# Single Open Reflector for MEO/GNSS type Satellites. A Status Report

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# Motivation

•Improved performance (accuracy and signal strength) compared to currently used flat reflector arrays

## Requirements for a GNSS Satellite Retroreflector

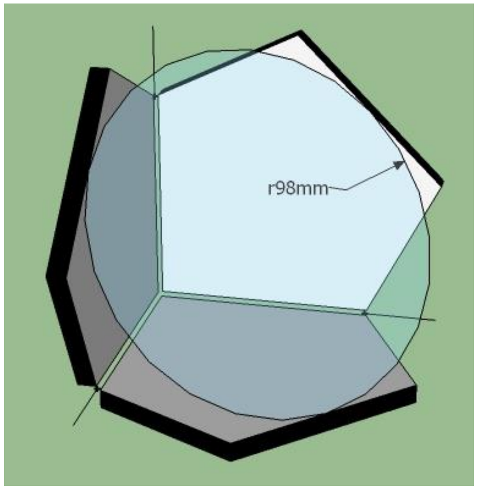
•Effective Cross Section 100 Million sqm. or more
•Low pulse spreading
•Passive, smaller accomodation area and low mass

## Special characteristics:

•Angle of incidence always small (< 12°)
•Annular far field required for satellites where the alongtrack orientation is not fixed (e.g Galileo)

**→ Concept of a Single Element Open/Hollow Reflector „SEH-R“**

# Geometry of the Reflector




Hexagonal active area

Maximum diameter of inscribed circle: 196mm

Offset angle: $\delta$ = 2" = 9.7 $\cdot 10^{-6}$ (+/- 0.2")

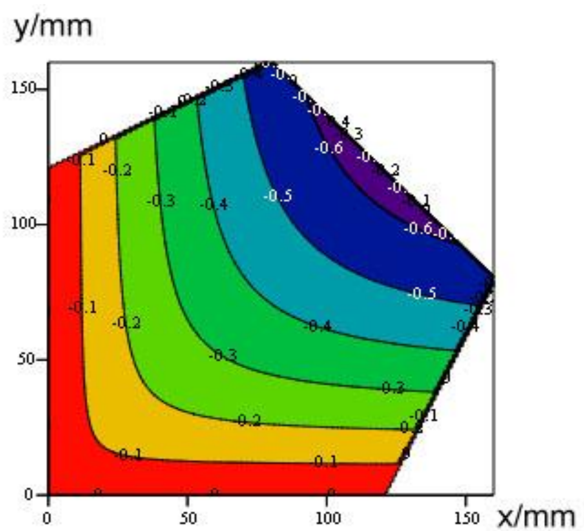
Conical concave surface of the mirrors according to:

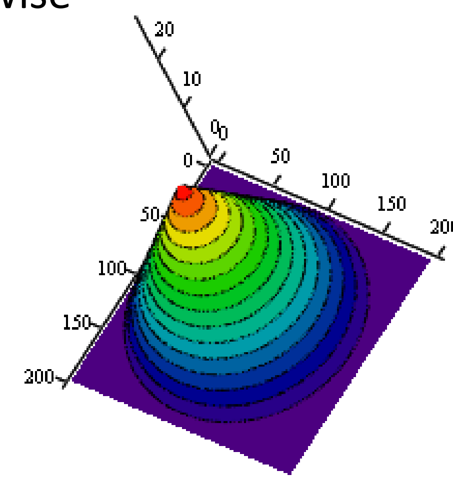
$$z(x,y) = \frac{\delta}{2}\cdot\left(\sqrt{x^2 + y^2} - x - y\right)$$

Z(0,y) = Z(x,0) = 0, Z < 0 otherwise

$Z_{min}$ = -340 nm = -0.63$\cdot\lambda$ ,

$\lambda$ = 532 nm

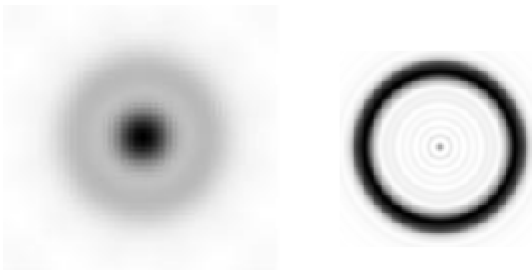


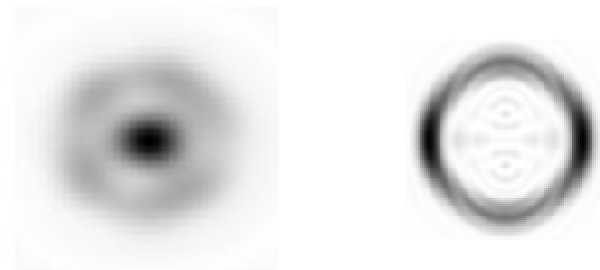
# Effective Radar Cross Section:

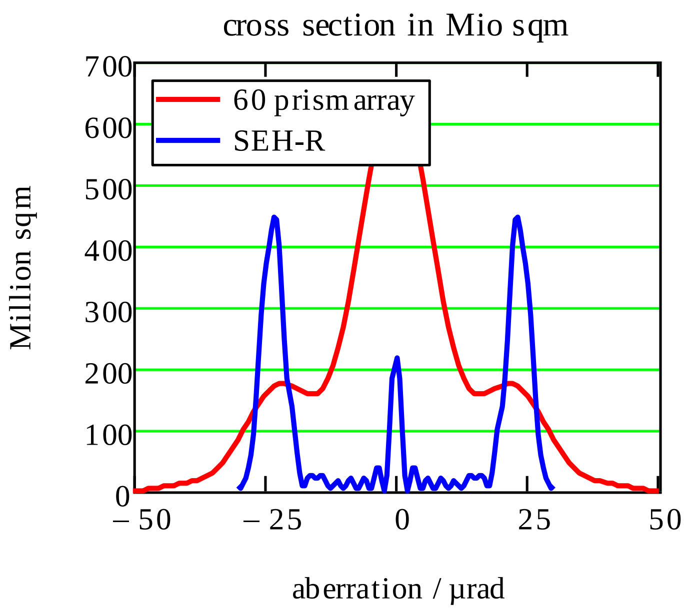
## Prism Array (60 prisms @ 33 mm diam.) versus SEH-R

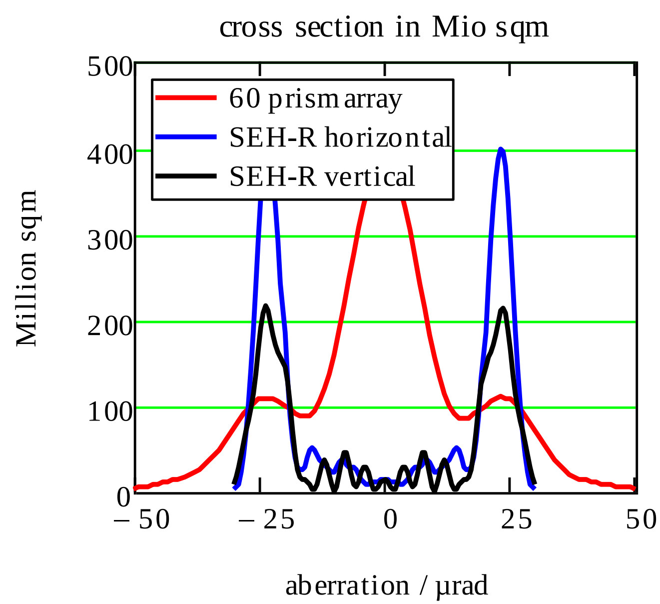
### Incidence: 0°



### Incidence: 10°

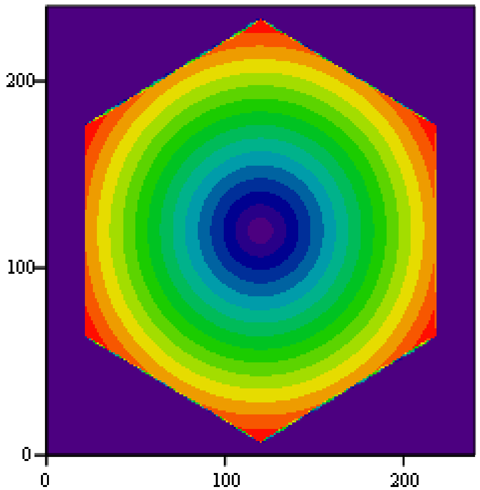




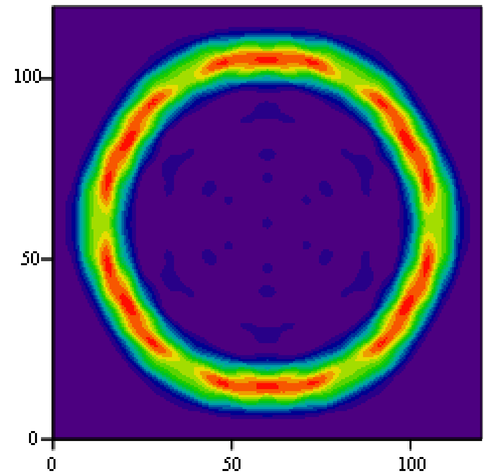



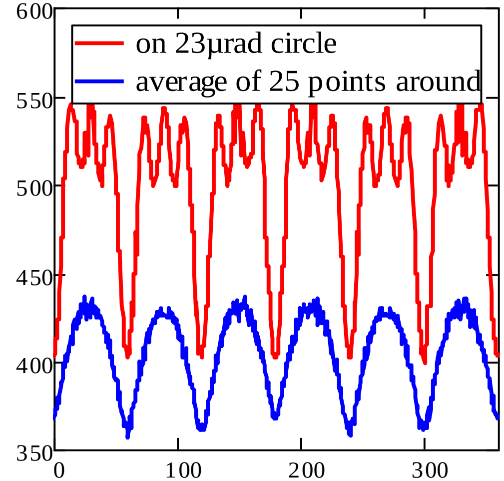
# Wave Front and Far Field at Normal Incidence and at 10° Incidence

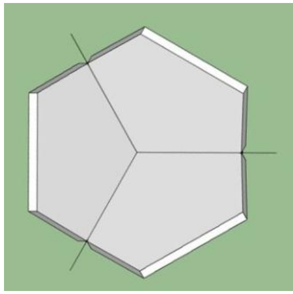
Wave Front



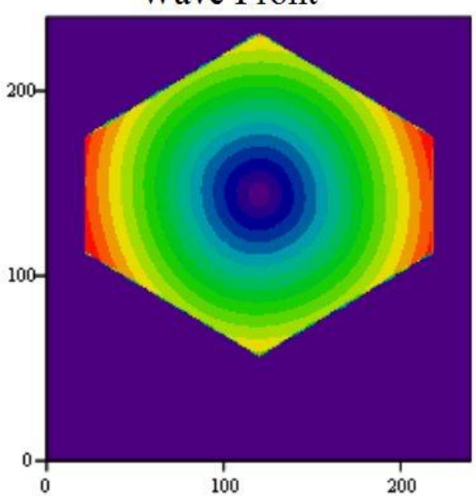

Far Field



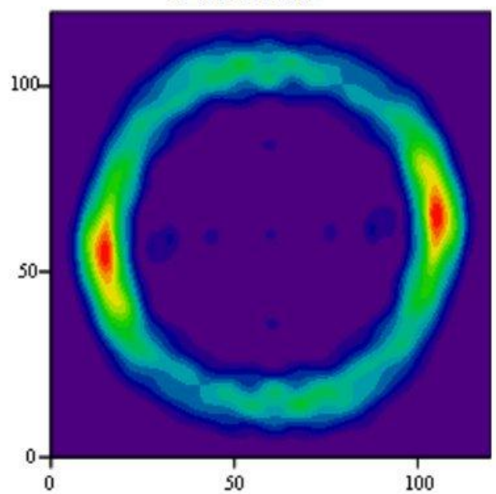



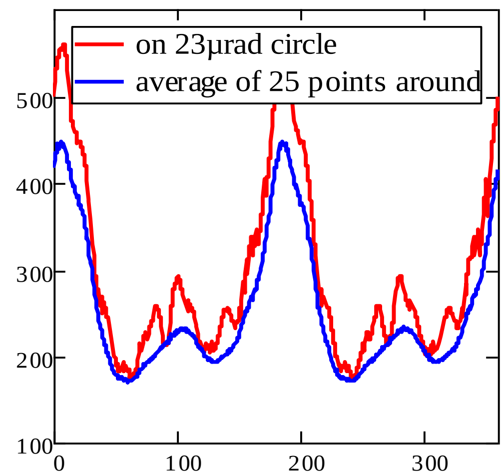



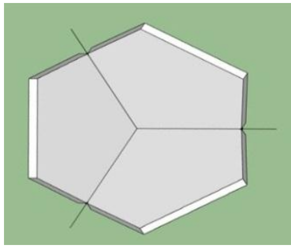
Wave Front




Far Field

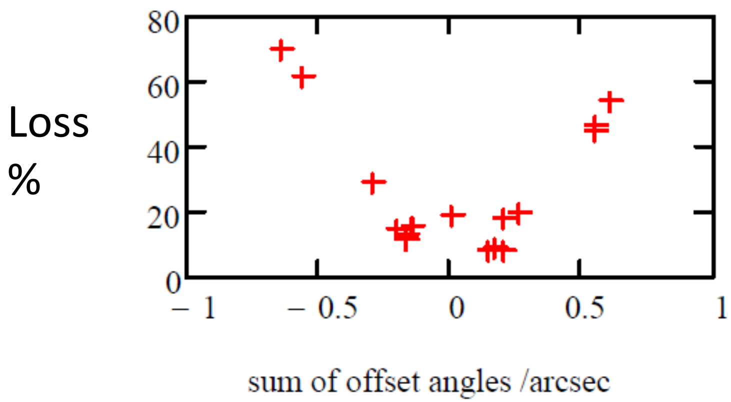


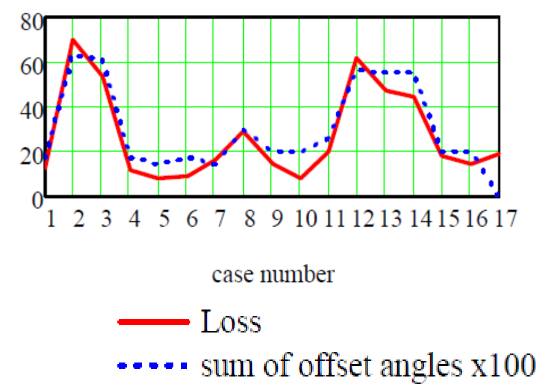



# Analysis of energy losses in the Annular far field versus the dihedral angle errors

| | F1 | F2 | F3 | F4 | F5 | F6 | F7 | F8 | F9 | F10 | F11 | F12 | F13 | F14 | F15 | F16 | F17 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | α2+ | α2- | α2+ | α2- | β2+ | β2+ | β2- | β2- | α2- | α2+ | β2- | β2- | β2+ | β2+ | α2+ | α2- | |
| | α3+ | α3+ | α3- | α3- | β3+ | β3- | β3+ | β3- | β3- | β3- | α3- | α3+ | α3- | α3+ | β3+ | β3+ | |
| $\Delta\delta_{12}$ | 0.02 | -0.02 | -0.01 | 0.02 | .15 | .15 | -.15 | -.3 | 0 | .0 | -.14 | -.16 | .15 | .15 | 0 | 0 | 0.4 |
| $\Delta\delta_{13}$ | -0.22 | -0.21 | 0.2 | -0.2 | -0.2 | -.2 | -0.2 | -.02 | -.2 | 0.0 | 0 | -0.2 | 0.2 | 0 | -.2 | -.2 | -0.2 |
| $\Delta\delta_{23}$ | 0.03 | -0.41 | 0.42 | 0.01 | 0.2 | .22 | 0.2 | +.02 | 0 | 0.2 | .4 | -0.2 | 0.2 | .4 | .4 | 0 | -0.2 |
| Loss % | 13 | 70 | 54 | 12 | 8 | 9 | 16 | 29 | 15 | 8 | 20 | 62 | 47 | 45 | 18 | 15 | 19 |
| Mean Loss % | 27.1 | | | | | | | | | | | | | | | | |




Conclusion: The sum of angular errors should be small

# Characteristics and Challenges

- „nominal“ performance is superior compared to flat reflector arrays but…
- it is very sensitive to:
  - angular accuracy of mirrors relative to each other
  - any surface deformation ( 1g/0g effects, thermal effects, S/C interface effects etc. )
- Development of a robust mechanical/thermal design ( using existing materials and processes )
  - Minimizing temperature excursions over orbit
  - „Trimming“ average temperature to above 0° C
- Performance check at „ambient“ temperatures
- Development of an analysis package for end to end performance simulation
- Development of the mirror alignment technology

# Concept and General Layout

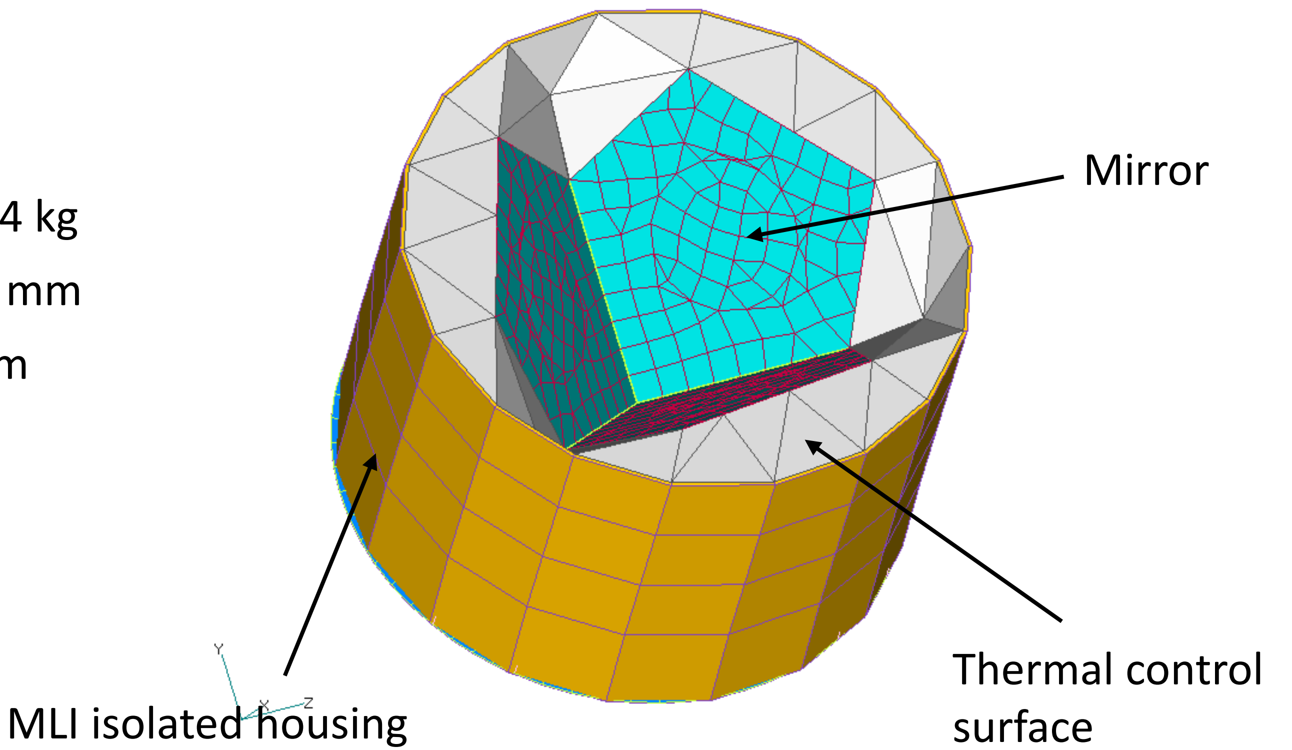
- From various trade offs a SSiC mirror assembly is the most promising solution
- Enhanced silver surface coating
- Housing and thermal enclosure targets for trimming to minimum gradients

Mass: approx. 4 kg

Diameter: 300 mm

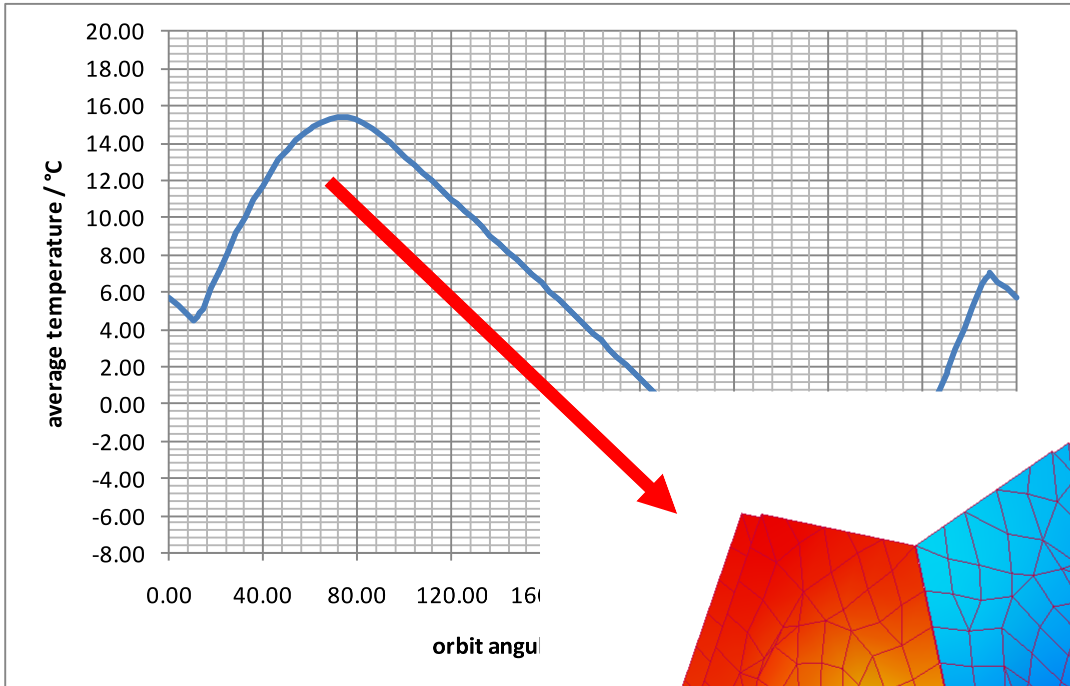
Height: 190 mm

SC-I/F: 4 x M5

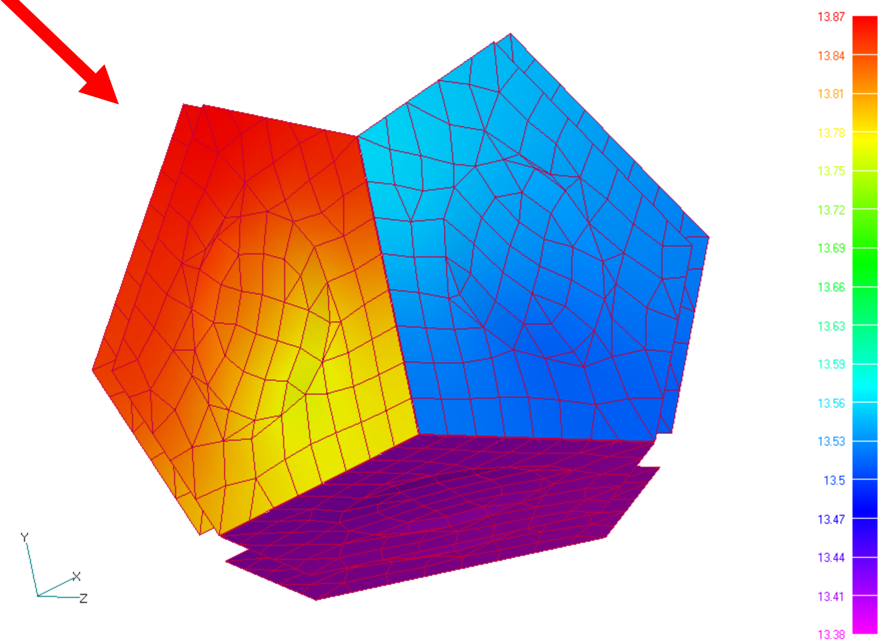


# Thermal Design

From the transient temperature of the mirror…..

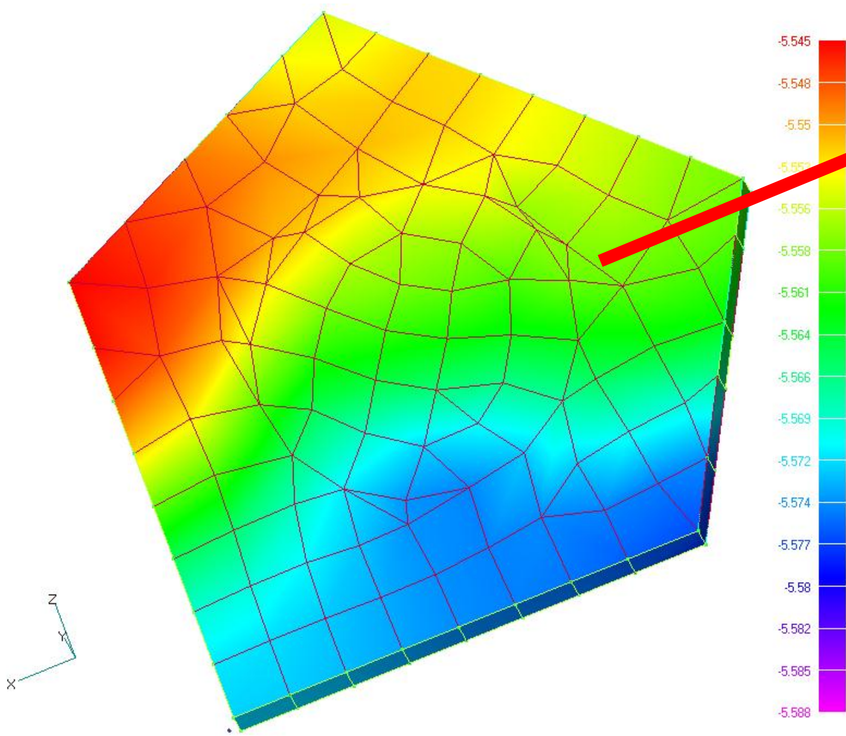


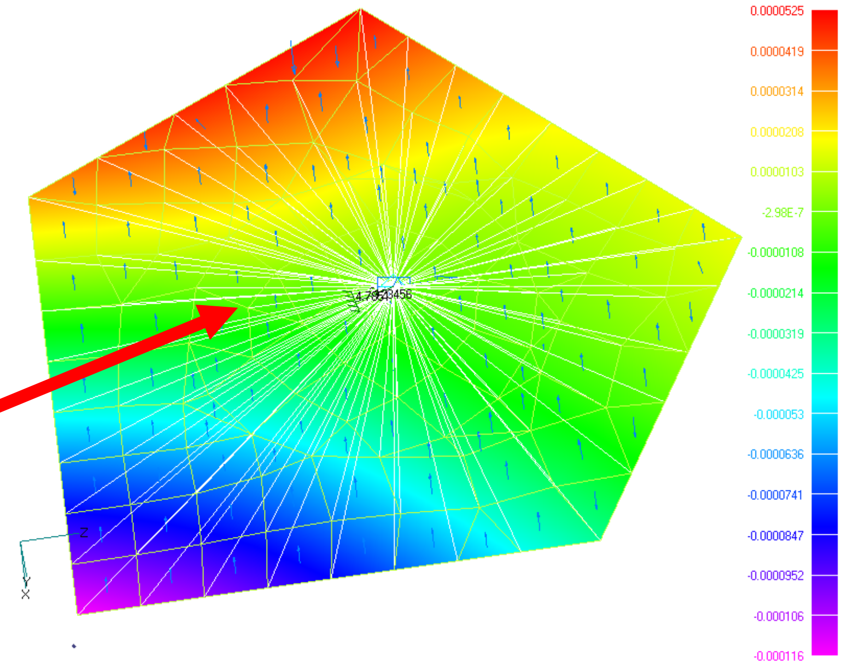

….to the spatial distribution at each time step.



# Mechanical Stability

The temperature distribution is mapped as input for a mechanical FEM model.




The thermal deformations normal to the mirror surfaces are computed and transferred to the optical performance analysis.

# Alignment Technology

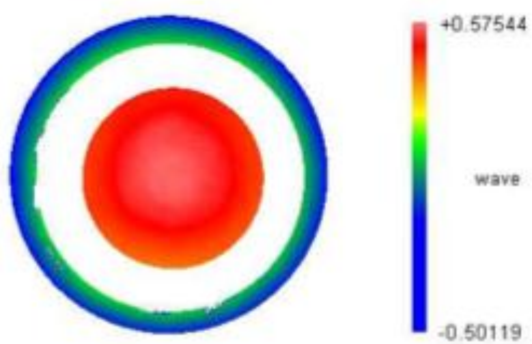
Measuring the tilt between two flat surfaces with interferometer technology

Measurement inaccuarcy: s = ± 0,05 arcsec

Adjustment sensibility: < 0,15 arcsec

Fixing: < 0,2 arcsec

After fixing: < 0,5 arcsec




Test example (figure): 0,14 arcsec

# Conclusion:

What we have:

•Matching the far field to the velocity aberration, optical specification
•Thermal modelling and material selection (substrate and coatings)
•Mechanical design
•Assembling technology:  0.2 arcsec accuracy demonstrated

What has to be done:

•Bread board model to investigate the angular accuracy and long term stability
•Prototype manufacturing and test