SEGMENTED DEFORMABLE MIRROR FOR ADAPTIVE OPTICS

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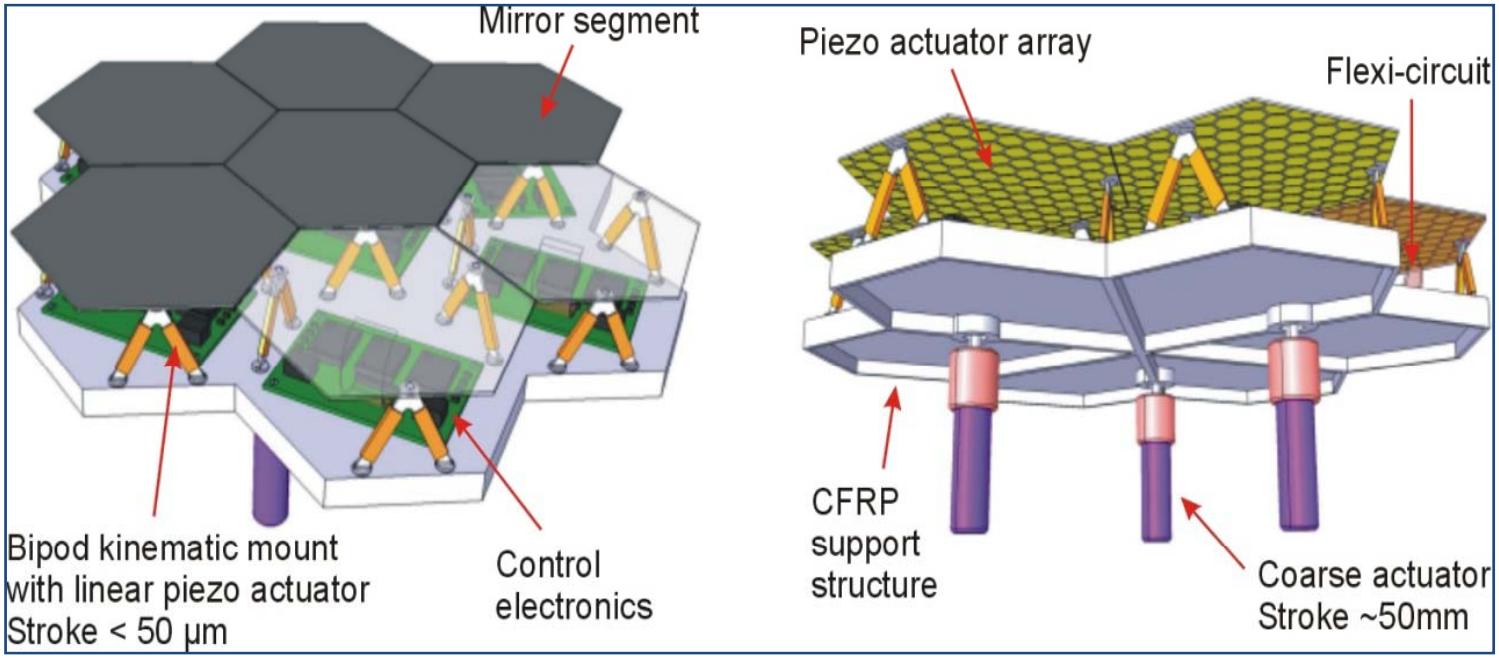
Motivation for using segmented DM mirrors based on bimorph Si wafers:



+ Si wafers are **inexpensive** and have good surface quality (up to 300 mm)
+ The segmented architecture is **scalable to infinity**
+ Manufacturing costs increase moderately with the size of the mirror
+ **Natural frequency** is that of one segment
+ Lightweight (future space applications)
+ Good morphing capability (large number of d.o.f.)
- **Metrology** more complicated (co-phasing)

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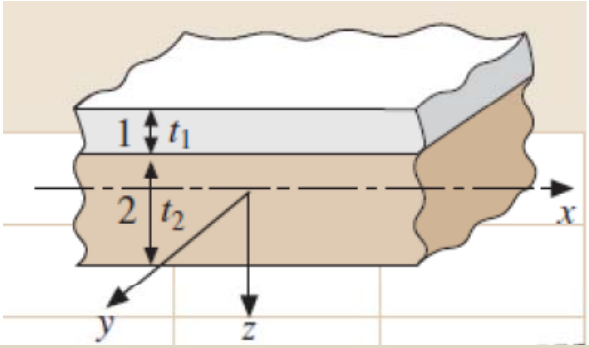
Figures of merit

1. Natural frequency: $\omega \sim (\frac{E}{\varrho})^{1/2}$ (specific stiffness)
2. Thermal differential expansion PZT-substrate: $\frac{d_{31} E_{max}}{\Delta\alpha T}$
3. Control authority: $\kappa \sim \frac{M_1}{M_2} \sim \frac{E_{PZT}}{E_{Sub}}$

Natural frequency of a circular plate of radius *a*

$$\omega_{ns} = \frac{\lambda_{ns}^2}{a^2}\sqrt{\frac{D}{m}}$$

	Si	SiC
1. Specific stiffness:) $\frac{E}{\varrho}$ (Gpa/g/cm³)	56	130
2. CTE mismatch: $\frac{d_{31} E_{max}}{\Delta\alpha}$ (°C)	120°	120°
3. Piezoactuation: $\frac{E_{PZT}}{E_{Sub}}$	0.48	0.15



Stoney formula (thin film)

Thermally induced curvature:

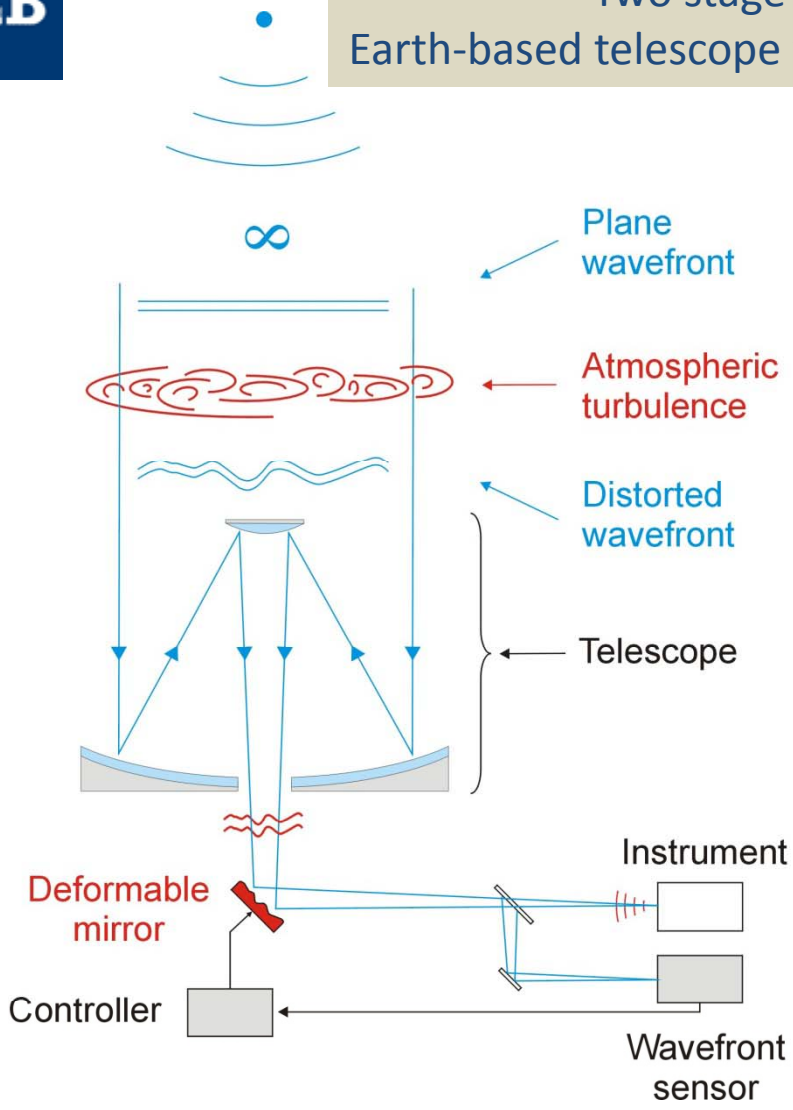
$$\kappa = \frac{6\,\Delta\alpha T}{t_2}\left(\frac{t_1}{t_2}\frac{M_1}{M_2}\right)$$

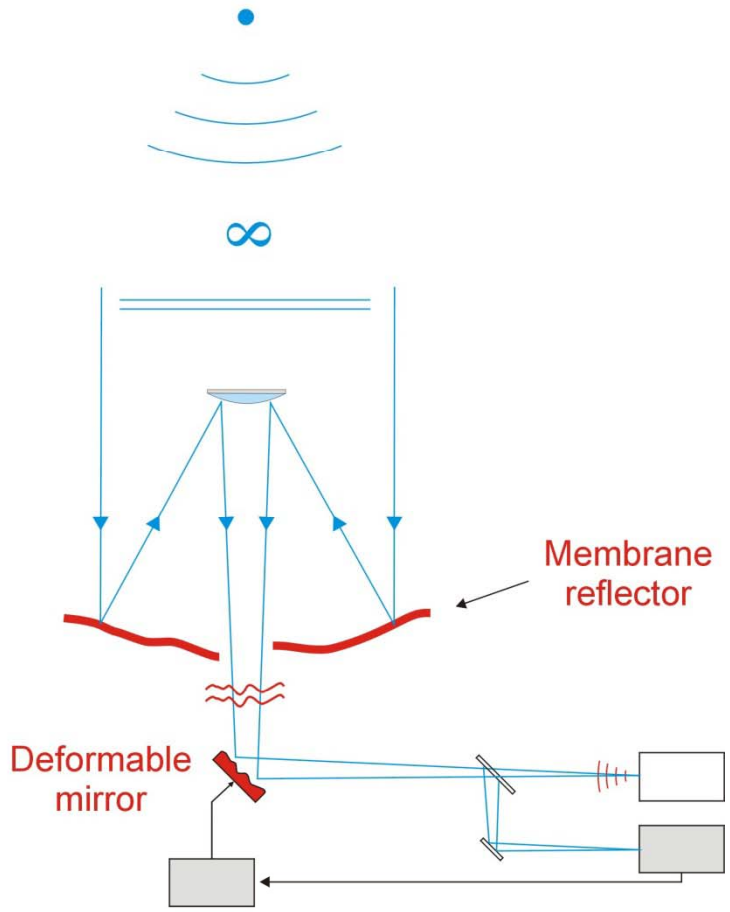
Piezoelectric actuation:

$$\kappa = \frac{6\,d_{31} E_{max}}{t_2}\left(\frac{t_1}{t_2}\frac{M_1}{M_2}\right)$$

$$M_i = \frac{E_i}{1-\nu_i}$$ (bending stiffness)

Two stage wavefront control:
Earth-based telescope vs. **Membrane space telescope**

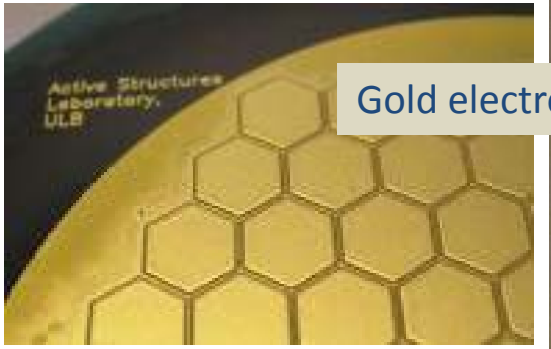




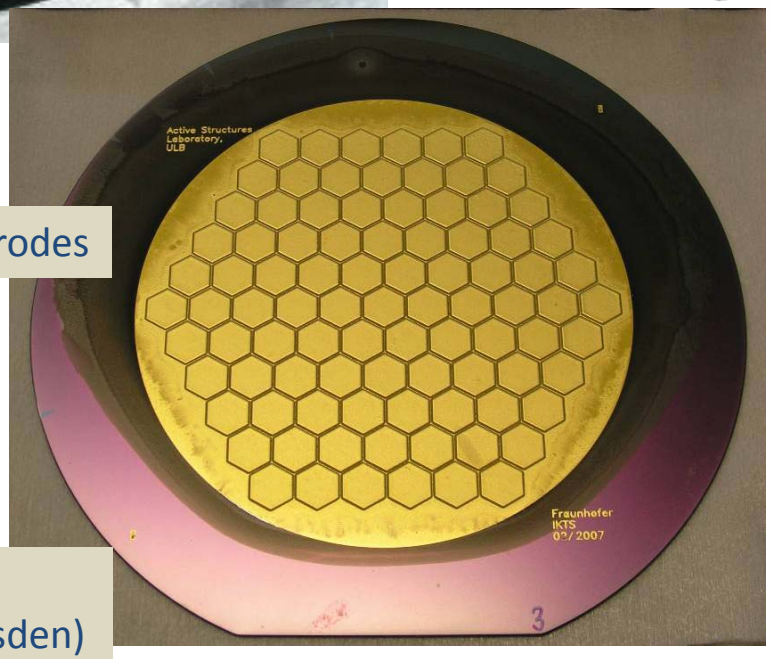
Sources of surface figure error:
- Manufacturing errors
- Thermal gradient
- Gravity gradient

Bimorph Adaptive Optics Silicon Mirror

PZT
Thick film
deposition
(80 microns)



Gold electrodes



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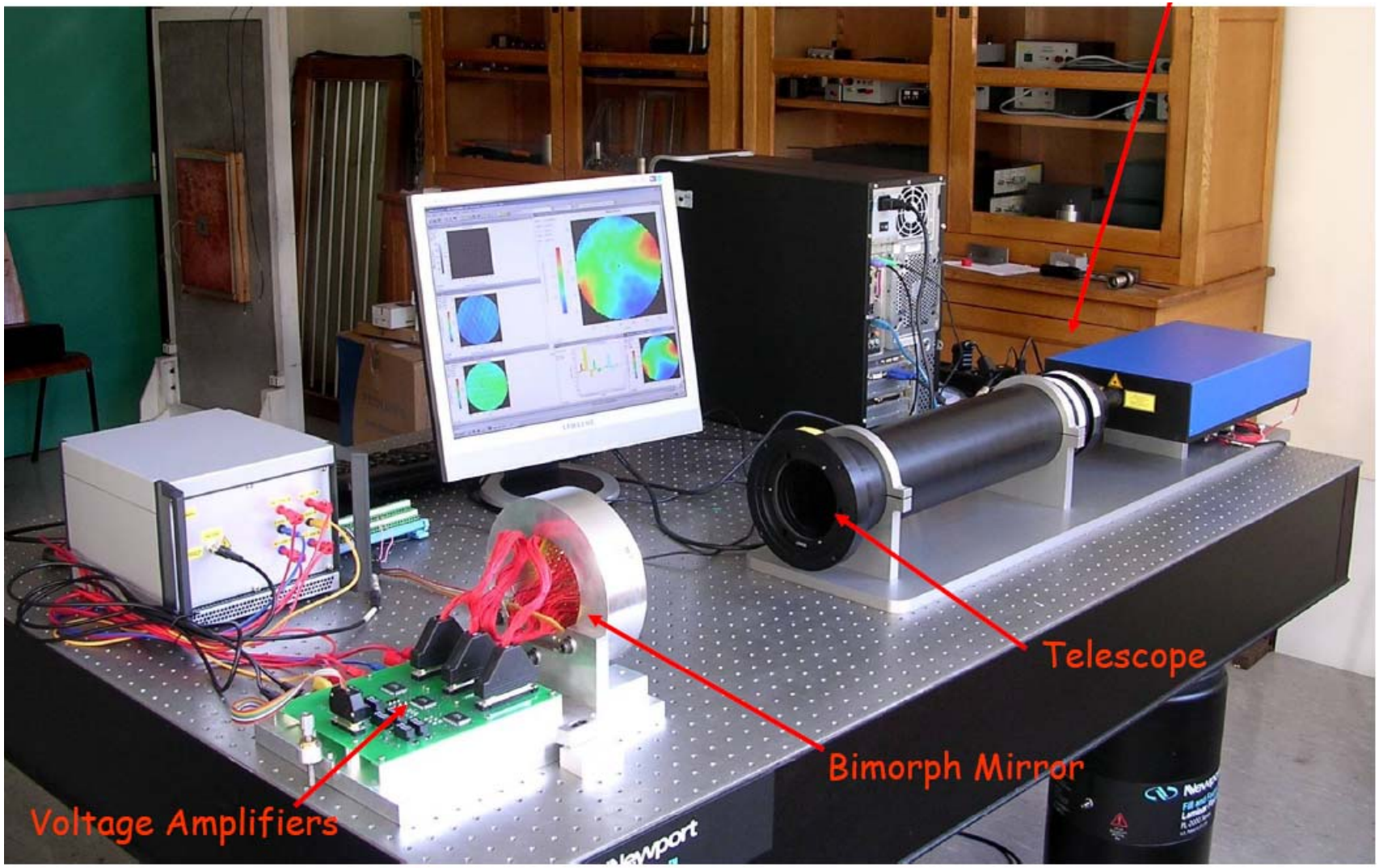
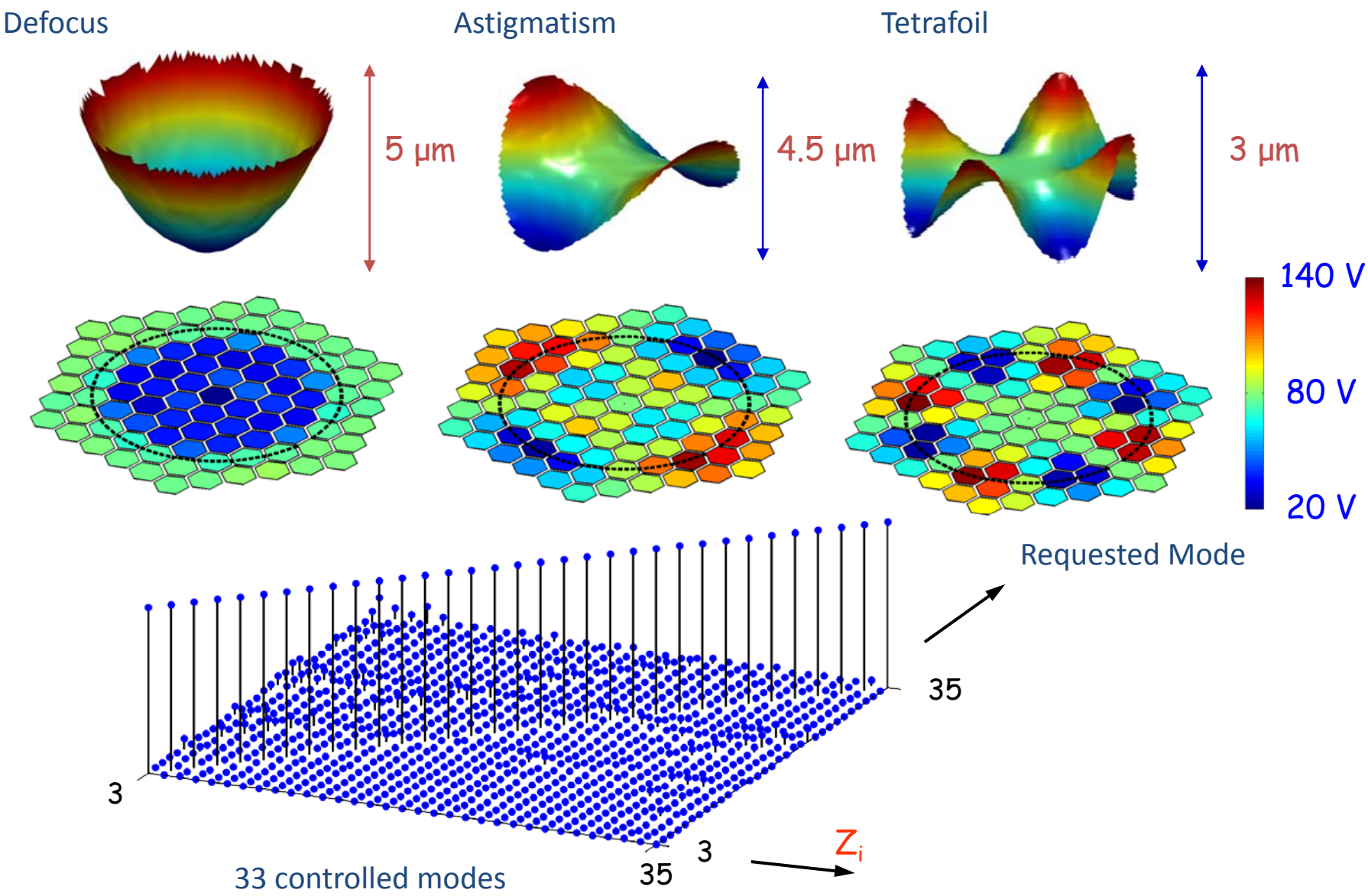
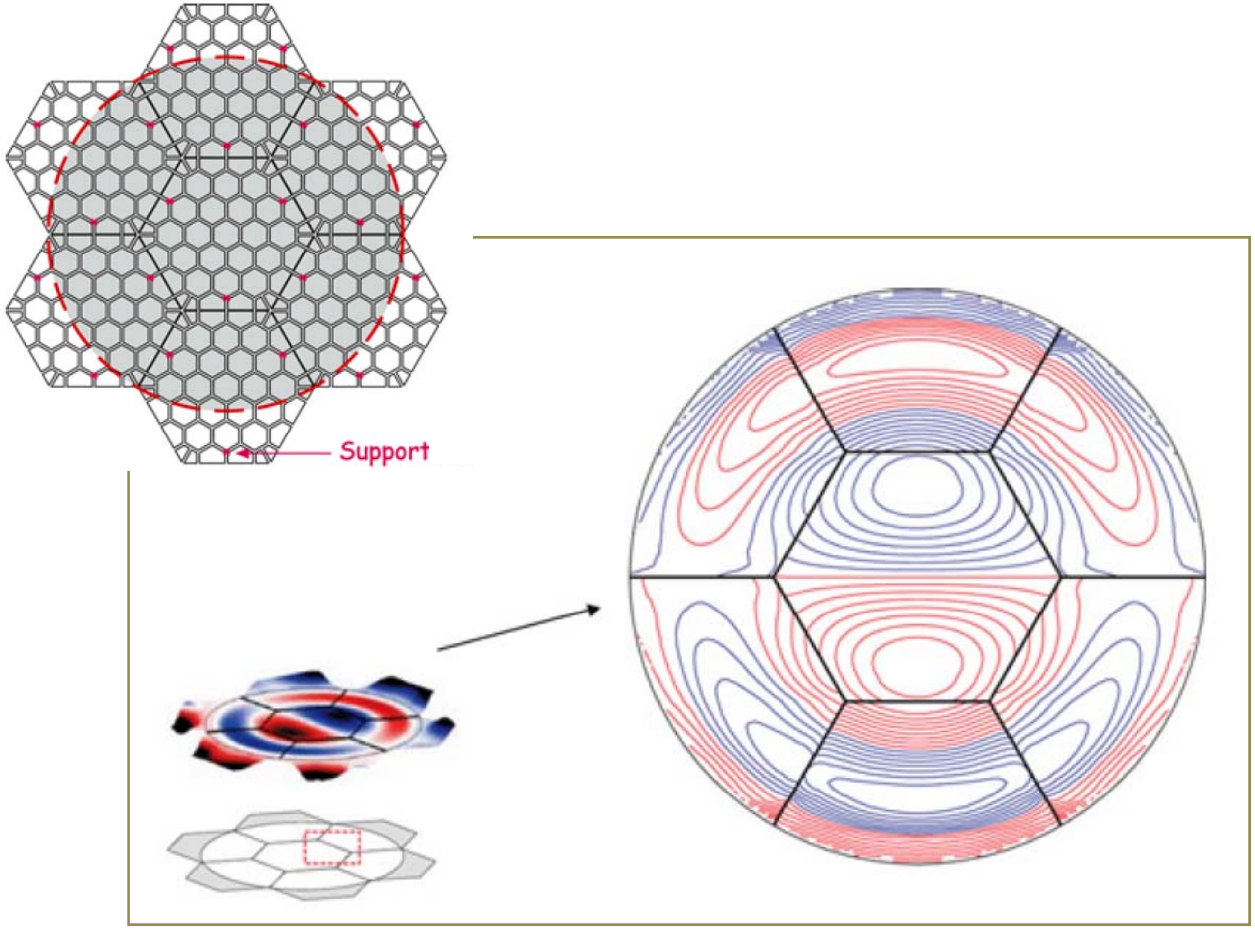
Source: G. Rodrigues
Manufacturing: Fraunhofer IKTS (Dresden)


Shack-Hartmann
101 x 101 micro-lenses
Telescope
Bimorph Mirror
Voltage Amplifiers
Newport

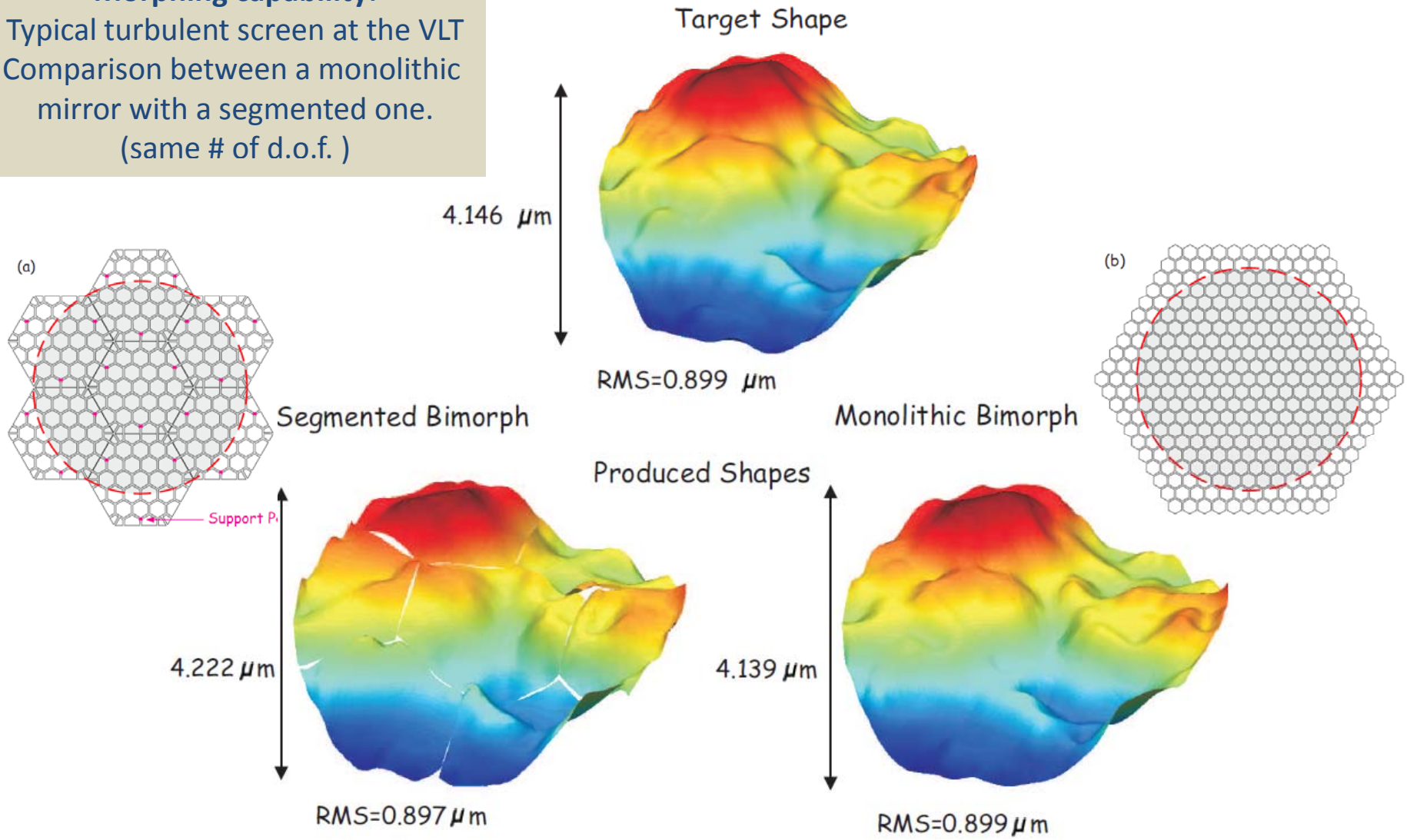
Closed-loop experiment (relative measurements)



Segmented DM mirrors morphing capability: numerical simulation (5th order coma)

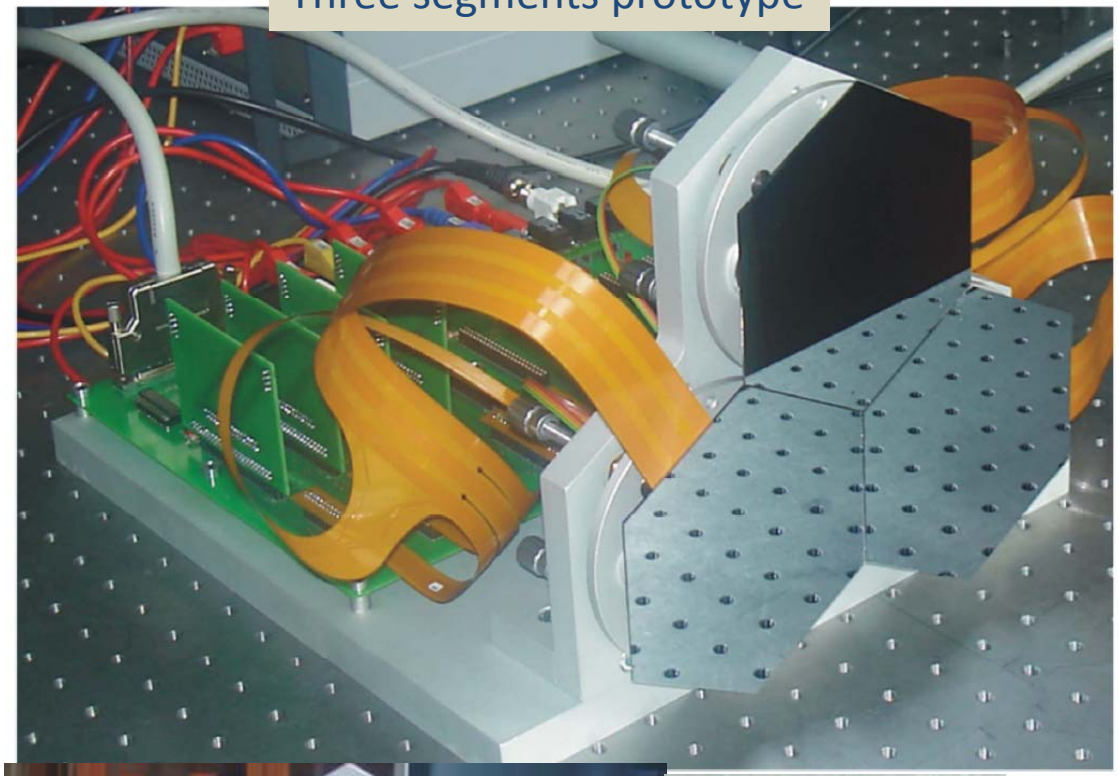


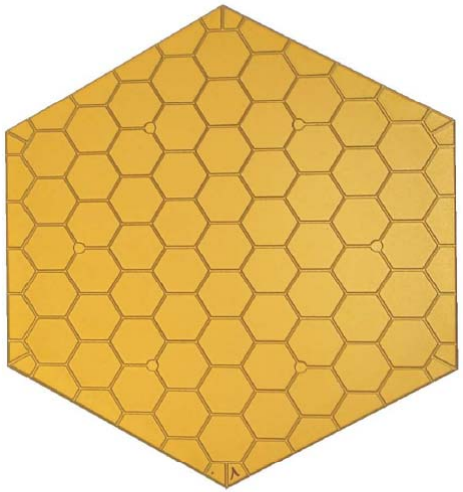
Morphing capability:
Typical turbulent screen at the VLT
Comparison between a monolithic mirror with a segmented one.
(same # of d.o.f.)

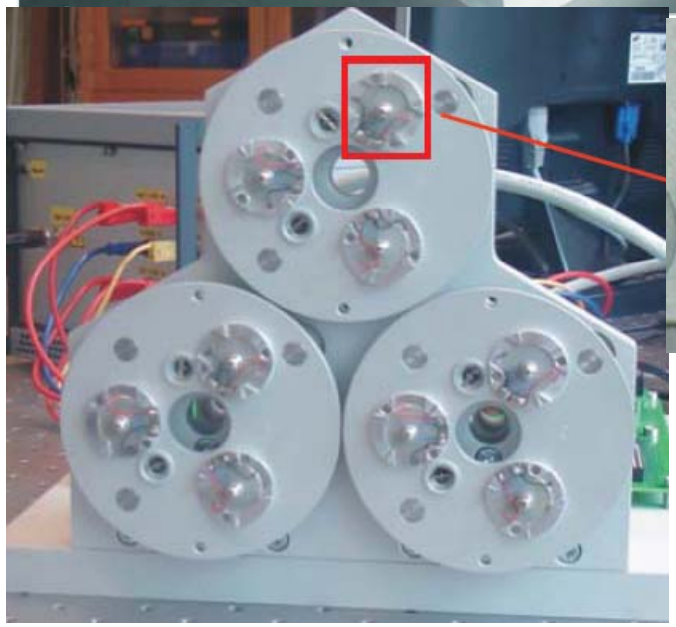


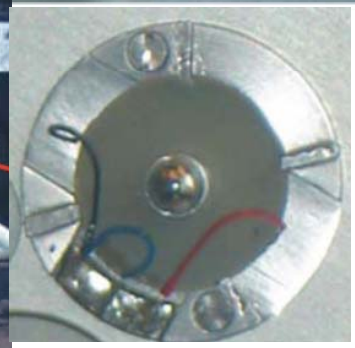
Three segments prototype

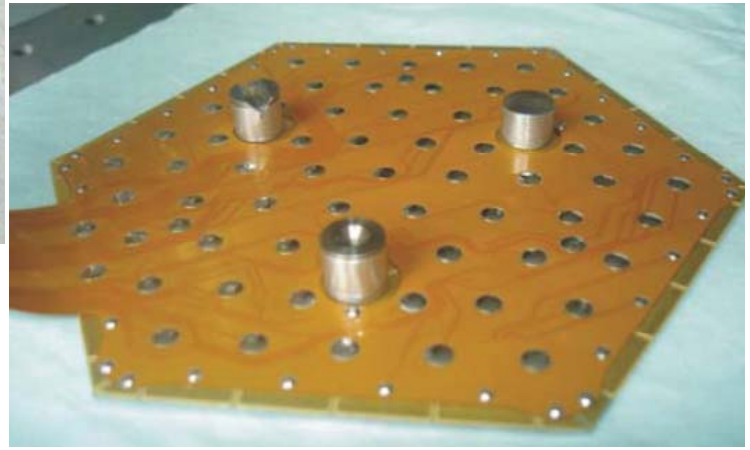
(PhD G. Rodrigues, Feb. 2010)











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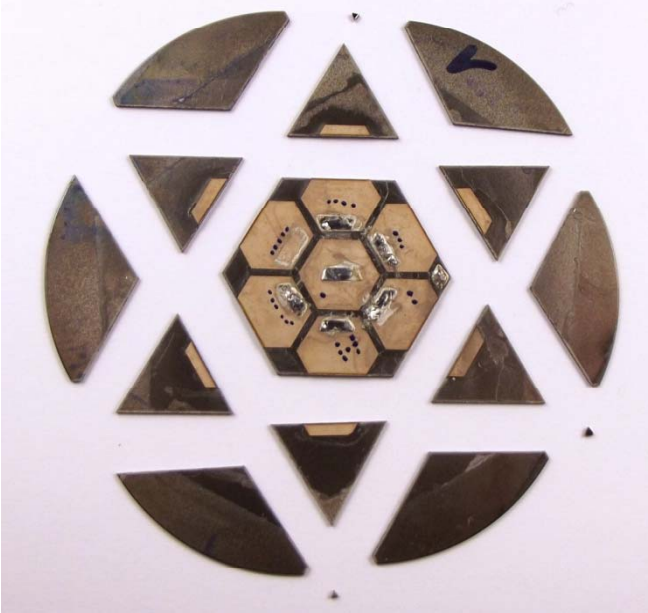
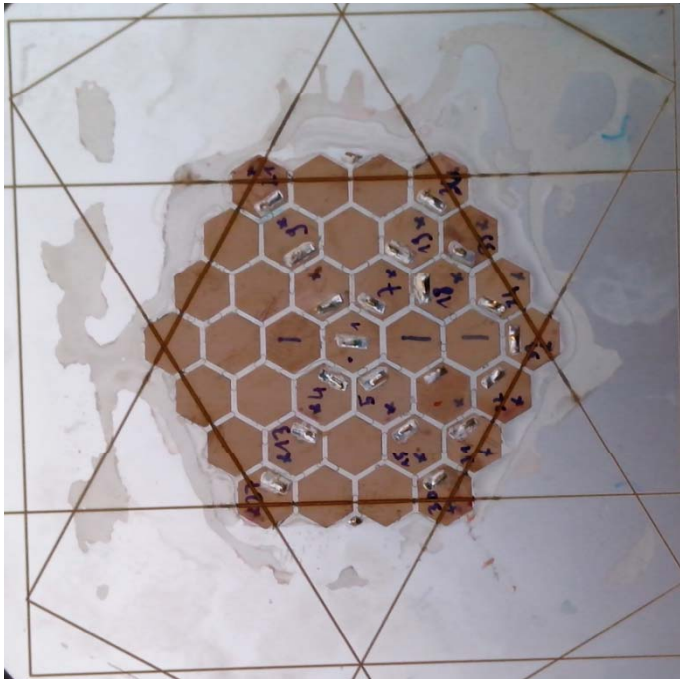
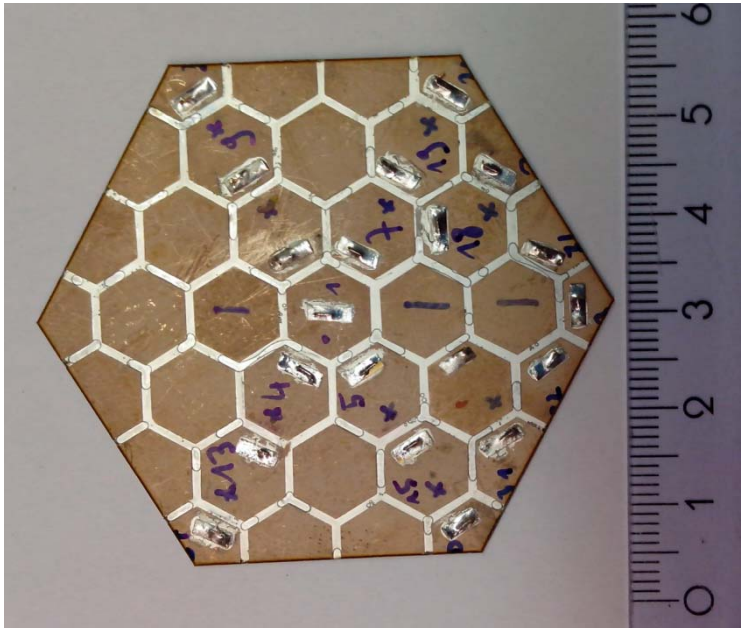
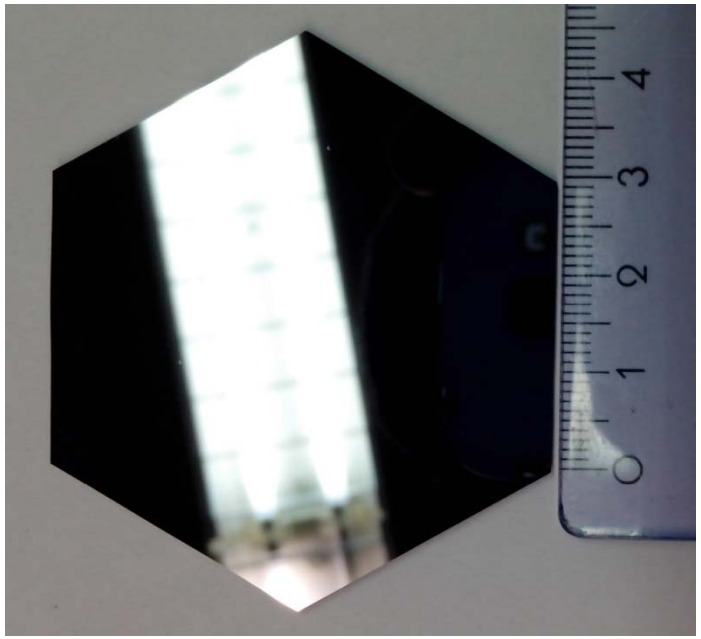
Current developments:
Gluing PZT patches and Laser cutting









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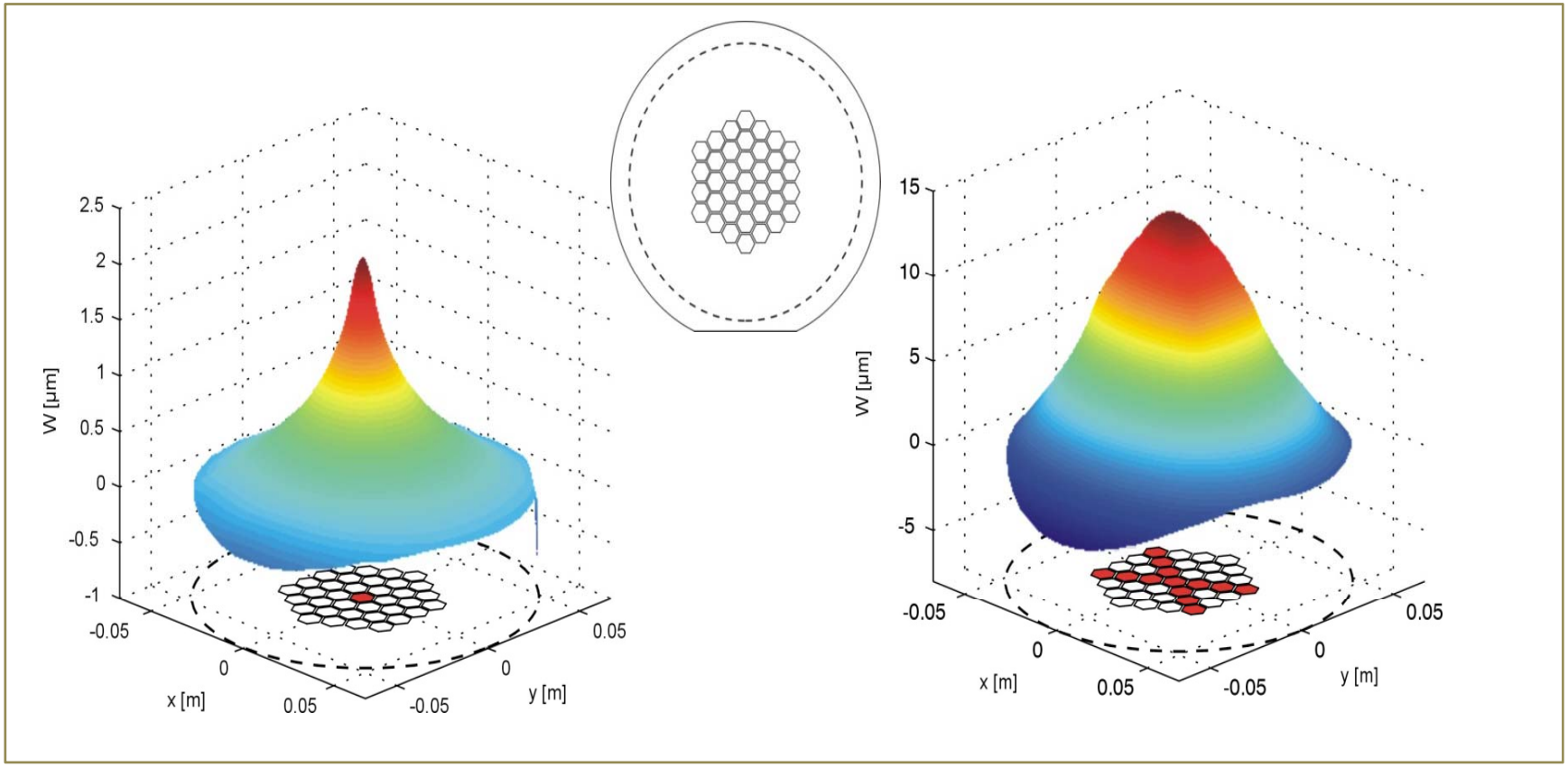

Experimental Influence functions of the control electrodes are in good agreement with numerical predictions.

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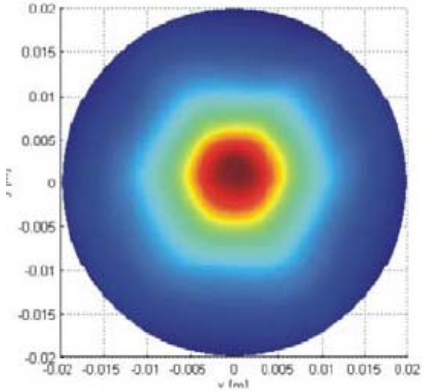
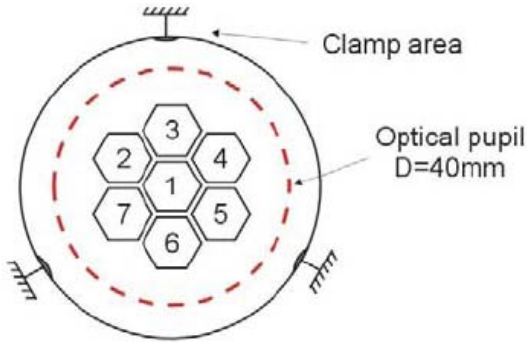
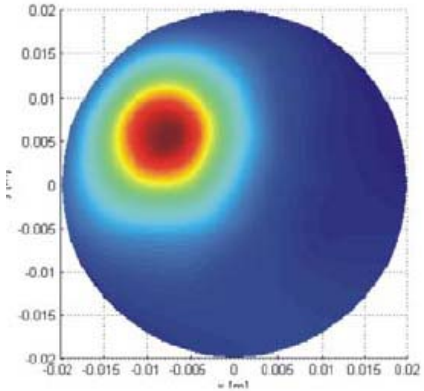
Influence functions of individual patches (experiment, pupil = 40 mm, V=60 v)



IF1

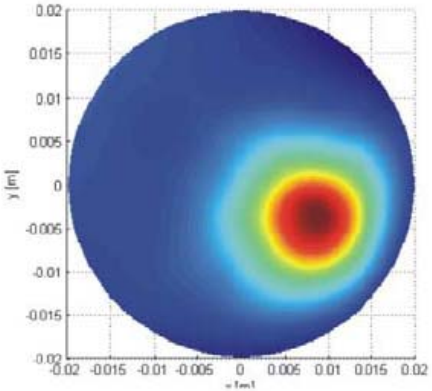
1.57µm PV
0.32µm RMS





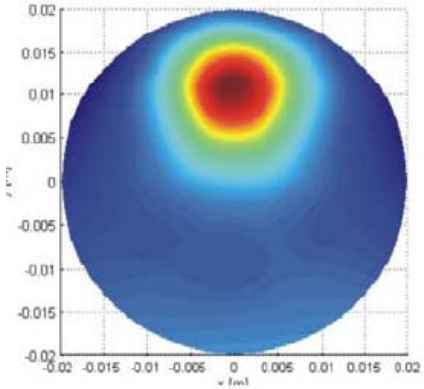
IF2

1.75µm PV
0.37µm RMS



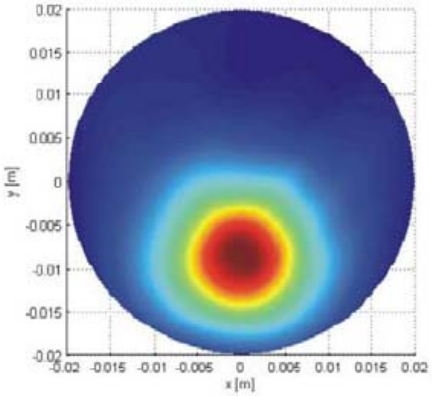
IF5

1.68µm PV
0.33µm RMS



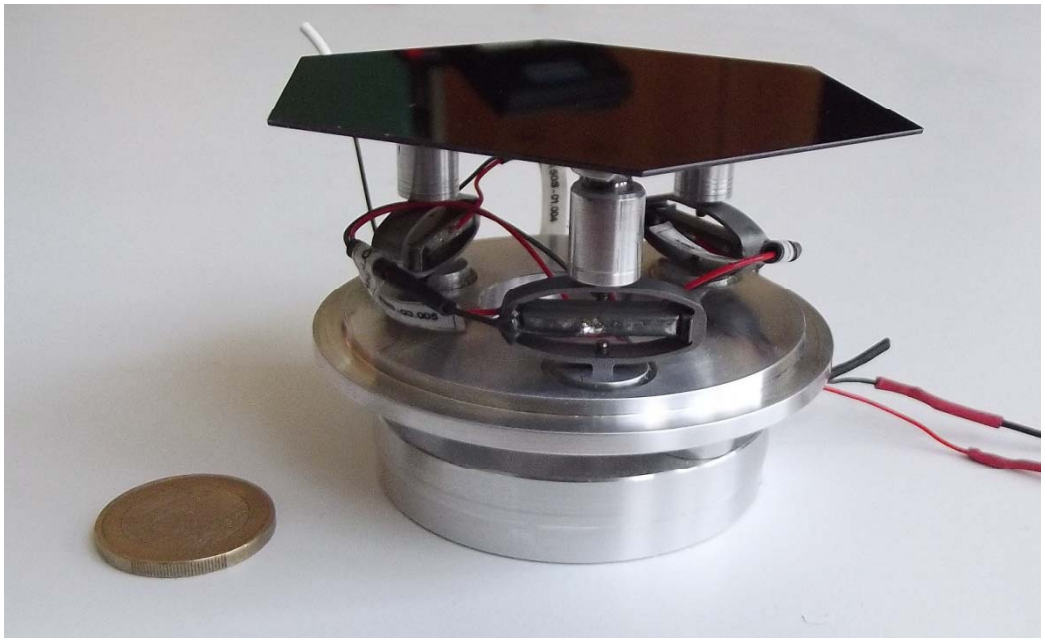
IF3

1.60µm PV
0.30µm RMS

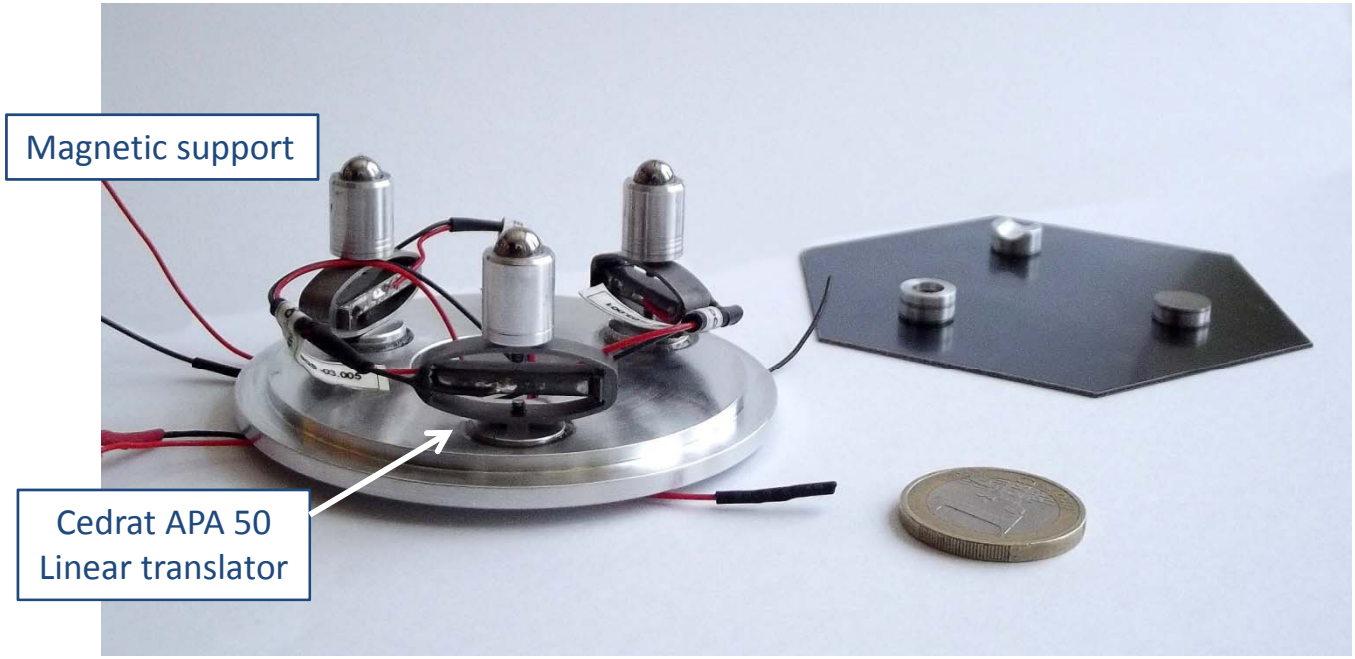


IF6

1.65µm PV
0.37µm RMS



Isostatic support



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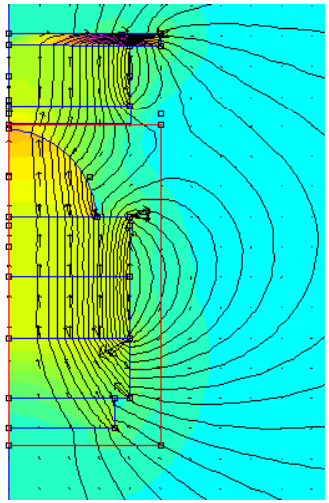
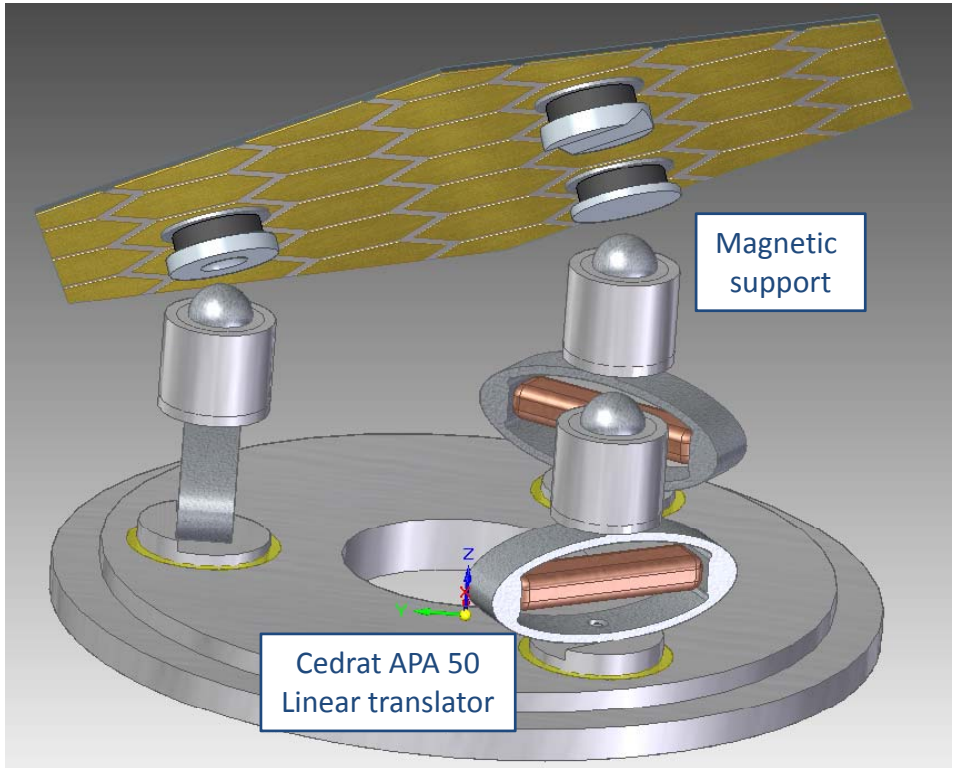
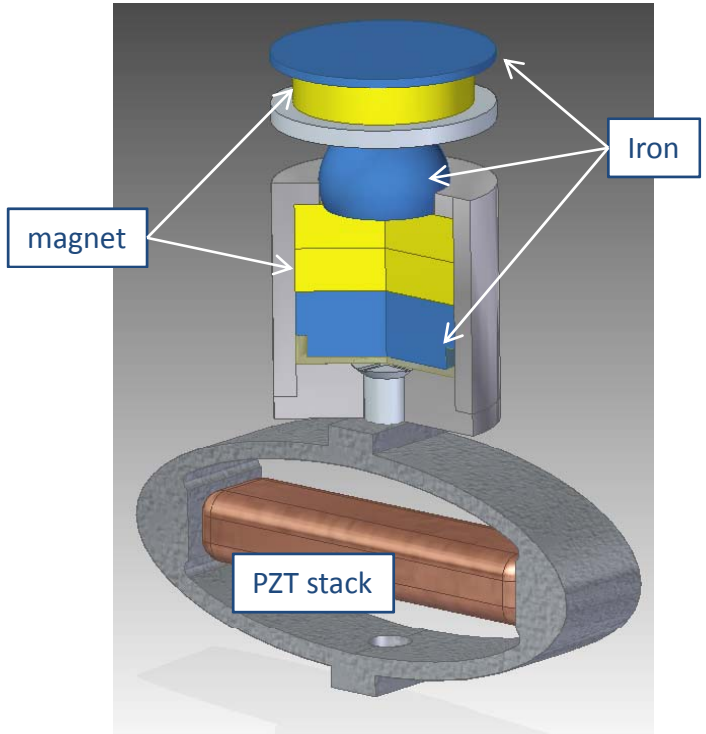
Magnetic flux
Density *B*
F = 5 *N*



Isostatic support (detail)





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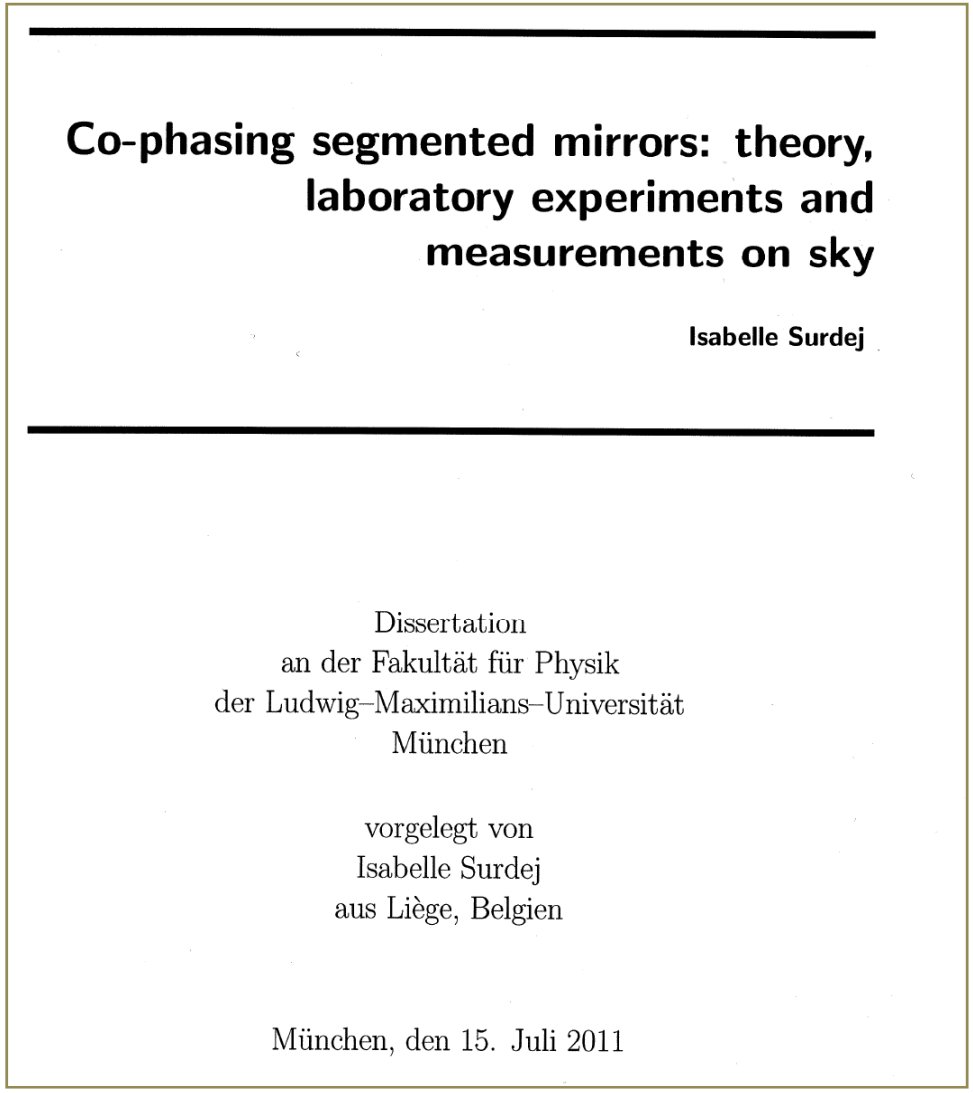
Metrology



Co-phasing segmented mirrors: theory, laboratory experiments and measurements on sky

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