Preliminary design status of the M4AU based on piezo-stack technology

B CREPY (b), S CHAILLOT (g), JM CONAN (d), R COUSTY (b), C DELREZ (c), M DIMMLER (a), JL DOURNAUX (f), S DE ZOTTI (e), E GABRIEL (c), R GASMI (f), R GRASSER (b), N HUBIN (a), P JAGOUREL (f), L JOCHUM (a), F LOCRE (b), P-Y MADEC (a), P MORIN (b), M MUELLER (a), G PETIT (d), D PETITGAS (b), JC SINQUIN (b), E VERNET (a)

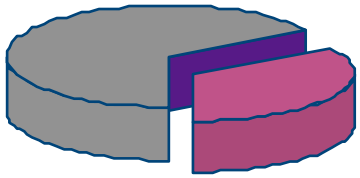
ESO (a), CILAS (b), AMOS ©, ONERA (d), ASTRIUM (e), ObsPM (f), Boostec (g)

AO4ELT2 28/09/2011

CILAS at a glance

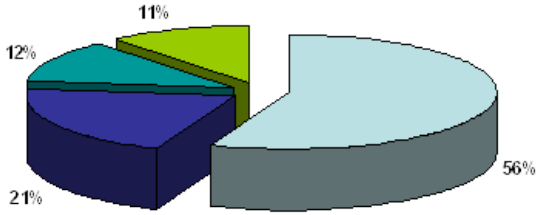
Shareholders

ASTRIUM SAS 63 %
(EADS)

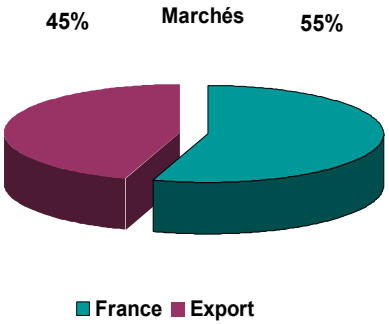


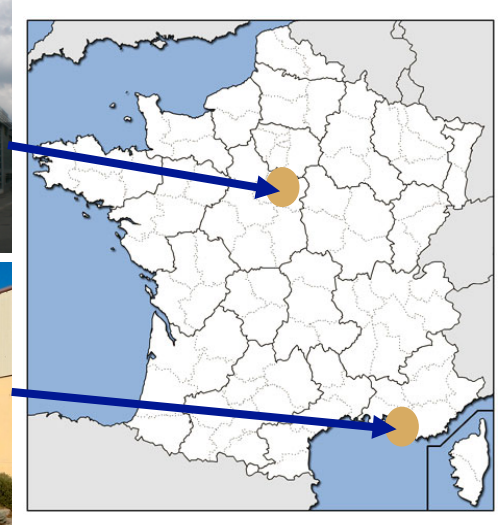
AREVA 37 %

140 employees



Turnover (FY2010) M€19,3

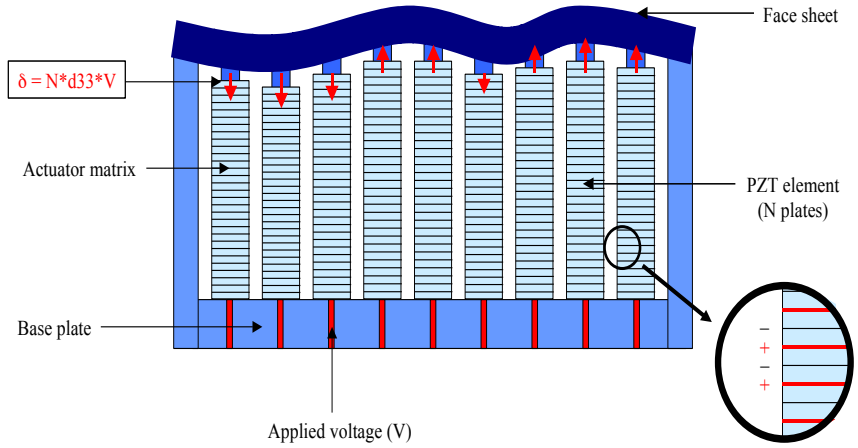




Introduction

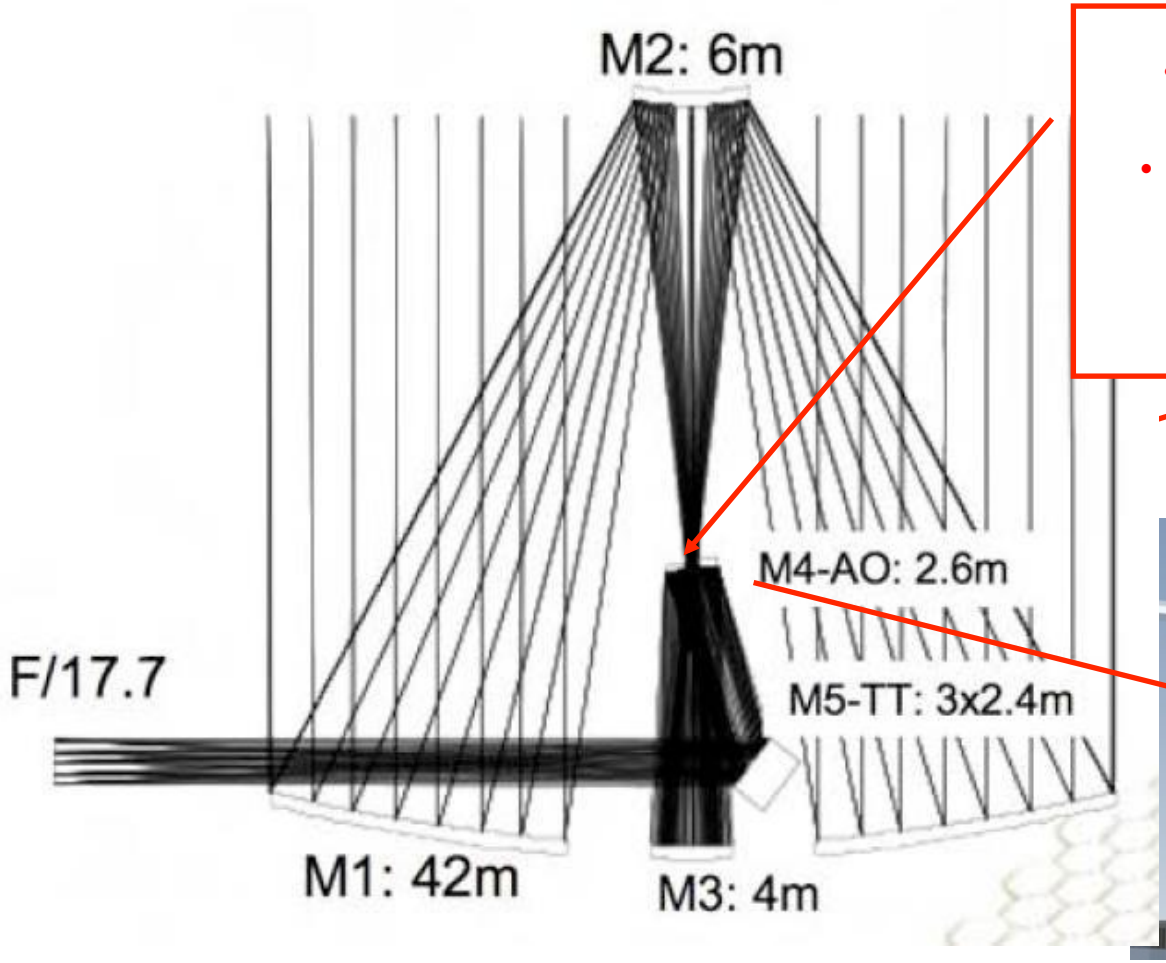
- ESO has initiated in 2007 a preliminary design study (5,2Meuros / 30 months) to demonstrate feasibility of an adaptive unit (M4AU) ϕ2,7 m, for the E-ELT
  - Preliminary design study
  - Breadboards tests
  - Demonstration prototype tests

- CILAS proposed a solution based on piezo-electric ceramics (SAM=piezo-stacks) for the adaptive mirror



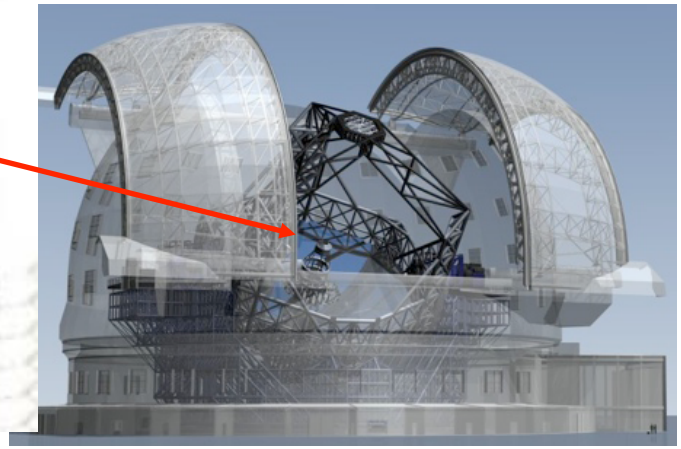
- CILAS and its partners have successfully passed the preliminary design review in July 2010

M4AU in the E-ELT

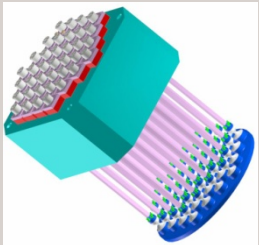
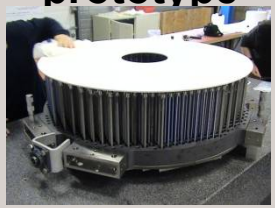


- **Correct the atmospheric turbulences**
- **Correct deformation of the telescope (wind, thermal, gravity…)**
- **Select Nasmyth foci**

M4AU

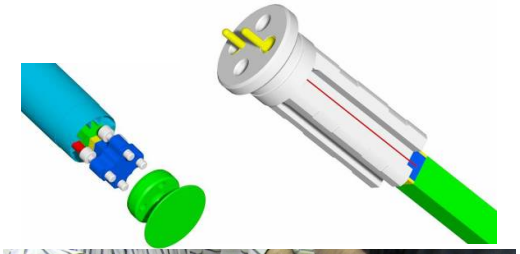


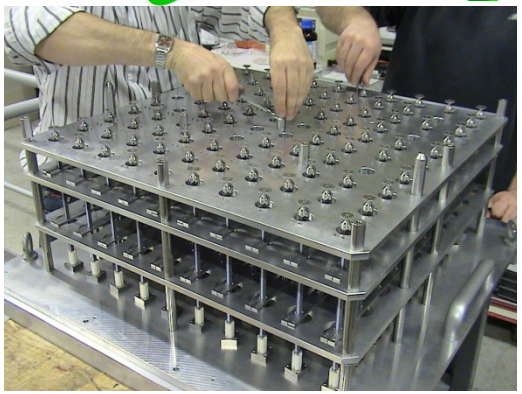
Risk assessments

Risks list	Breadboard 1 	Breadboard 2 	Demonstration prototype 
Free stroke	x		
Mechanical coupling and effective stroke		x	
Thermal behavior		x (local)	x (global)
Dynamical behavior		x (local)	x (global)
Hysteresis et creep		x	
Replacement of an actuators		x	
Reliability of the actuators	x (envt stress)	x (meca stress)	
Large size mirror credibility			x

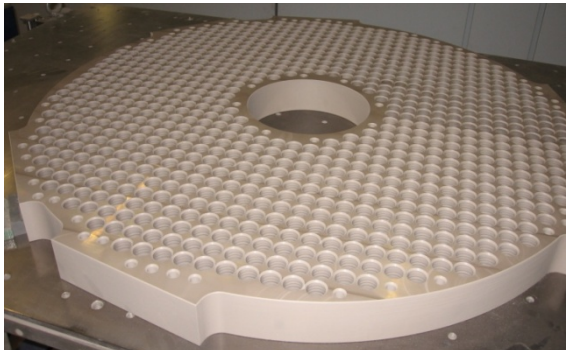
DP subsystems manufacturing (step 1)

Actuators

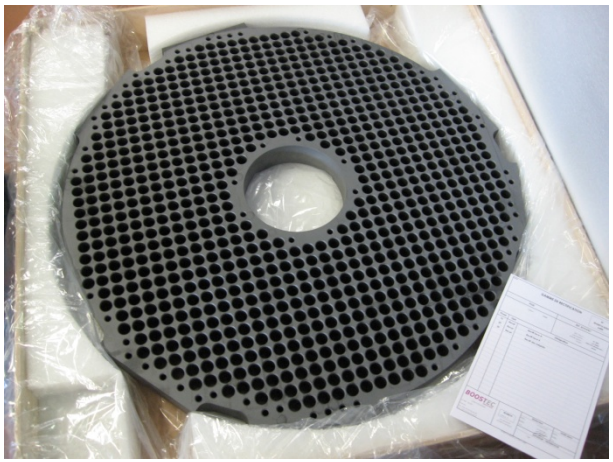




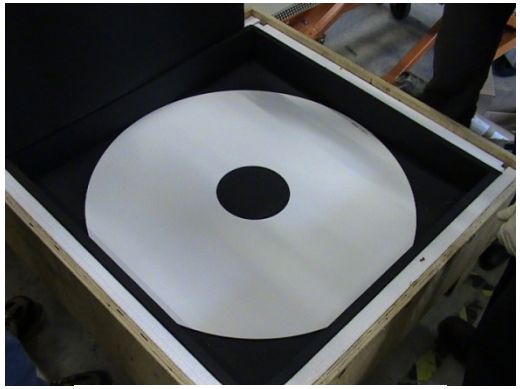
Base plate



BOOSTEC INDUSTRIES

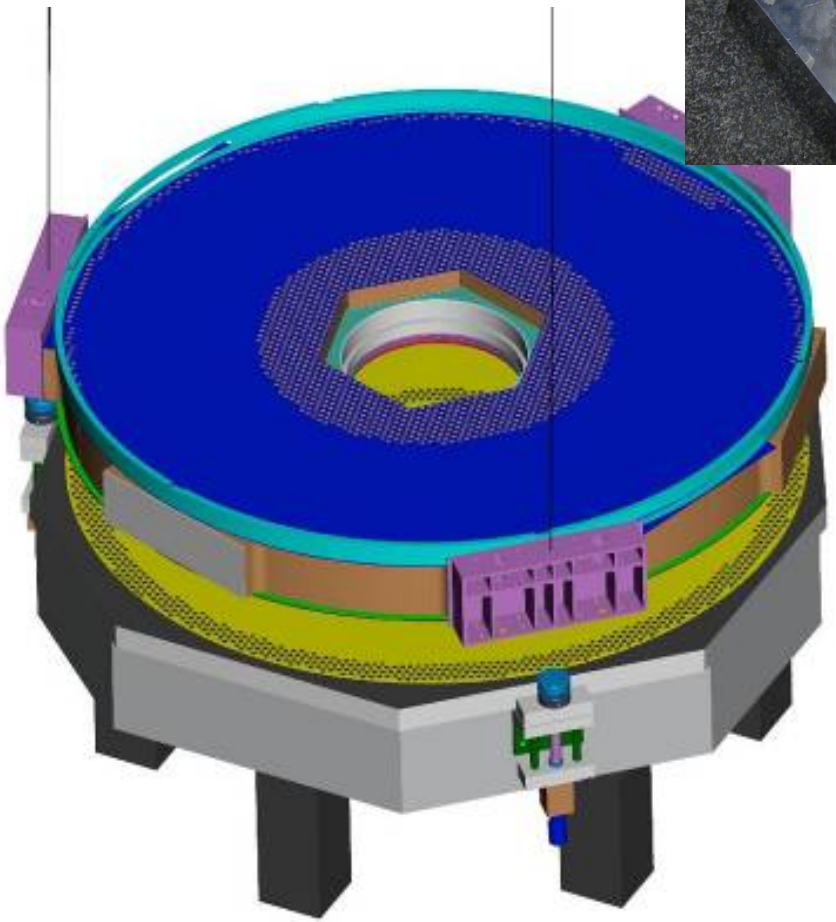


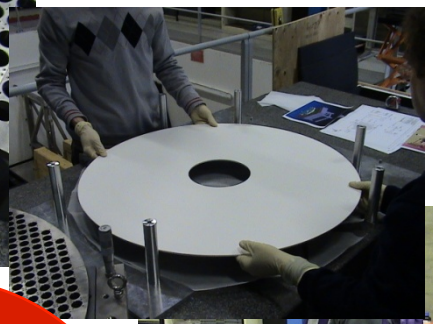
Optical plate

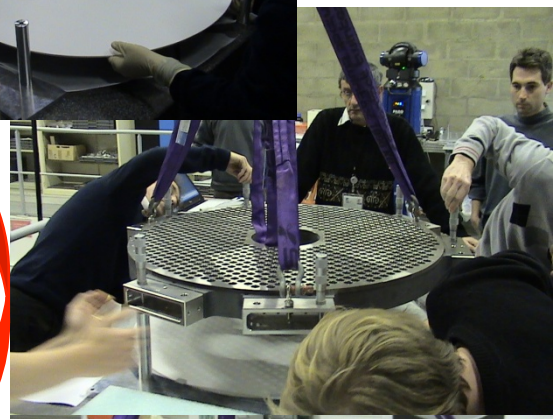


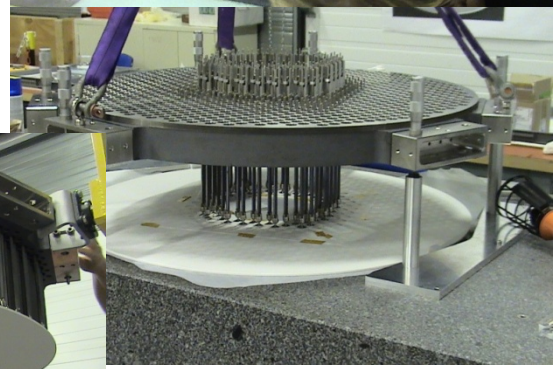
SCHOTT

Assembling of the DP (step 2)





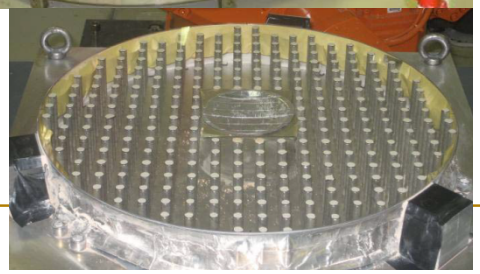




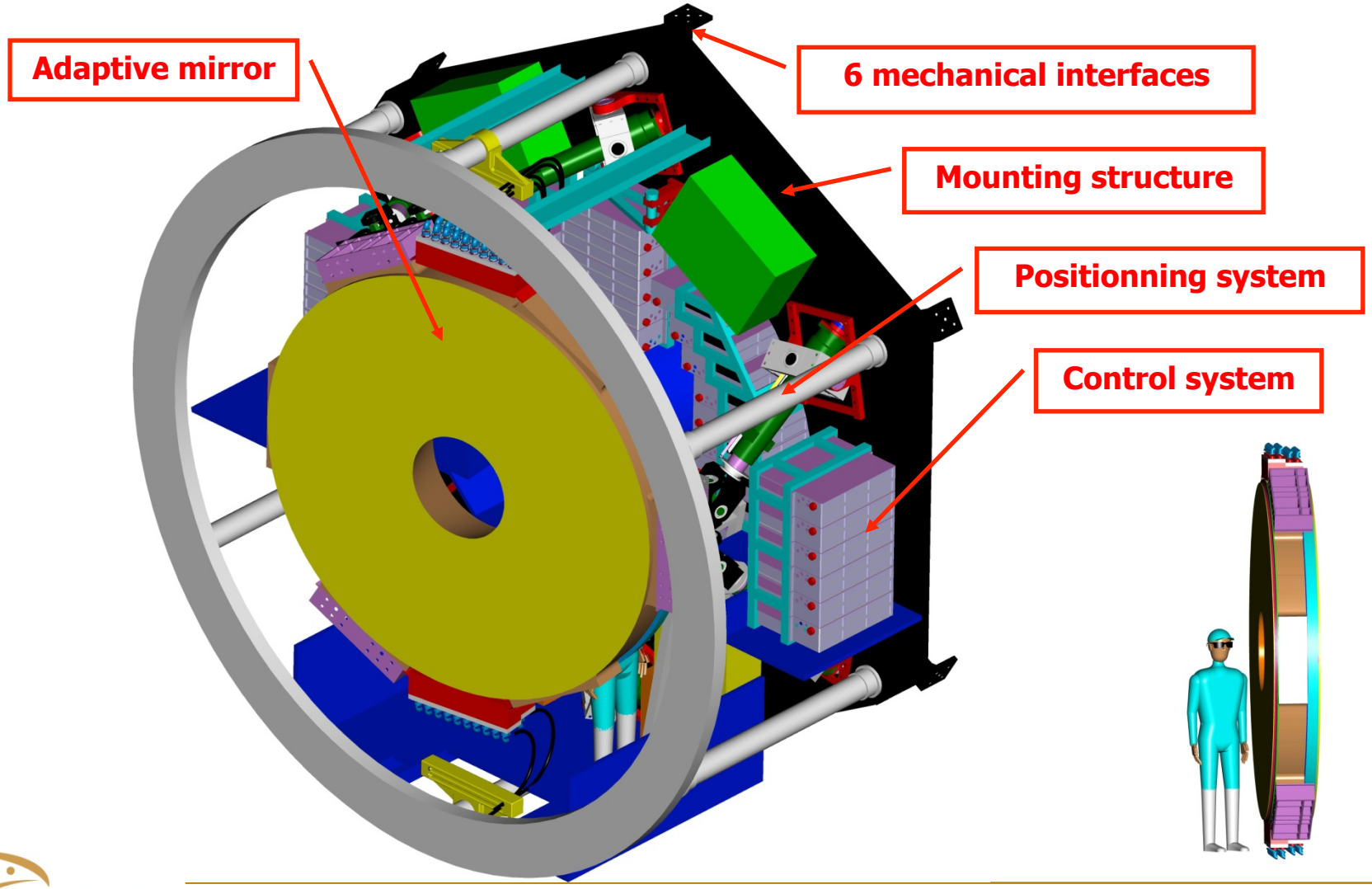
Lapping and polishing (step 3)

- CILAS technology enables final polishing after assembly allowing to suppress possible defects
- Dedicated tools:
  - Waterproofing
  - Optical plate blocking
- Process in 4 steps:
  - Thickness reduction (1mm)
  - Lapping
  - Polishing (<5µm PV)
  - Figuring (CCP) (<7,5nm rms)

AMOS
ADVANCED MECHANICAL AND OPTICAL SYSTEMS



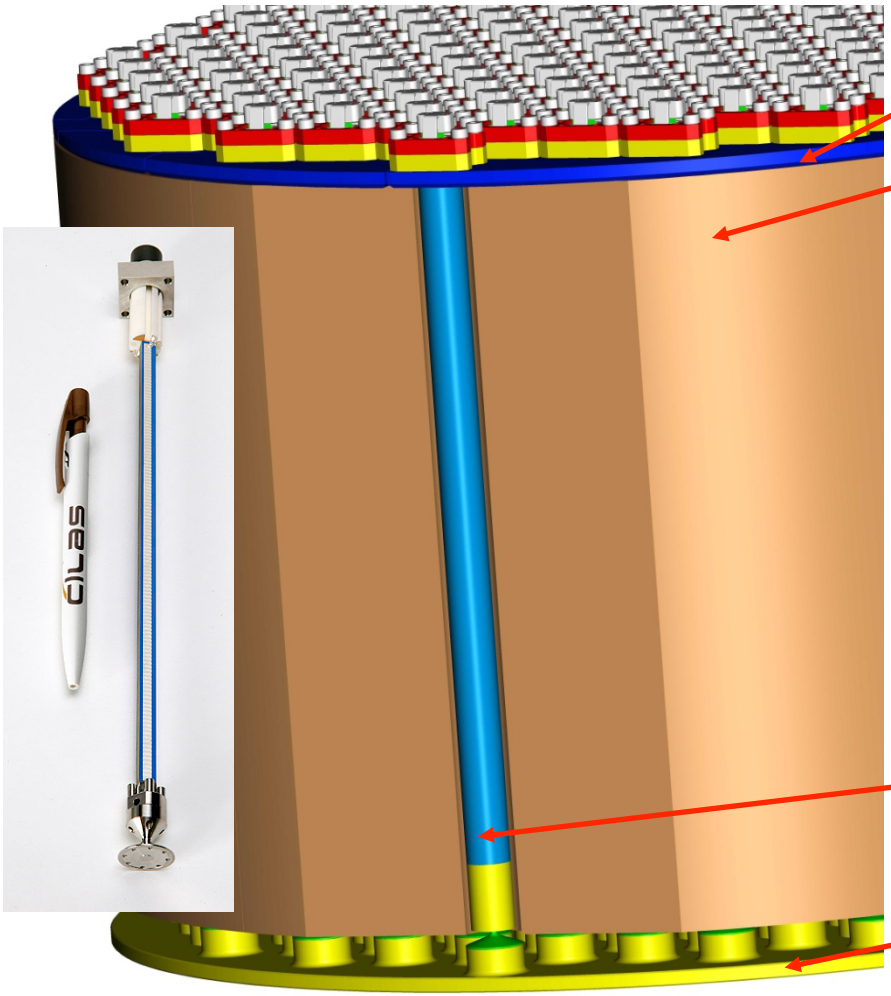
Mechanical design of the M4AU



Mass breakdown

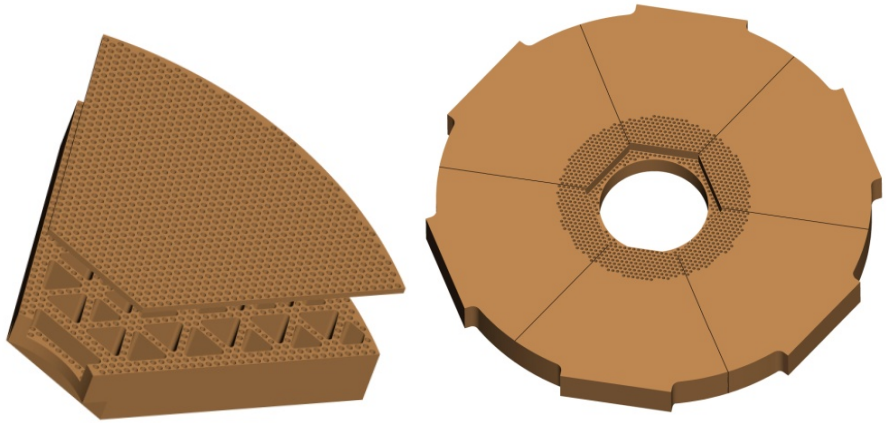
Sub-system n-1	Subsystem n-2	Mass (kg)
M4AM		**3126**
	Optical plate	*126*
	Actuators	*833*
	Equipped Base plate	*1970*
	HV distribution	*147*
	Main covers	*50*
M4PS		**2155**
M4CS		**2200**
M4MS		**1900**
M4AU total		**9380**

Cutting the Mirror



Fixing structure: Invar

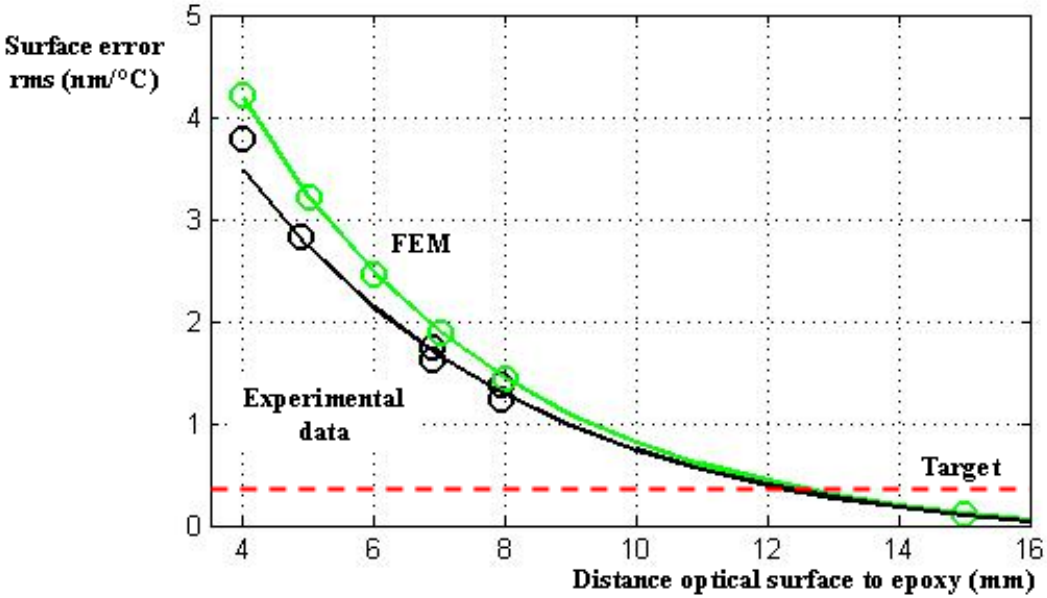
Base plate: Silicon carbide



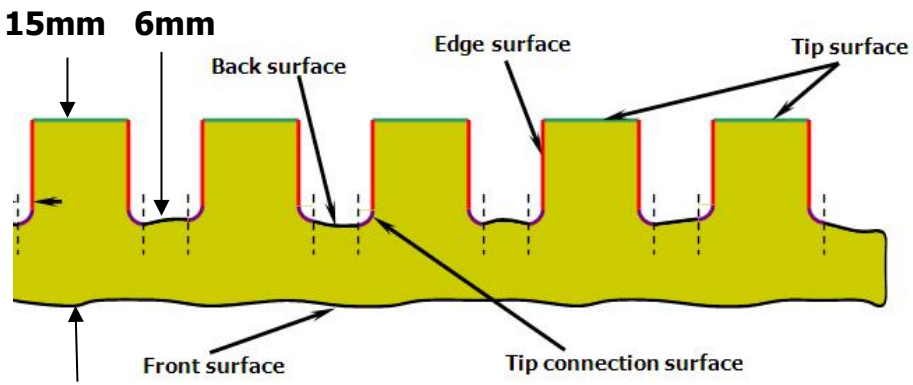
Actuators : Hard PZT
Removable !

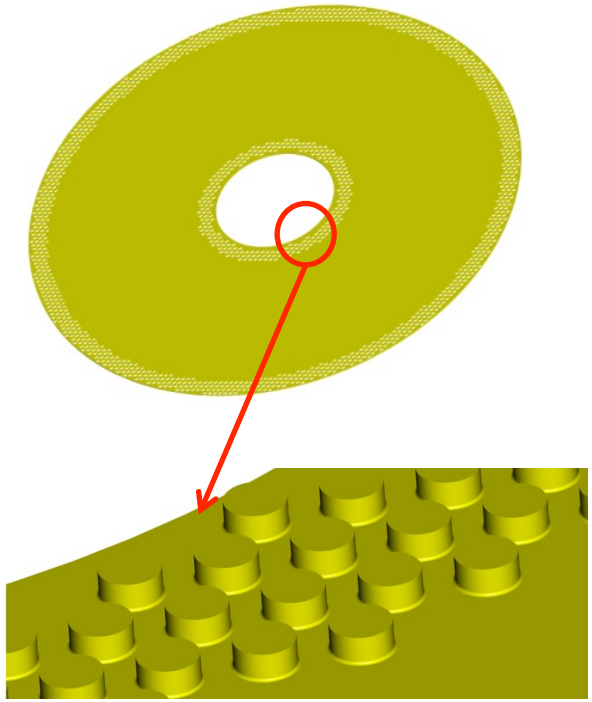
Optical plate: Zerodur®

Print-through issue

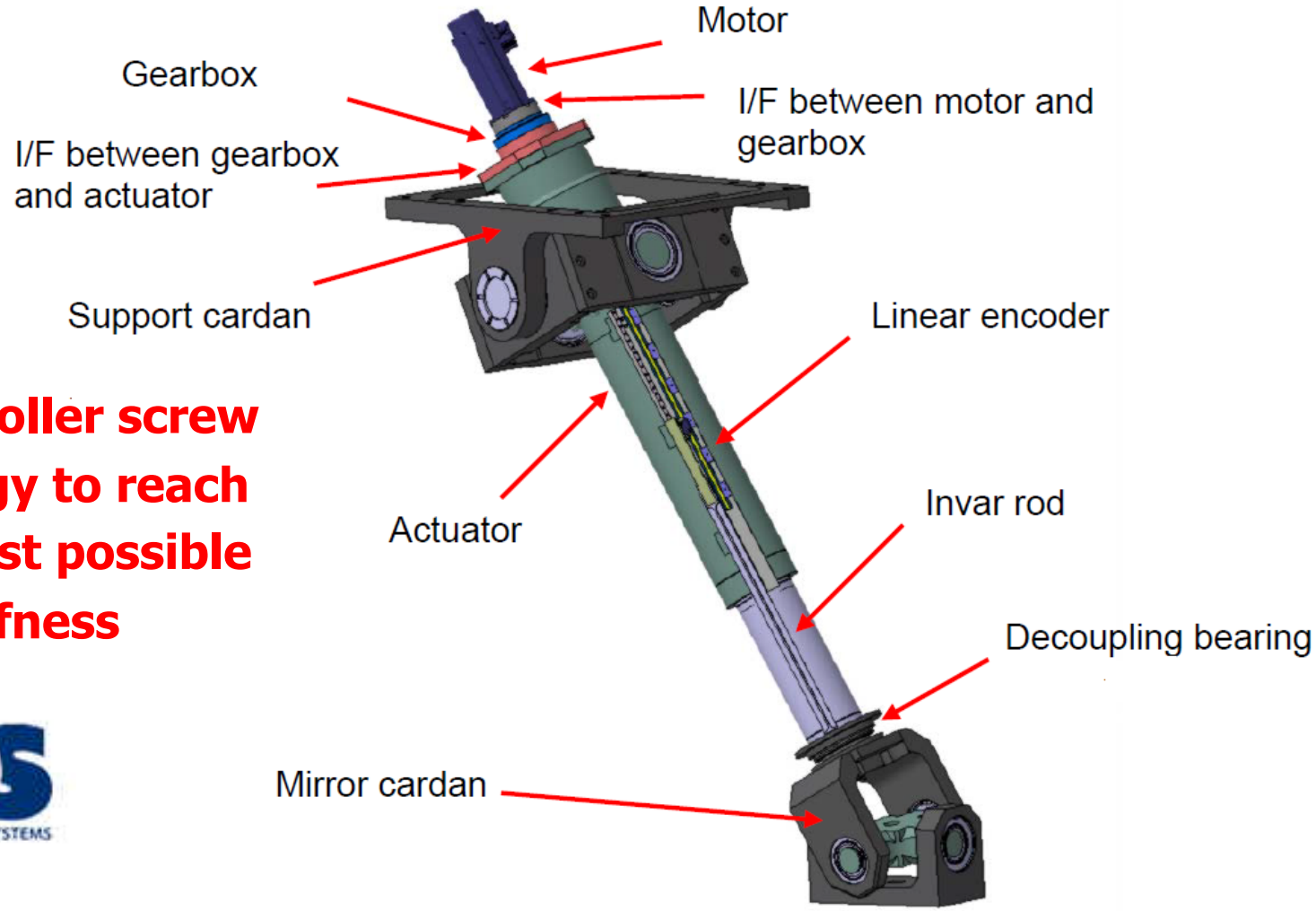


New design with tips :
2nm/°C -> 0,2nm/°C





Design of the positioning system



Satellite roller screw technology to reach the highest possible stiffness

Stroke capability

	Stroke PV
Static stroke	37 µm
Dynamic stroke	50 µm
Total	87 µm
Stroke capability	96 µm

margin 10%

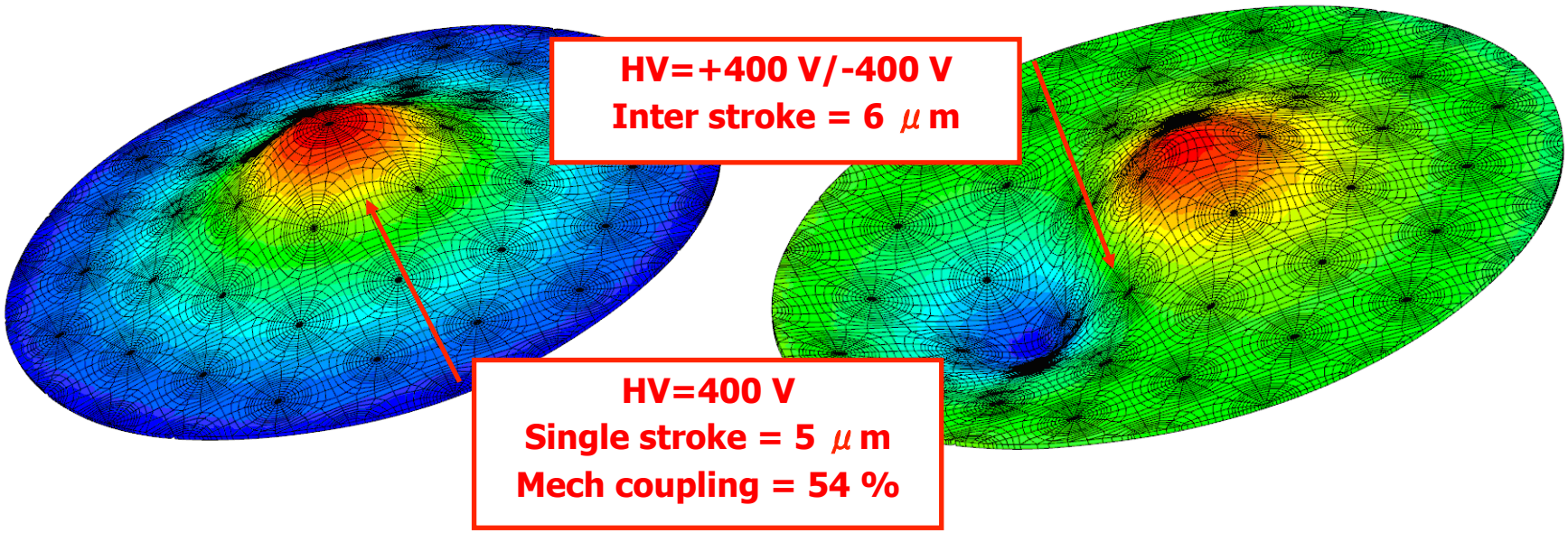
Telescope optical : 5µm
Gravity/thermal load : 27µm
Polishing : 5µm
Telescope vib & atmo t/t: 38µm
Telescope vib defocus: 7µm
Atmo (without t/t) : 32µm

New design with more PZT plates :

250 PZT plates -> 400 PZT plates per actuator

Arrangement of the actuators

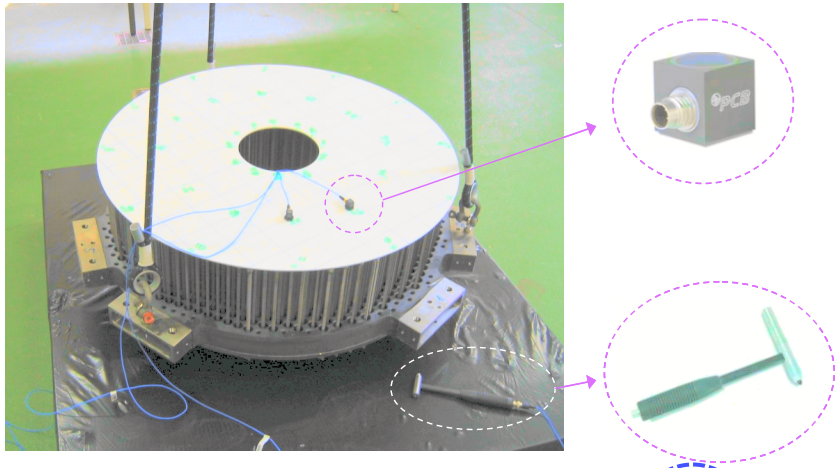
- Triangular meshing geometry
- Inter actuator spacing of 29mm for reaching the FE goal value (113nm around REQ 110nm, confirmed by ONERA)

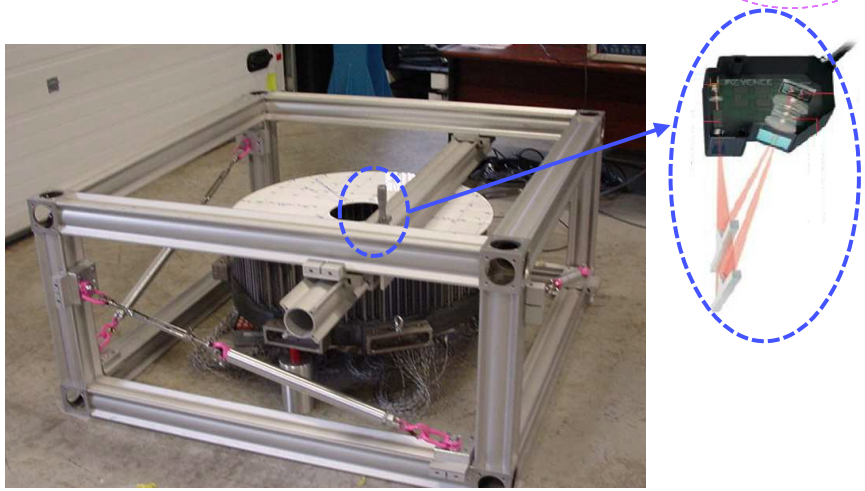


Dynamical behavior test benches

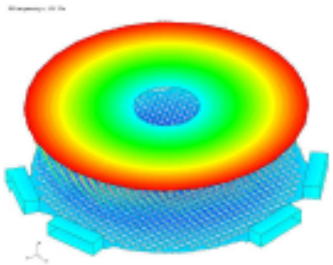
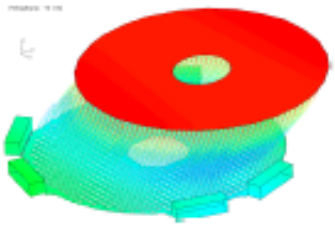
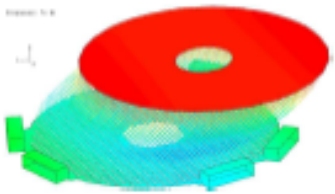
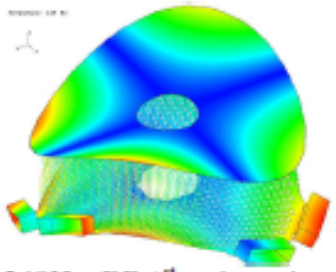
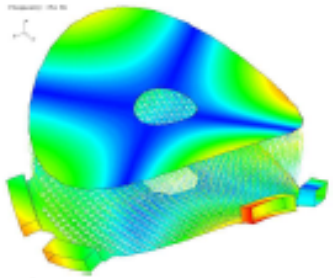
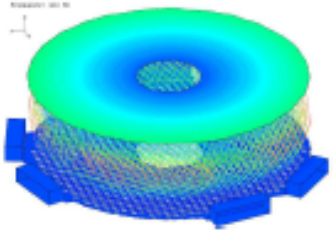
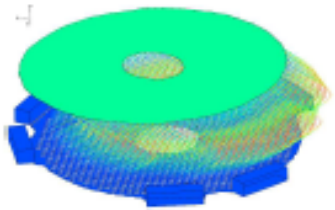
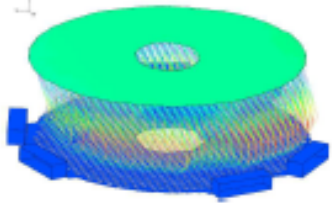
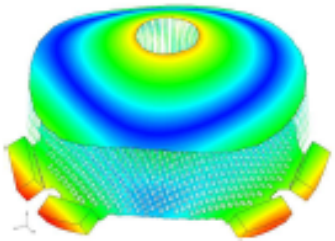
Divided in two steps:

- EMA performed to identify eigen-modes and damping factors
  - Validation of the FEM
- Spurious modes study
  - Identif. spurious modes
  - Validation state model



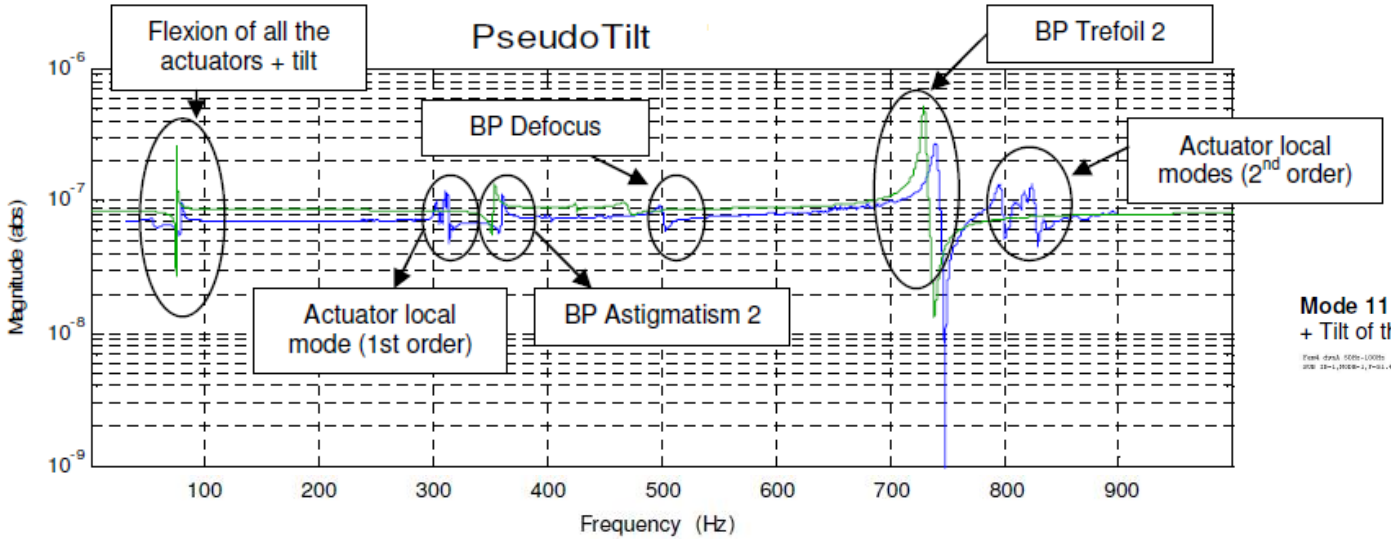


Main eigen modes of the mirror

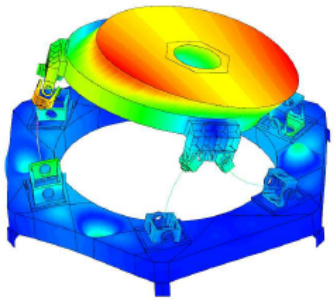
Mode 1  69Hz: actuator modes with rigid body rotation of the OP around z axis.	Mode 2  76Hz: actuator modes with rigid body translation of the OP along Y axis + tilt of the BP	Mode 3  76Hz: actuator modes with rigid body translation of the OP along X axis + tilt of the BP
Mode 4  249Hz: BP 1st astigmatism	Mode 5  354Hz: BP 2nd astigmatism	Mode 6  424Hz: actuator modes with rigid body rotation of the OP around Z axis
Mode 7  426Hz: actuator modes with rigid body translation of the OP along X axis	Mode 8  426Hz: actuator modes with rigid body translation of the OP along Y axis	Mode 9  471Hz: BP defocus

Dynamical behavior status

- FEM model validated (δ exp/theory<5%)
- State model validated (all main modes)



Mode 11 @51Hz : M4PS mode + Tilt of the M4AM around X-axis



- Thanks to theses models, we predict active damping of the base plate necessary to reach residual on-sky tip-tilt errors

Conclusions

- PDR successfully passed July 2010 (PDR=2311 pages delivered to ESO)
- The study allowed to show that CILAS technology for AO is adaptable for decametric to multi-metric dimensions (challenging but realistic)
- One meter prototype manufactured in short time (~1,5 yr)
- Progress in various domains such as lifetime of the PZT actuators, finite element model of complex structure, control of the hysteresis and creep effect, improvement of local thermal behavior, active control of high degrees freedom structure, mass production…

THE END

Thanks for attention!
Questions ?