Alignment of mirrors

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Outline

- Short review about alignment in other telescopes
- Options for SST
- Conclusions

Alignment phases for prime focus

- Mounting of the optics at the telescope
- Set each segment at middle of actuators' range
- Point and Focus something (laser, star, or send someone with a lamp at 10km)
- Calibrate actuators vs spot movements (also doable at factory)
- Center each spot on the target at camera lid
- Repeat at different EL, Temp → lookup table
- Easier if you pre-align laser on each segment

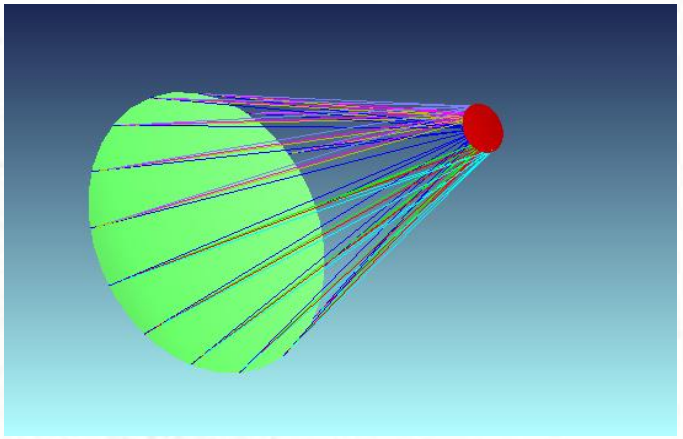
Alignment phases

- First part time consuming for big telescopes usually manually (and on many mirrors). Only done at the beginning and at every recoating;
- Second part depends on structure stiffness, temperature gradients, actuators stability when sw/off, wind strenght, ramp of acc/deceleration when fast pointing, etc
- One can compensate flexures with active correction of mirror at “any” pointing (laser spots, no star needed, maybe edge sensors).

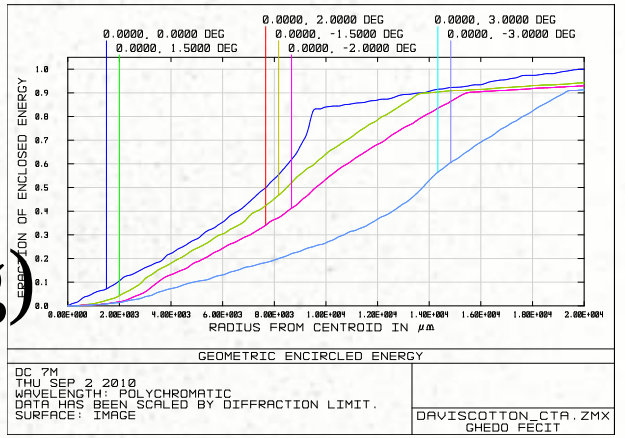
Alignment of some telescopes (with prime focus design)

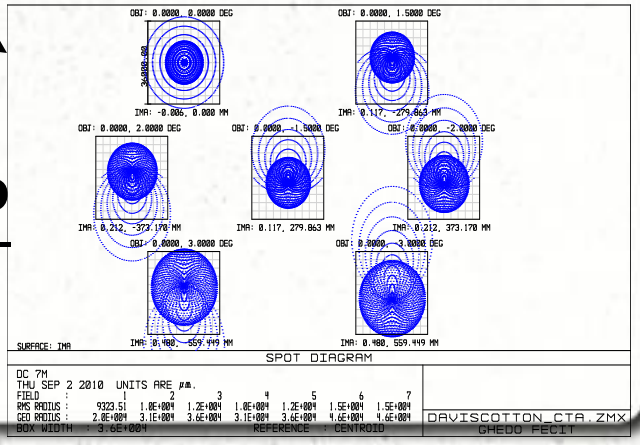
	LAMP	LASER on camera lid	STAR on camera lid	RASTER scan of star
MAGIC	@1km Manually adj	X AMC	X	
HESS			X	
CANGAROO	@6km		X	
VERITAS				CCD at FP 21x21 steps of, 0.025deg Manually adj.

SST prime focus: some numbers



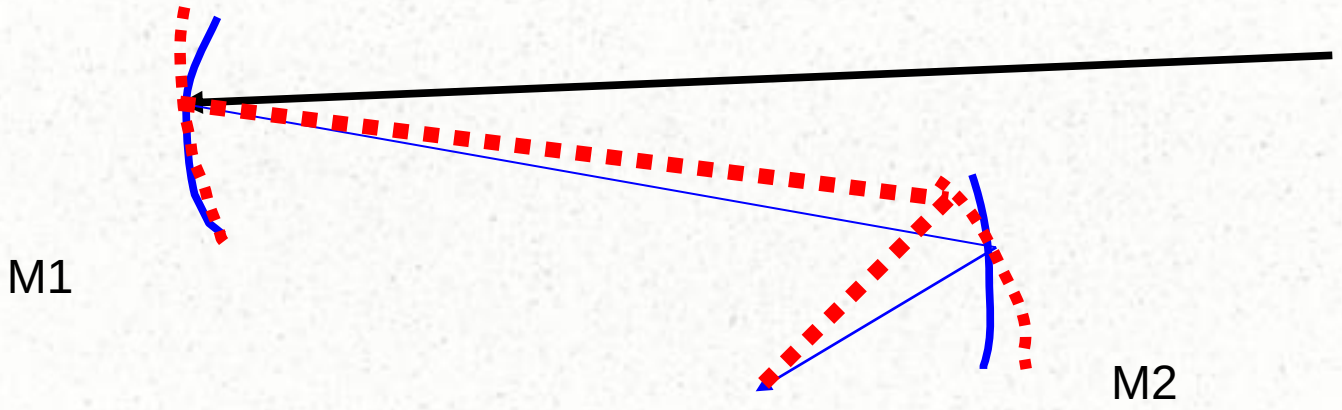
- D=7m, R=~21m
- f=10.5m, F/#=1.52
- Scale = ~20arcsec/mm
- EE_d80<36mm=pixel(~0.2deg)
- Spot_r RMS=15mm@3deg
- Act dist ~ 80cm (?)
- Act steps=10um->0.3mm @FP





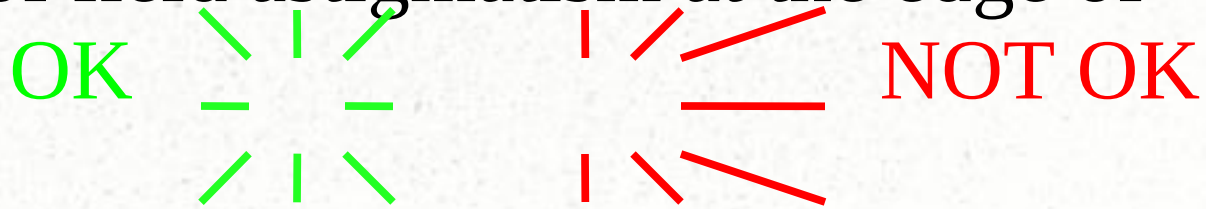
Alignment of telescopes with secondary optics

- A double tilt to adjust spot position → easy to introduce 3rd order aberrations



Alignment of telescopes with secondary optics

- Not only tip/tilt of the segments but also High Order Aberrations: Need of Wavefront Sensing? (Pyramid or SH Wavefront Sensors)
- Analysis of off-axis spots? (i.e. radial symmetry of field astigmatism at the edge of FoV)



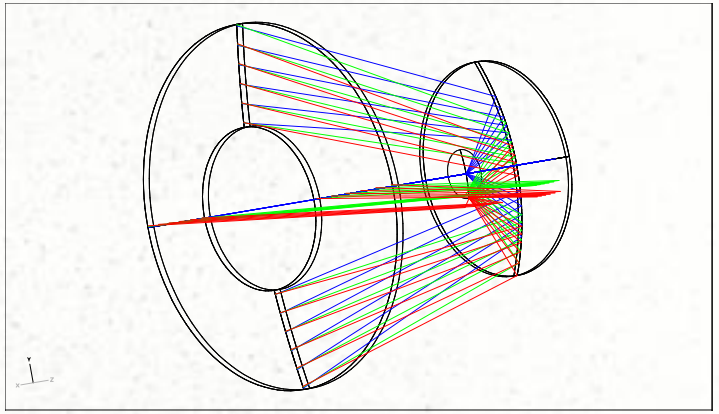
- Edge position sensors: capacitive, inductive, light encoders (see AGIS)

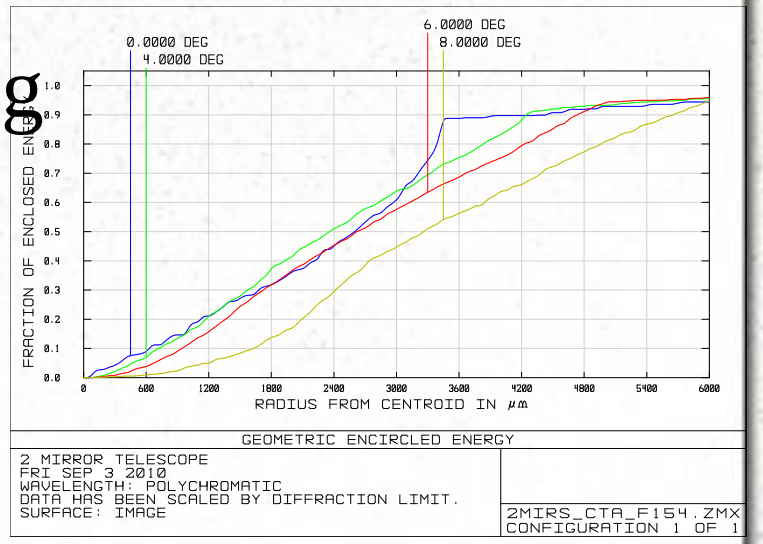
Alignment of telescopes with secondary optics...cont'd

- If 1/1 relation between segments of M1 and M2, mark center of secondary segment and align laser on M1 center to point towards the mark...then align secondary segment...
- Measure tolerances in optical design; precision in mounting and flexures of structure, find available compensators:
  - Dec/Tilt of M2 → Dec/Tilt of Focal Plane
  - Dec/Tilt of M1/M2 as a whole and effect of each segment

SST w/secondary optics: let's give some numbers...

- D_1=4m, f_1=6.15m
- α=0.65
- R_2=2.5m, M_1M_2=4m
- f=~2.5m, F/#=0.62
- Spot_r RMS ~4.2mm @8deg
- EE_d80 ~9.6mm @8deg
- Plate scale 43mm/deg





SPOT RMS (radius) @6deg [mm]

Dec Y [mm]	0	1	5	10	20	50
M2+FP	3.9	3.9	3.9	4.0	4.2	5.2
M2 only	3.9	3.9	4.0	4.3	5.3	10

Tilt X [deg]	0	0.1	0.2	0.5	1	2
M2+FP	3.9	4.0	4.1	4.7	6.4	11
M2 only	3.9	4.0	4.2	5.4	7.9	13

Dec +/-Z [mm]	0	1	5	10	20	50
M2+FP	3.9	3.9	3.9	3.9	4.0	5.4
M2 only	3.9	4.0	6.6	11	21	50

Hold the camera “with” secondary optics?

Right numbers?

- Not discussing here the optical design, just some numbers for behavior
- Adapted from: “Wide field aplanatic two-mirror telescopes for ground-based γ-ray astronomy” (2007, V. Vassiliev, S. Fegan and P. Brousseau).
- Will need to go to non sequential optics to better understand behavior of segments over the final psf

Conclusions

- Alignment for prime focus design; not an issue
- Alignment for secondary optics; tricky but easier than Keck or ELT, probably consider HO aberrations.
- ....