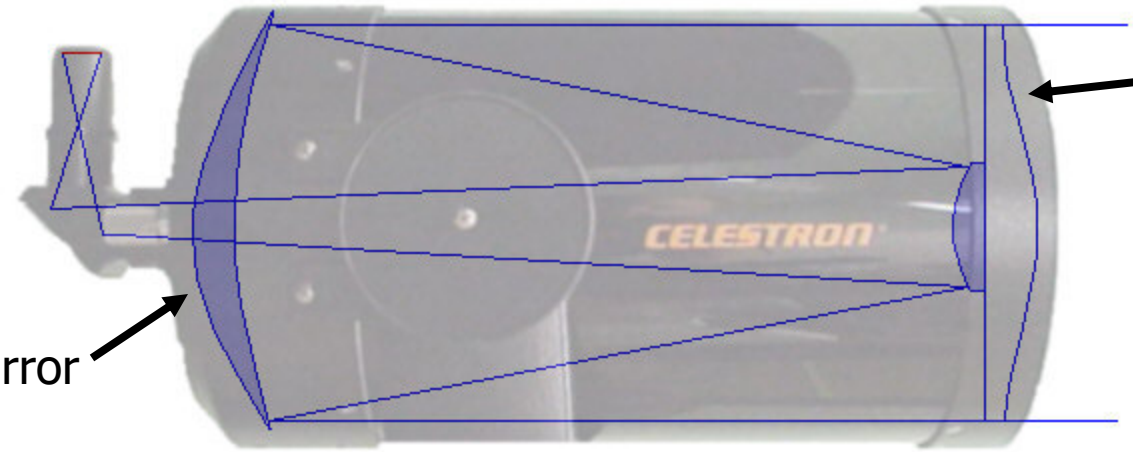




VISTA 4m IR survey telescope

Schmidt-Cassegrain

- RC provides very good image quality in a relatively small field
- For larger FoV Schmidt-Cassegrain is the preferred design:

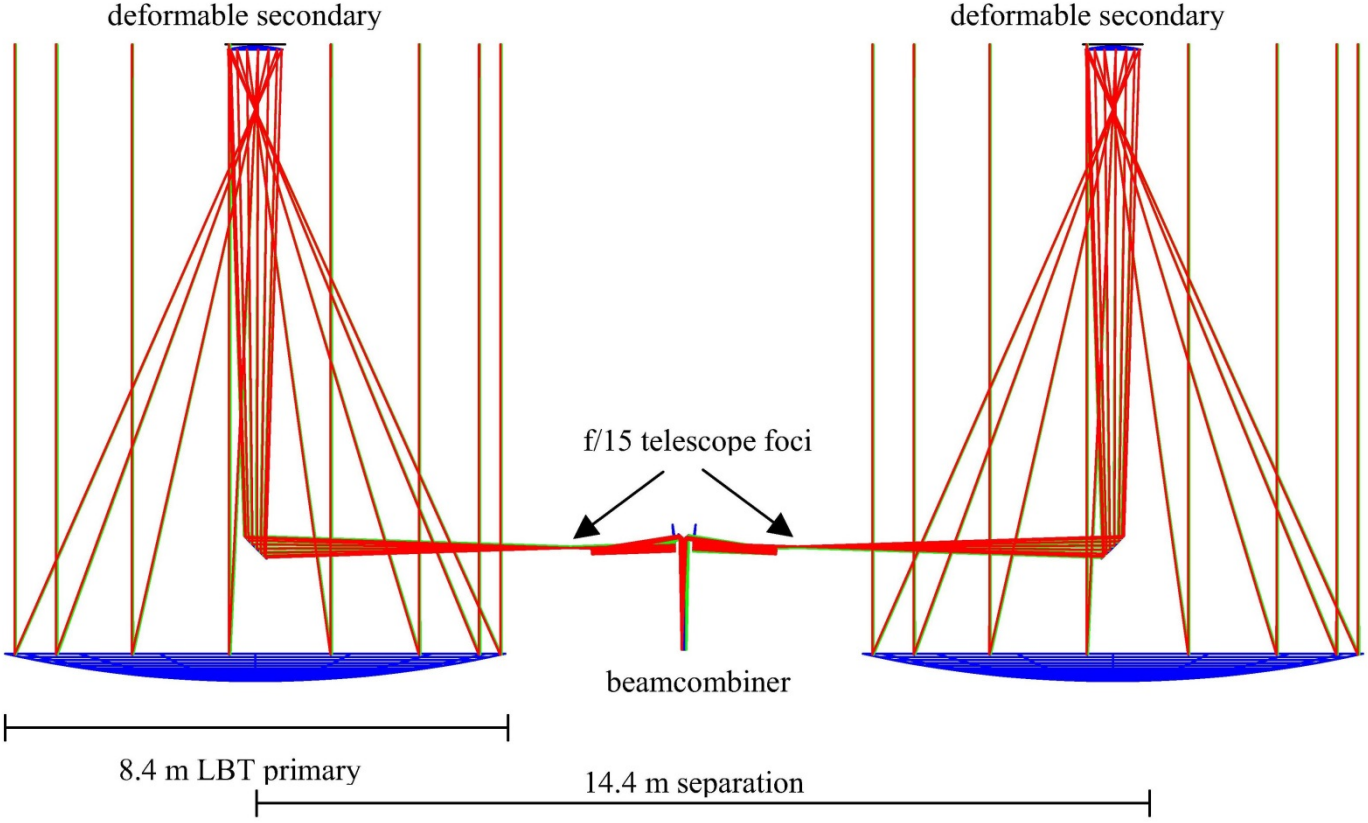


Correction plate

Spherical mirror

Alternatively Gregorian system

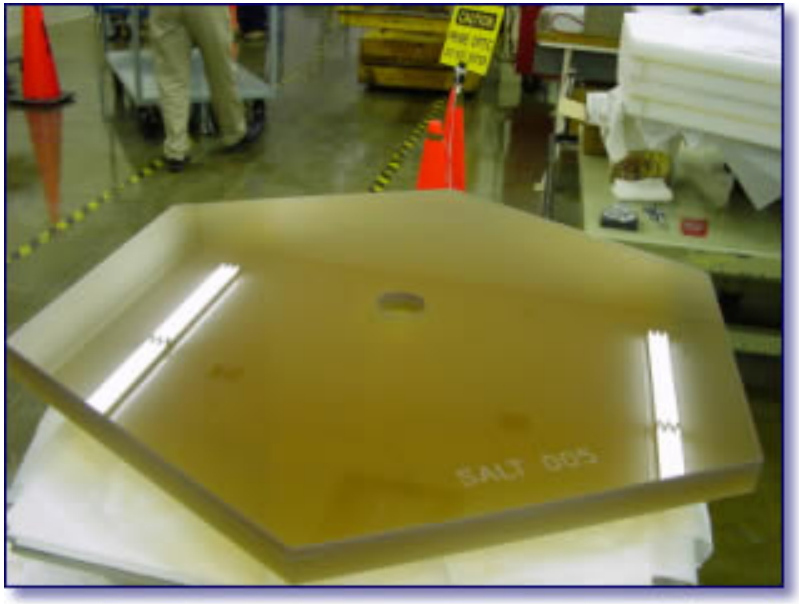
Concave secondary after the primary focus:



Courtesy of MPI Potsdam

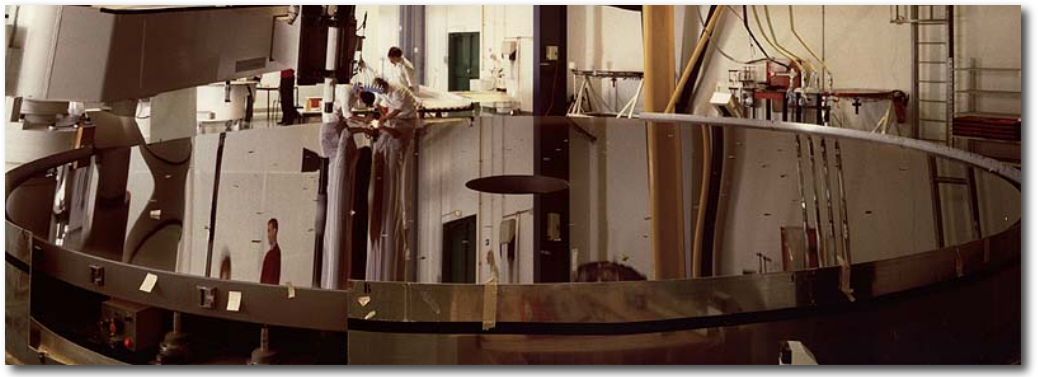
Materials

- Low thermal expansion: zerodur & sitall



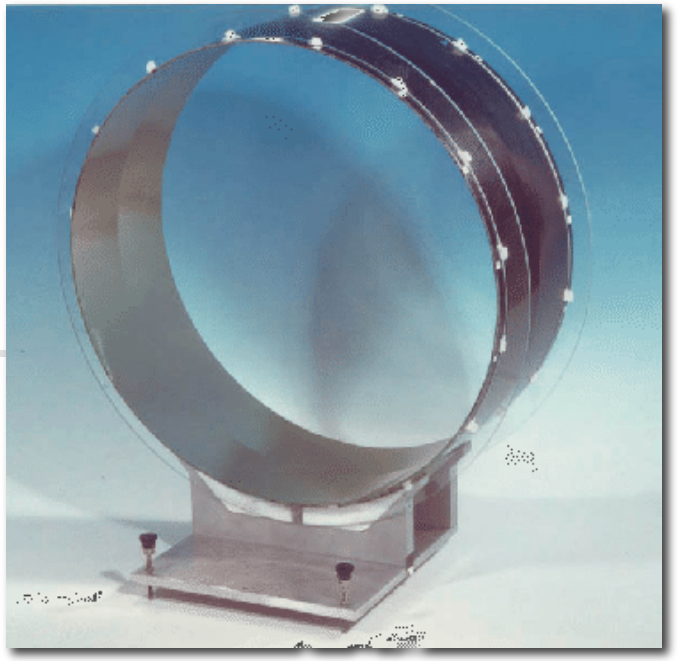
Astro-sitall blank at LZOS (VST, VISTA, SALT, LAMOST, BWT)

mean linear coefficient of thermal expansion within temperature range -60° to +60° C is $<10^{-8}$ cm $^{o}C^{-1}$



Zerodur VLT primary at REOSC

More materials



SiC 60 cm X-ray mirror
Weight: 6.2 kg

Silicon Carbide

- Low thermal expansion (not as good as glass)
- Very light
- Very hard, keep the shape well
- Hard to make in large pieces
- Fragile, hard to process

Mirror production

Mirror mold is prepared by installing hexagonal silica fiber cores

Cells of silica fibers are filled with glass balls of several types

The mold is heated and rotated. Vertical mixing is by convection. Radial mixing is by Coriolis force. Cooling down takes months.

Mirror production

Supports are attached to the bottom

Blank is flipped over and grinded to the rough shape

Mirror is polished to the optical quality with simultaneous interferometric control

Coatings

- Mirrors are coated to achieve high reflectivity
  - Aluminum with SiO on the top
  - Silver-based coatings. Needs coating to prevent mechanical damage during washing
- Lenses are coated to minimize reflectivity
  - MgF_2

Coating machine

JWST mirror coating

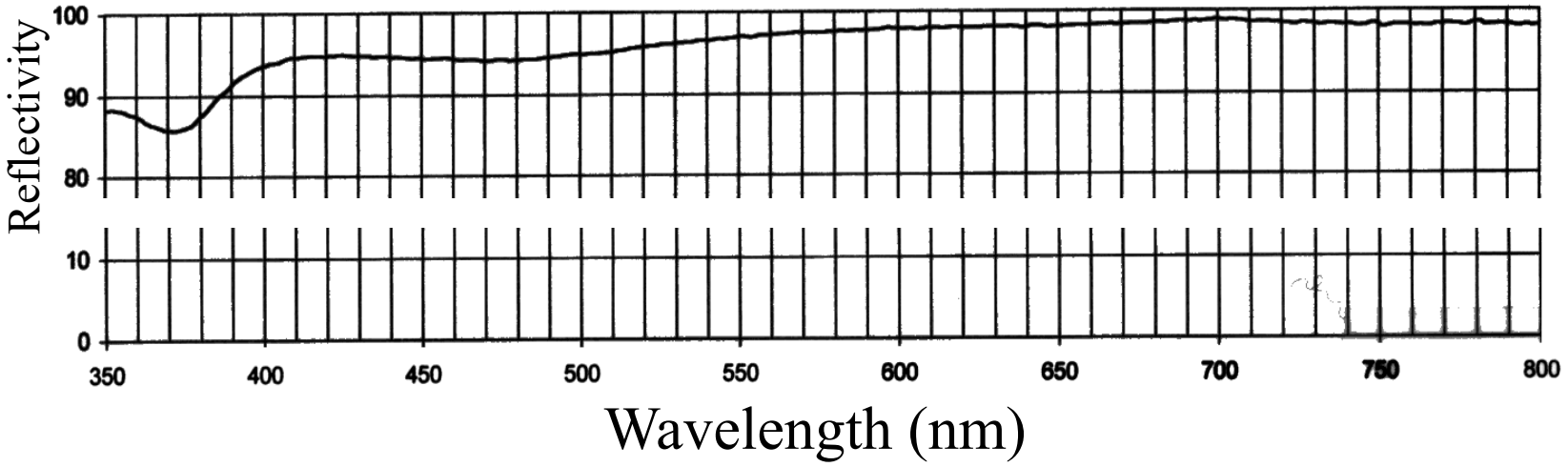
How to achieve homogeneous layer?
How to avoid covering the vacuum chamber in gold?

Coating big mirrors

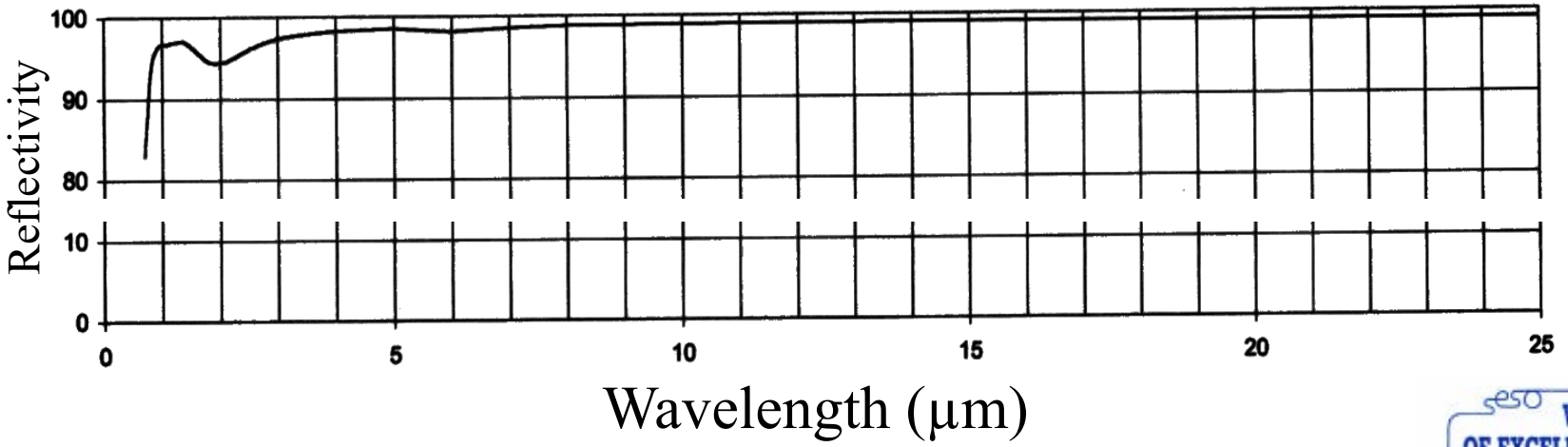
VLT 8.2m mirror coating chamber installed on Paranal

Effects of mirror coating

Enhanced Silver coating results (from 350 nm to 800 nm)

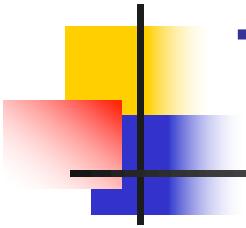


Hard Gold coating results (from 0.7 µm to 25 µm)



Telescope mechanics

Anything from this to that



Telescope mechanics

What are the main requirements on the mechanics?

1. …
2. …
3. …

Home work

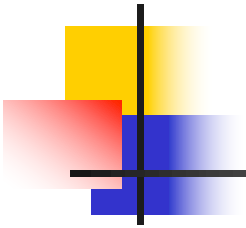
- Look at the IDL program I used to illustrate spherical and parabolic mirrors. Try to compute ray-tracing for non-axial beam for a parabola.
- Extend the calculations to an RC system

for the brave . . .

$$z = \frac{cr^2}{1+\sqrt{1-(1+k)c^2r^2}}$$

c - curvature

k - conic constant: <-1 hyperbola, -1 parabola



Next time…

… Active and Adaptive Optics