THALES

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Issue January 2013







X-RAY MIRRORS

THALES SESO's KNOW-HOW

Our products:

- **Mirrors**
- **Benders**
- **Bimorph Mirrors**
- **KB**
- **Crystal Analysers**
- **EUV Collectors**
- **Mandrels**
- **X-Ray Beam Monitor**

ISO 9001-2008
CERTIFIED

Thales SESO S.A.S
S.A.S. au Capital de 449 024 €
SIRET : 399 064 963 000 16
RCS : Aix en Provence 94 B 1302
APE : 2670 Z – TVA : FR 46 399 064 963

CHAPTER 1
MIRRORS

WHAT THALES SESO CAN DO

1. SHAPE

- Flat
- Spherical
- Aspherical
    - Toroidal
    - Off-axis elliptical

2. DIMENSIONS

- Up to 1500 mm
- Special polishing machines have been manufactured by THALES SESO

3. MATERIALS – ROUGHNESS RMS

- SiC	3 Å RMS
- Silicon	3 Å RMS
- Zerodur – Glass	2 Å RMS
- Copper + Nickel	5 Å RMS
- Glidcop + Nickel	5 Å RMS

4. SURFACE QUALITY

- Flat or Spherical	0.1" to 0.3" RMS up to 1500 mm
- Aspherical	
o Toroidal	0.3" RMS from 500 mm to 1000 mm
o Off-axis elliptical	0.5" RMS

SILICON CARBIDE MIRRORS
Length = 60 cm – Slope error = 0.5" RMS

THALES SESO's REFERENCES

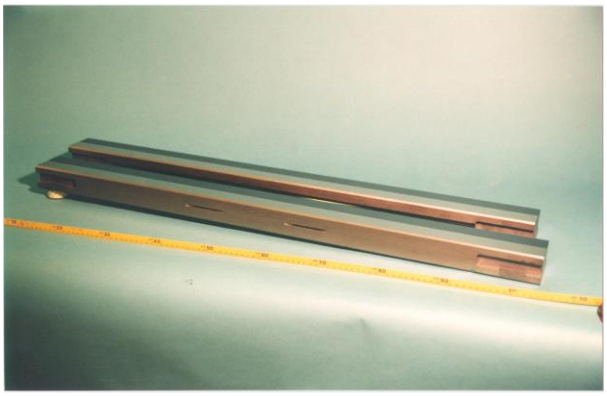
Here are some examples of mirrors THALES SESO has achieved:

Substrate	Roughness Å RMS	Sizes (mm)	Shape	Slope error Manufactured
Silicon	2 Å	250x50x20	Flat R > 1 km Flat R > 1 km	1 µrad 1 µrad
Silicon	2 Å 2 Å	200 150	Flat (trapezoidal) Flat (trapezoidal)	0.9 µrad 0.7 µrad
Silicon	1.9 Å 2 Å 2 Å	50x600x60 15x200x30 20x100x30	Plan R > 20 km Plan R > 20 km Plan R > 20 km	0.5 µrad 0.7 µrad 0.7 µrad
Silicon	1.5 Å 1.4 Å	464x60x50 1000x70x70	Flat elliptical bent ∞ to 2450 m Flat > 40 km	0.5 µrad 0.7 µrad
Silicon	2 Å	1400x125	Flat bendable 3km<R<flat(>40km)	0.8 µrad
Silicon	2 Å 2 Å	1300x100 1300x100	Flat bendable 3 km to infinity Flat bendable 3.5 km to infinity	0.9 µrad 1 µrad
Silicon	2 Å	1350x105	Toroidal R=66 ± 0.5mm	0.7 µrad
Silicon	2 Å	400x60x50	Cylindrical R=28mm	0.9 µrad
Silicon	2 Å	400x50x30	Flat	0.6 µrad
Silicon	2.5 Å	800x100	Flat R > 15 km	0.5 µrad
Silicon	2 Å 2 Å 3 Å	120x20x50 300x20x50 170x30x8	Flat R > 1.5 km Flat R > 5 km Flat R > 1 km	0.8 µrad 0.5 µrad 0.5 µrad
Silicon	1.3 Å	1000x114x52	Cylindrical R=71.60 mm	0.5 µrad
Zerodur	2 Å 2 Å	240x30 240x30	Cylindrical R=4620mm Cylindrical R=2483mm	1 µrad 1 µrad
SiC	2 Å	280x40x25	Cylinder R infinity>50km r=1257mm	1 µrad
SiC CVD	2 Å	450x30	Flat R > 30 km	0.5 µrad
ULE	2 Å	1240x70	Toroidal R=4.5km r=30mm	1 µrad
SiO2	2 Å 2.5 Å 2 Å 2 Å	420x40 300x40 350x60 350x60	Spherical R=174383 mm Spherical R=75253 mm Spherical 105457.7 mm Spherical 52567.8 mm	0.8 µrad 0.9 µrad 0.8 µrad 0.5 µrad
Silica	2 Å 2 Å	1000x100 1000x100	Cylindrical R=106.4 mm Cylindrical R=101.9 mm	1 µrad 1 µrad
Silica	2 Å 2 Å	220x40x40 220x40x401	Meridional cylinder R=71598mm Sagittal cylinder R=59.87mm	0.8 µrad 0.7 µrad
Glidcop	2 Å	168x76x50	Spherical R=86.91 mm	1 µrad
Glidcop	2 Å	1000x120x50	Flat R= infiny to 3 km	1 µrad
Single crystal Si Single crystal Si Single crystal Si	2 Å 2 Å 2 Å	1000x30x80 1200x30x70 800x30x60	Flat > 50 km Flat > 30 km Flat > 30 km	0.7 µrad 0.9 µrad 0.7 µrad
Single crystal Si Single crystal Si	2 Å 2 Å	812x76x101 812x76x101	Cylindrical R = 2.51 cm Cylindrical R = 6.00 cm	1 µrad 0.7 µrad
Single crystal Si Single crystal Si Single crystal Si	2 Å 2 Å 2 Å	900x65x55 1200x50x55 1200x65x50	Flat R > 30 km Flat R > 30 km Flat R > 30 km	0.5 µrad 0.7 µrad 1 µrad
SiO2 SiO2	1.8 Å 1.9 Å	450x70 450x70	M1 Flat R > 50 km M1 Flat R > 50 km	0.4 µrad 0.5 µrad
Silicon Silicon Silicon Silicon Silicon Silicon	2.7 Å 2.5 Å 1.9 Å 1.9 Å 1.7 Å 1.9 Å	350x40x50 350x40x50 250x40x40 250x40x40 250x40x40 250x40x40	M2 Flat R > 30 km M3 Flat R > 30 km M5 Flat R > 30 km M6 Flat R > 30 km M7 Flat R > 30 km M8 Flat R > 30 km	0.47 µrad 0.5 µrad 0.4 µrad 0.4 µrad 0.4 µrad 0.4 µrad
Silicon Silicon	0.9 Å 0.9 Å	260x60x50 210x60x50	PM1 Plane r>30km PM2 Plane r>30km	0.2 µrad 0.3 µrad

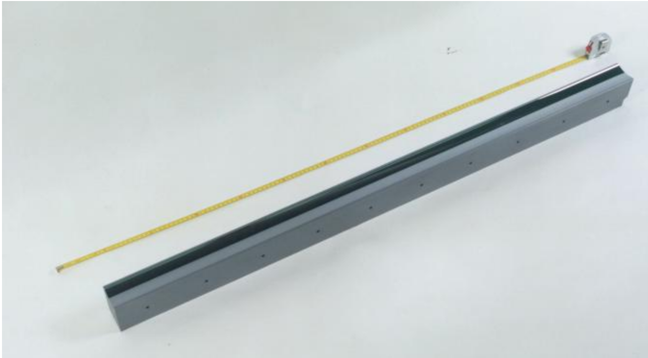
Up to now THALES SESO has manufactured more than 1250 X-Ray Mirrors and 250 Benders

<u>Our customers are:</u>

- **ESRF, LURE, Synchrotron SOLEIL, … (France)**
- **BESSY, PTB, FZK, ANKA, EMBL, DESY, Universität Würzburg, ACCEL … (Germany)**
- **Institute of Physics and Astronomy Aarhus University (Denmark)**
- **MAXLAB (Sweden)**
- **SPring 8, University of Tokyo, JASRI, KEK, HEARO, IMS… (Japan)**
- **LBL, APS/ANL, SLAC, BNL, PNC-CAT, UNI-CAT, COM-CAT, CMC-CAT, CHESS, CORNELL, CAMD, Brookhaven, IMM-CAT, DND-CAT, SRI-CAT, University of California NER-CAT, SGX-CAT, HP-CAT, Wisconsin University, … (USA)**
- **NSRRC (Taiwan),**
- **SRLI (Thailand)**
- **PAL/POSTECH (Korea),**
- **Sincrotrone Trieste, INFM, INFN, Cinel, CRS SOFT,… (Italy)**
- **PSI/SLS (Switzerland)**
- **DLS, CLRC, Daresbury Laboratory, RAL, QOLS, Imperial College … (UK)**
- **LNSL (Brazil),**
- **CLS, University of Saskatchewan, (Canada),**
- **IHEP/BSRF, SSRF (China),**
- **SRLI (Thailand)**
- **ALBA (Spain)**
- **ASP (Australian Synchrotron)**
- **BARC, LASTEC, CAT, SINP, … (India)**



2 Flats mirrors



1 Cylindrical mirror

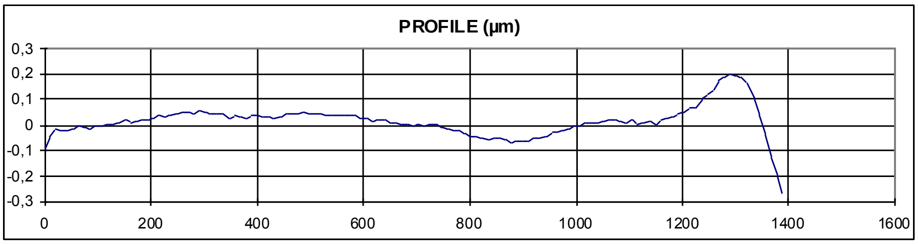
AFFAIR NUMBER :	3764
Programme Profils (10.97)	

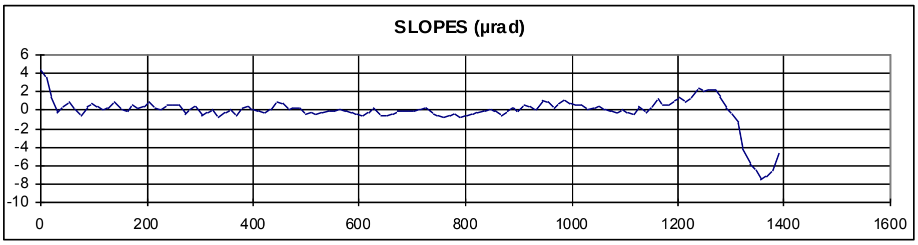
DATE :	04/02/99 09:41
OPERATOR :	Marie LECOMTE

PIECE SPECIFICATIONS	
1400mm	
radius	0,000E+00 (mm)
conicity	0,000E+00
real dimensions	1400 120 (mm)

CONTROL FEATURES	
control instrument	WYKO
correction file	/
result file	1A.XLS
previous file	/
profile	X
removed tilt	0° 0' .23''
interferometer file	1400A.ASC
measure angle	85 (°)
no smoothing, 129 measured points	
number of reflection	2

BEST FIT CONIC CHARACTERISTIC			
type	Best fit sphere (RMS slope)		
radius	201,4886		(km)
conicity	0,000E+00		
RESULTS ON MEASURED AREA			
measured dim.	1400	NC	(mm)
PTV on surf. prof.	5,00E-01		(µm)
RMS on surf. prof	6,84E-02		(µm)
PTV slope	1,18E+01		(µrad)
RMS slope	**1,65E+00**		(µrad)
RESULTS ON USEFUL AREAS			
	zone 1	zone 2	
useful lenght	1398	1300	(mm)
transv. posit.	200	200	/ 1 lin.
PTV on surf. prof.	4,75E-01	2,66E-01	(µm)
RMS on surf. prof	6,29E-02	5,25E-02	(µm)
PTV slope	1,18E+01	8,87E+00	(µrad)
RMS slope	**1,66E+00**	**1,10E+00**	(µrad)

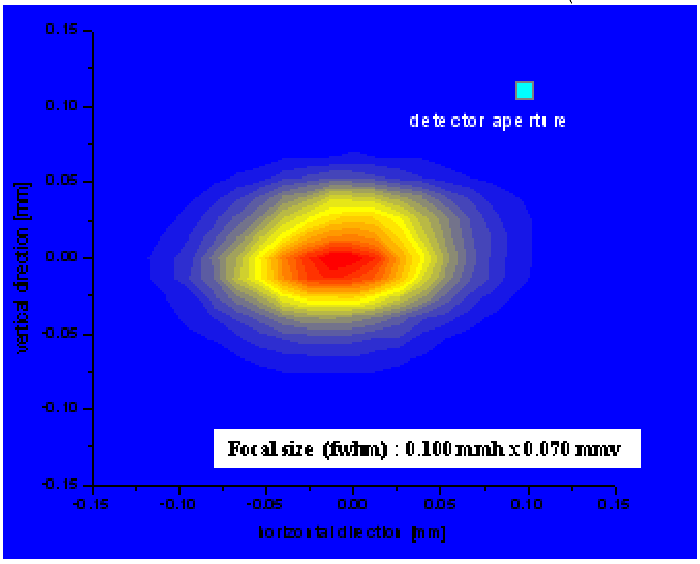




Example of results of mirrors manufactured

THALES SESO presents the best result, never obtained before, on a X-Ray Toroidal Mirror, delivered to the ESRF:

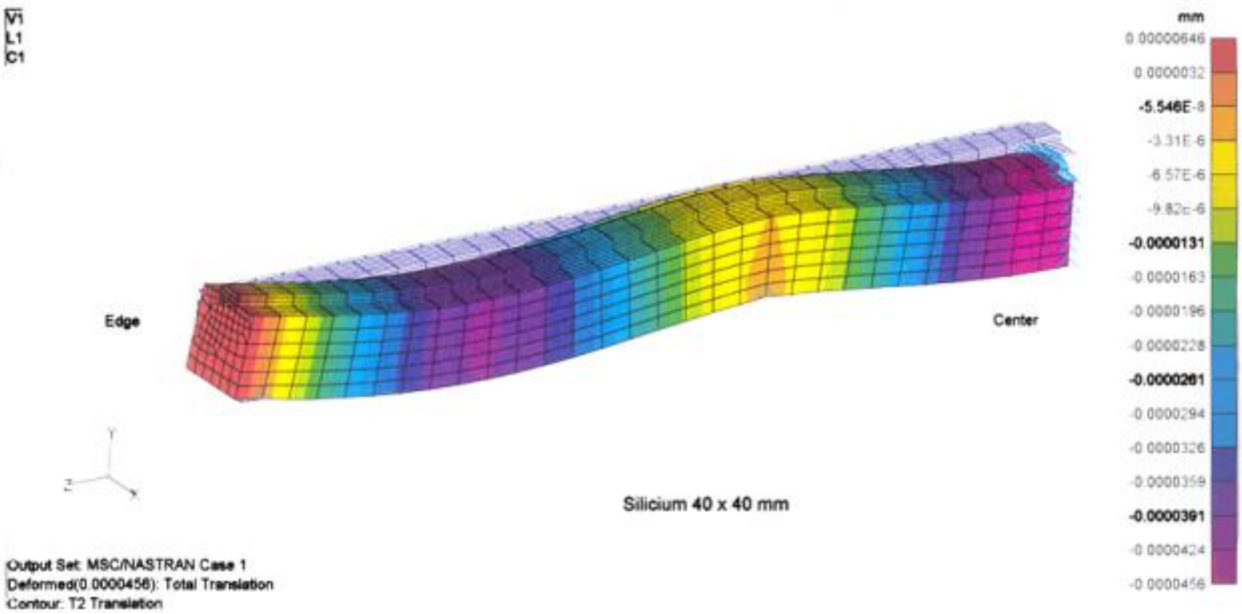
The Polychromatic focus from the toroidal mirror from THALES SESO U17 in-vacuum undulator on ID 09 (ESRF – France)



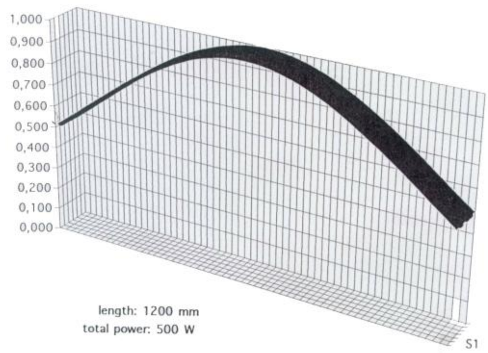
Message received from Michael Wulff ESRF Beamline ID09

I would like to express our great satisfaction with the new Toroidal mirror for Beamline ID09.
We have tested the mirror on the Beamline and the focal spot is excellent!
The mirror is installed 32 m from the source and we focus the beam 22 m downstream.
The focal spot is 0.100 x 0.070 mm2 in the horizontal and vertical direction respectively (fwhm).
The spot dimensions agree well with the LTP measurements made in our optics lab.

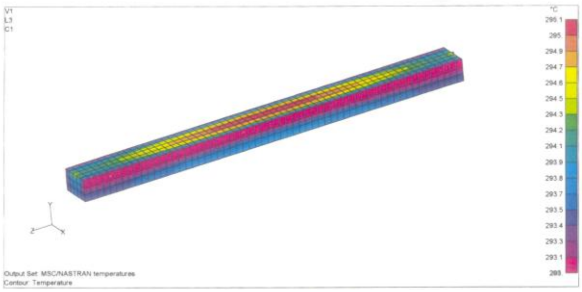
Deformation Under Gravity



THERMAL DESIGN

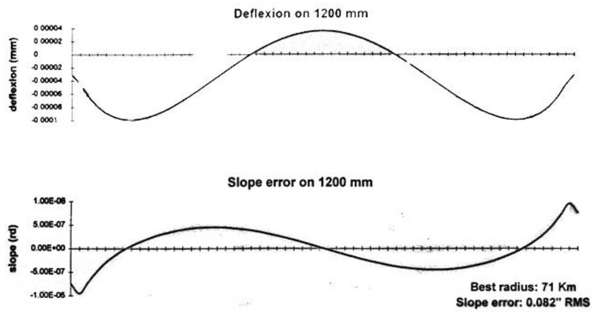


Thermal load Gaussian Law



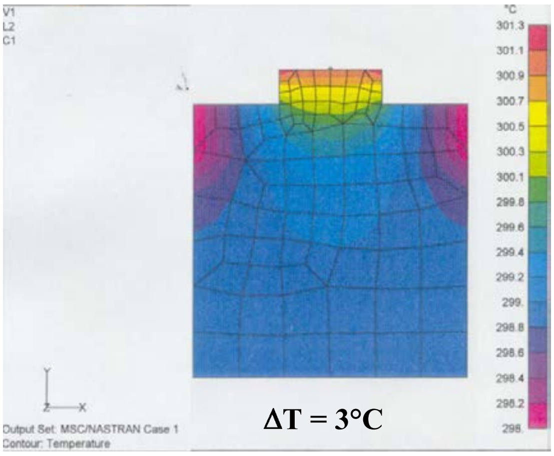
Cartography of temperature

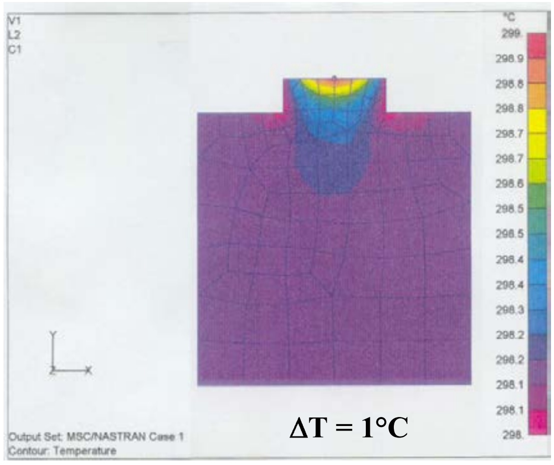
Deformation due to the thermal load temperature



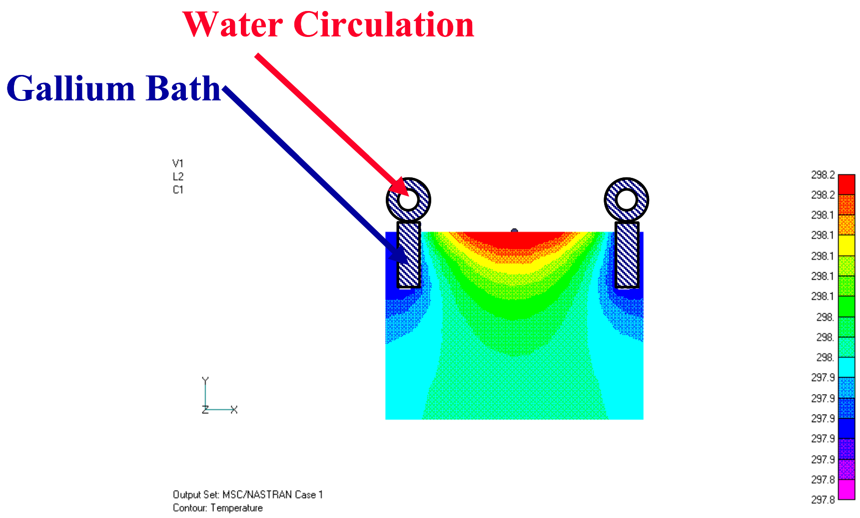
Thermal effect with total power 500 W and Gaussian Law

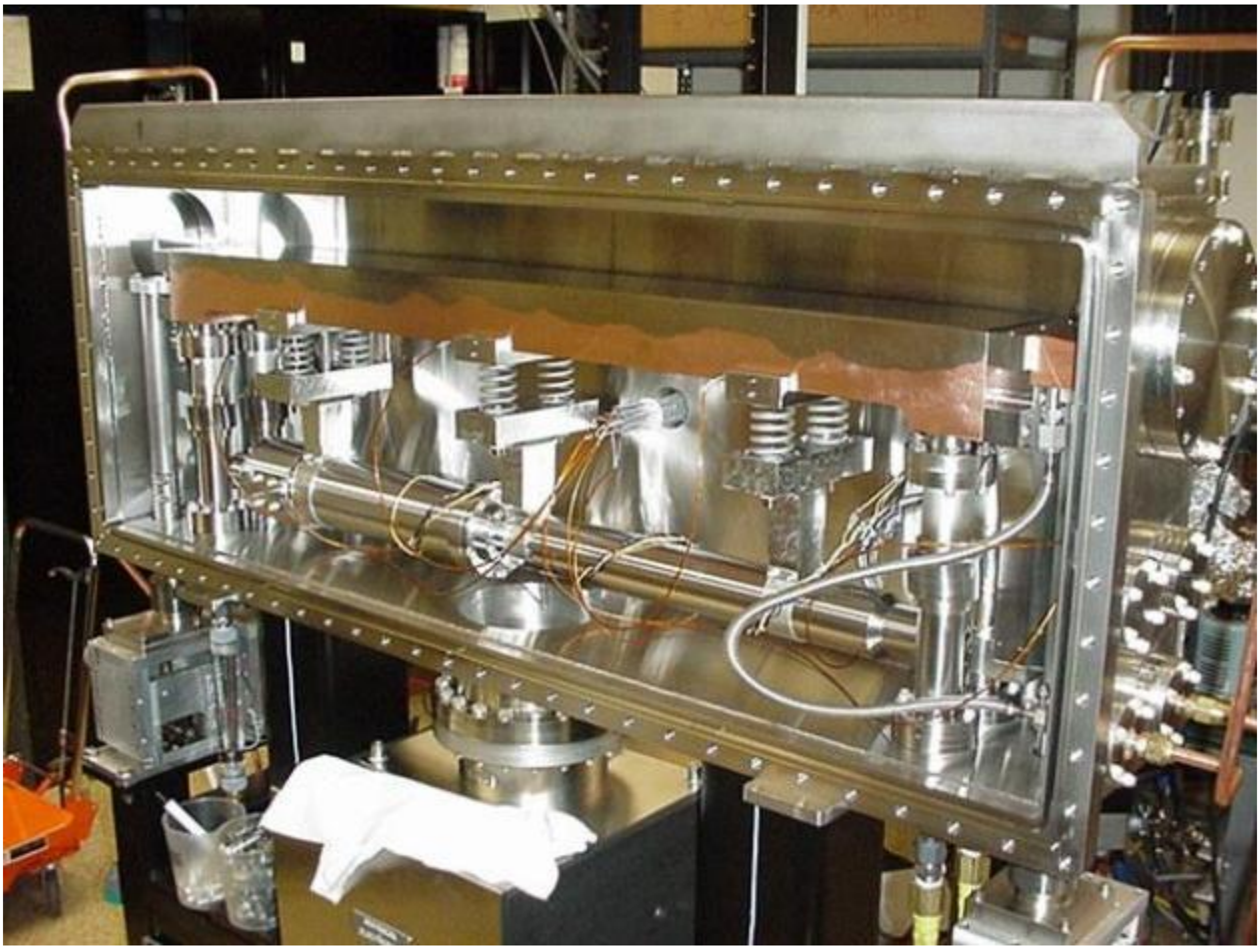
THERMAL DESIGN





Definition of side cooling





Internally Glidcop Cooled Mirror

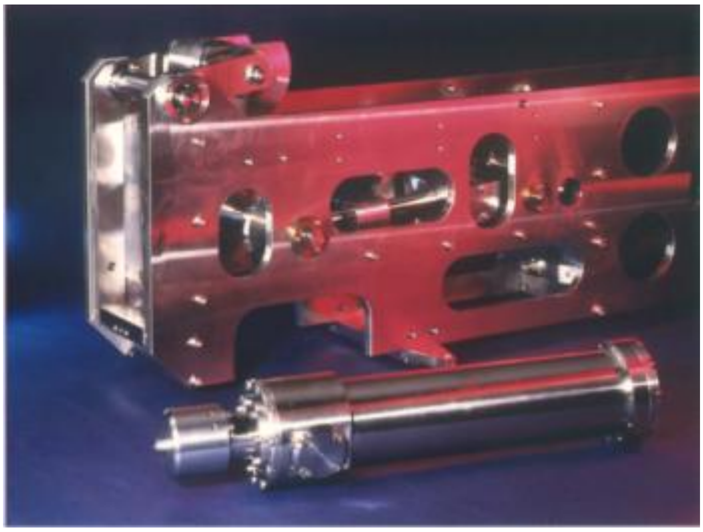
CHAPTER 2
BENDERS

BENDERS

4 CYLINDERS BENDER

- Mirror rests on two cylinders
- Two other cylinders push on the mirror surface through levers arms
- Torsion stresses prevented by making 3 or the 4 cylinders rotatable
- Bending is made by pushing on the two levers with an actuator

Example of 1.3 m silicon cooled mirror with its bender

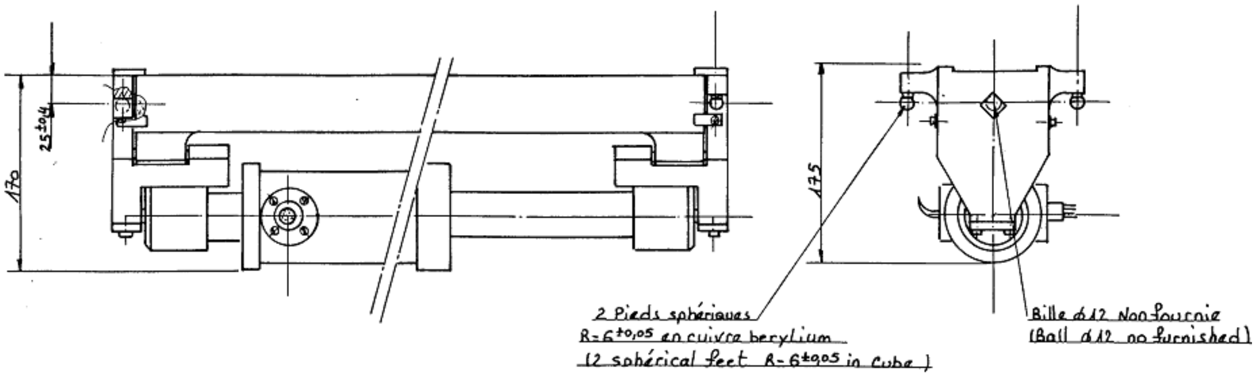


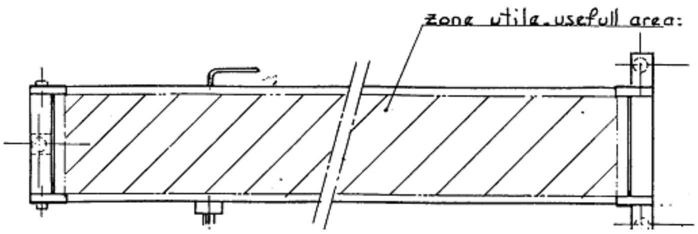
Bender detail with the compensation of gravity

BENDERS

ACTUATOR

- Container without leakage filled with helium
- Container includes a stepper motor pushing a spring
- Vacuum compensated bellows
- Irreversible mechanical transmission between stepper motors and levers: current can be lowered when at required radius
- Connection: feedthrough on the bottle (7 wires)
- Limit switches adjusted in house with the good range of curvature
- Calibration curve





BENDERS

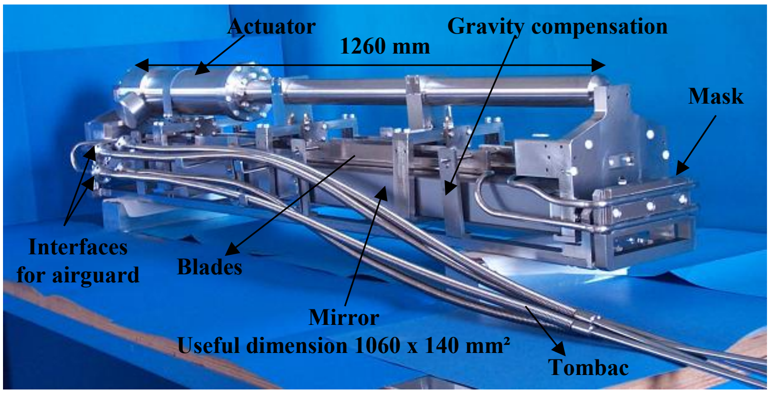
U-BENDER

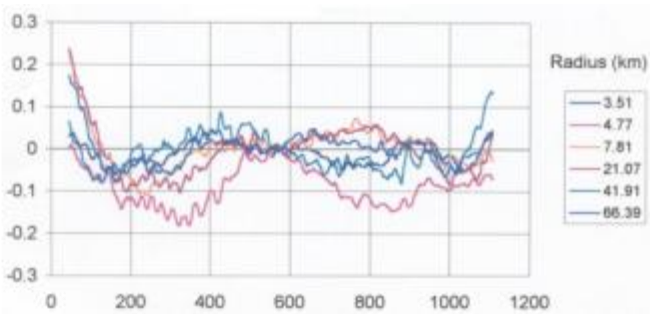
- The levers are clamped directly on the mirror
- Bending is made by pushing on the two levers with an actuator
- Kinematic interface is fixed directly on the levers

U-Bender 700 mm mirror reflecting upward

NEW IMPROVEMENT IN U-BENDER (Patent Pending)

- Gravity compensation included
- Cooling with slots and copper blade
- Mask included



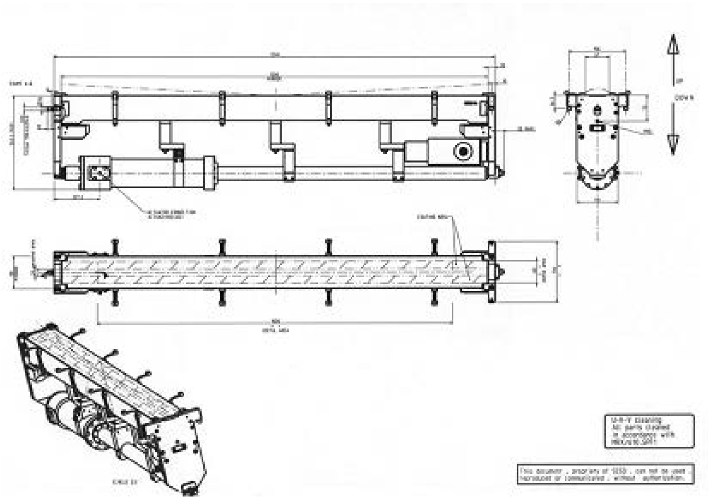


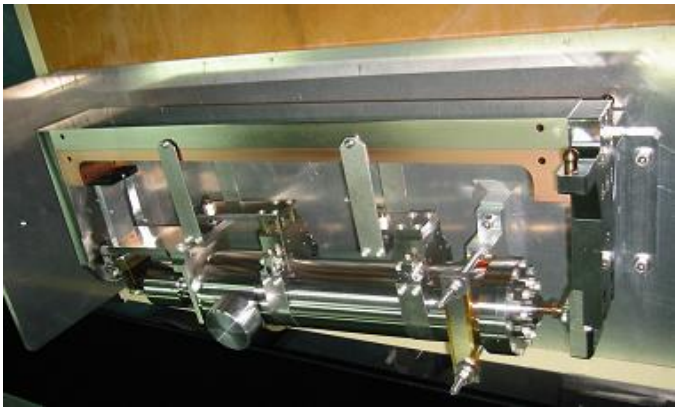
Radius of curvature	On 1060 mm length
3.51 km	1 µrad
5.7 km	0.9 µrad
13.11 km	0.9 µrad
26.5 km	0.7 µrad
66.39 km	0.7 µrad

Profile achieved at different radius (in µm)

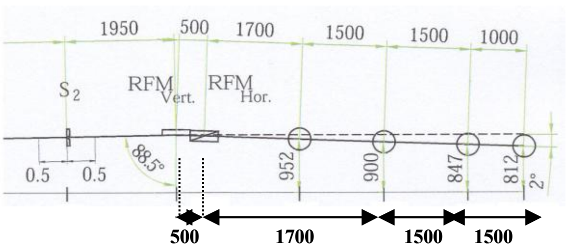
Corresponding slope errors (ESRF measurement)
Drift < 0.2 µrad over 20 hours
Hysteresis < 0.5% for radius ~ 5 km
MTBF > 8000 full cycles at full speed

U-Bender With 2 Actuators Elliptical Bent





Designed as a working KB pair of mirrors to focus in 3 different aligned hutches separated by 1.5 m (WERA Beamline ANKA)



	RFMV (500 mm length)			RFMH (560 mm length)		
	2200mm	3950mm	5700mm	1700mm	3200mm	4700mm
Theoretical bent cylinder (X^2)	3"	10"	12"	18"	3"	0.6"
Theoretical slope error (best polynomial fit with X^2 and X^3)	1.5"	1.2"	1 "	2.2"	0.4"	0.2"
Measured values including manufacturing error	0.8"	1.2"	2.5"	1"	1"	1.4"

COMPARISON CHART FOR BENDER MECHANISMS

Items	4 cylinder bender	U Mirror
Compensation of gravity	**Possible**	**Possible**
Relative sensitivity of the curvature (□C/C) to the temperature on the range of curvature	**10^{-4}/°C**	**3.10^{-4}/°C**
Interface with the vessel	**Included**	**Kinematic interface**
Slope error at Radius ∞ due to gravity	**0,2" RMS with compensation of gravity**	**0,2" to 0,3" RMS**
Slope error at the maximum curvature due to gravity and bending effect	**≈ 0,3" RMS for length of 1000 mm**	**< .3" RMS**
Interest	**Complete solution with the possibility of other functions (inlet baffle, cooling, …) and interfaces easy ELLIPTICAL bendable**	**Lower price Smaller dimensions**

At today THALES SESO has manufactured more than 250 Benders.

CHAPTER 3
BIMORPH MIRRORS

BIMORPH MIRRORS

Principle

Bimorphs are assembled by gluing together two pairs of bilayers consisting of an active element (zirconate lead titanate Pzt Ceramic) and a neutral fused silica plate, which is then polished. A specific feature of bimorph is that the bending mechanism is intrinsic to the mirror itself.

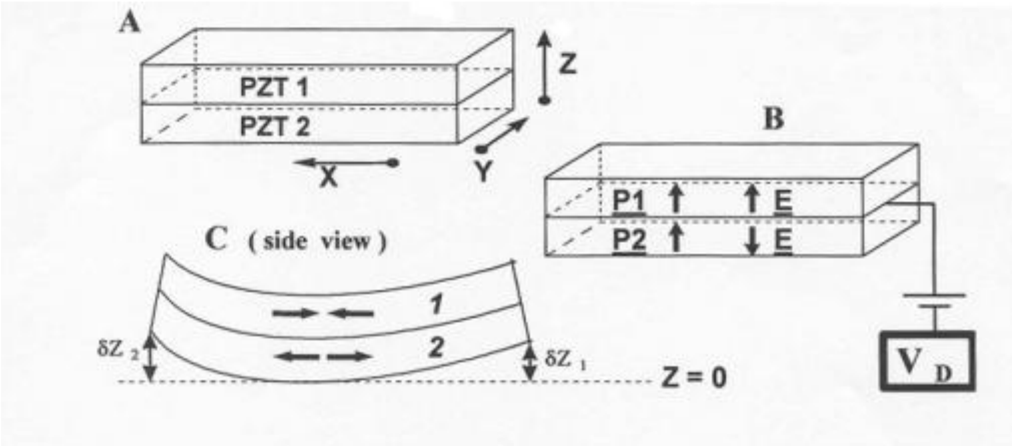
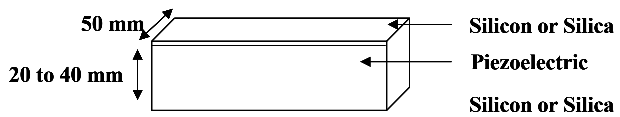
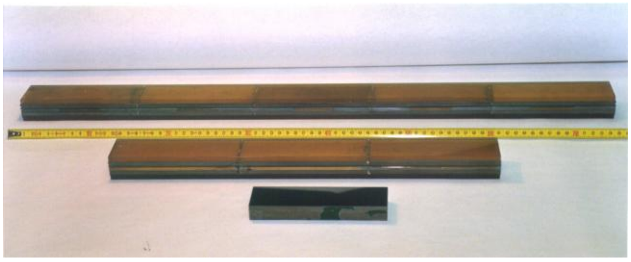


Fig. 2: PBMs bending principle (see text). The neutral plates on top of PZT1 and on the bottom of PZT2 are not represented for sake of clarity. The control electrode is situated at the Pzt-Pzt bonding interface. V_D represents the high voltage power supply.





Advantage of the bimorph design

- Up to 8 or 32 electrodes available, so correction of high space frequencies errors (a mechanical bender can only correct for the length if one actuator or the ½ length if two actuators).
- Can correct defect of the complete beamline
- Adaptive zonal control
- Compact and lightweight design
- No mechanism moving part

Note: no cooling available, can only works in monochromatic beam.

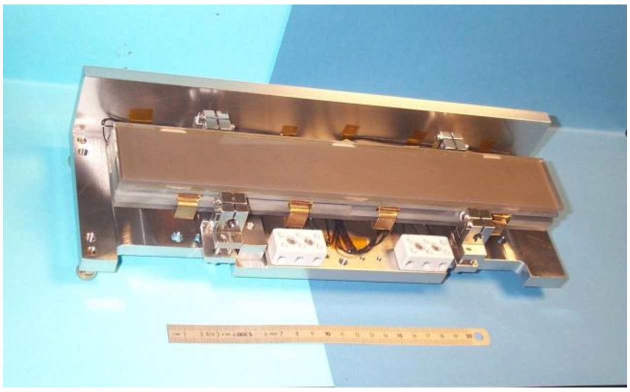
Specifications

We can offer:	
	- **Mirrors with length up to 1050 mm** - **Width up to 45 mm** - **Slope error: 2 µrad RMS (no voltage applied)** **1 µrad RMS after correction** **(can include correction of previous mirrors)** - **Mechanical structure compatible with horizontal and vertical focusing**

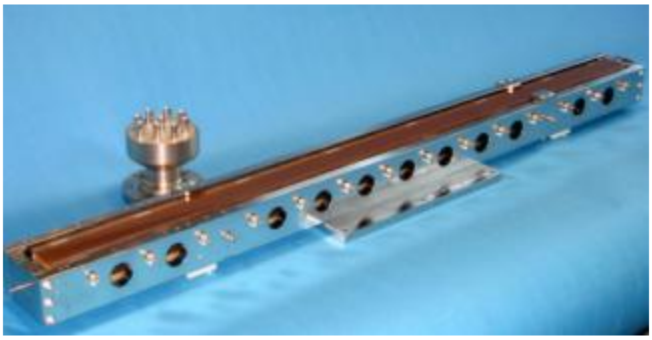
Our references

Customer	Bimorph mirrors manufactured
ESRF Fr	2 mirrors of 450 mm length and 1 mirror of 750 mm length
SP8 Japan	2 mirrors of 300 mm length
APS HP-CAT USA	2 mirrors of 300 mm length
APS GMCA-CAT USA	4 mirrors of 600 to 1050 mm length
Diamond UK	6 mirrors of 600 to 1000 mm length
APS Biocat USA	1 mirror of 600 mm length
SOLEIL Fr	5 mirrors of 300 to 400 mm length
BESSY Ge	1 mirror of 600 mm
Diamond UK	2 mirrors of 600 mm and 900 mm length
APS/IXS USA	4 mirrors of 500 mm and 900 mm length
Diamond UK	2 mirrors of 150 mm and 200 mm length
APS Sector 3 USA	1 mirror of 600 mm length
SP8 Japan	1 mirror of 300 mm length
Diamond UK	1 mirror of 220 mm long; 1 mirror of 280 mm long 2 mirrors of 1050 mm long; 2 mirrors of 600 mm long
ASP – PX2 Australia	1 mirror 300 mm long; 1 mirror 450 mm long
ASP – SAXS Australia	1 mirror 300 mm long; 1 mirror 750 mm long
LS-CAT USA	2 mirrors 400 mm long; 2 mirrors 700 mm long
Diamond UK	1 mirror 550 mm long – 1 mirror 1000 mm long
BNL USA	1 mirror 850 mm long – 1 mirror 400 mm long
IMCA-CAT USA	1 mirror 1000 mm long – 1 mirror 550 mm long
APS USA	1 mirror 550 mm long
DLS UK	1 mirror 150 mm long
KEK Japan	1 mirror 600 mm long – 1 mirror 450 mm long
EMBL Germany	3 mirrors 300 mm long – 3 mirrors 450 mm long
SOLEIL France	2 mirrors 450 mm long
Australian Synchrotron	1 mirror 300 mm long
DLS UK	1 mirror 600 mm long
DESY Germany	1 mirror 800 mm long

At today THALES SESO has manufactured more than 69 Bimophs.



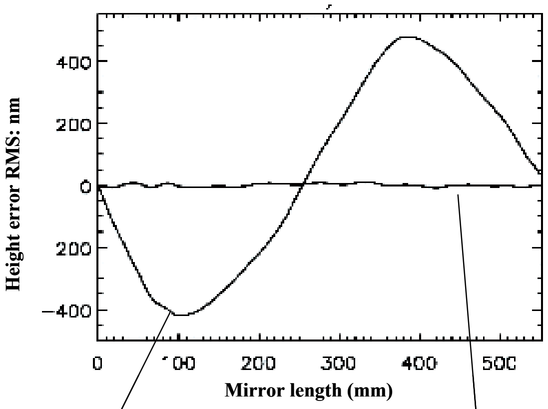
Bimorph mirror 1050 mm length →



600 mm Bimorph Mirror bent to a sphere of 5.24 km with adaptative correction

Shape error

Initial: 307 nm rms / Final: 4.6 nm rms

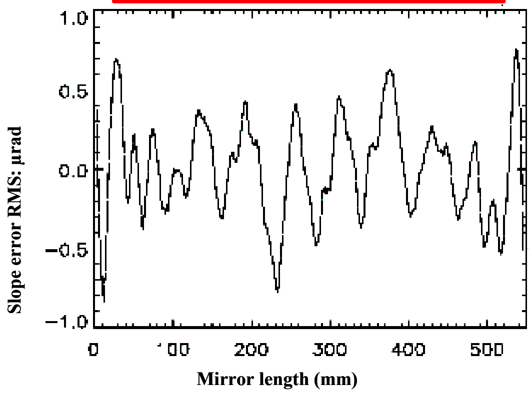


Main effect is due to gravity

After adaptative correction residue = 46 A RMS

Slope error

Final slope error: 0.31 µrad RMS



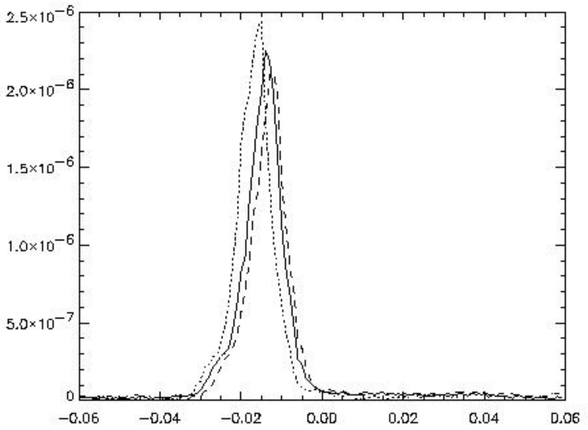
➔ Correction of gravity effect and polishing errors

ELLETRA LOT MEASUREMENTS (S. COCCO & G. SOSTERO)

Results obtained on HP-CAT

KB Configuration of 2 bimorphs of 300 mm length: demagnification 40:1 62-1

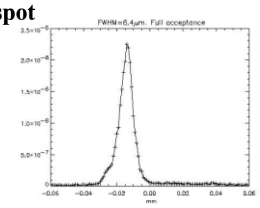
Stability



Better than 1µm at 1 m on a 18th hour run
No change of focal size

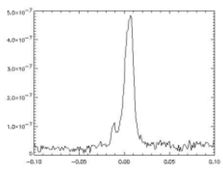
Wavefront correction

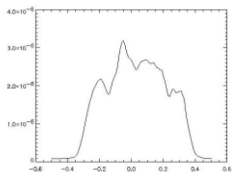
- **Optimized spot**



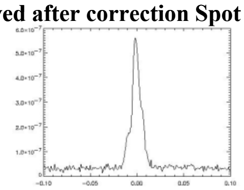
6 µm FWHM

- **Spot achieved after introduction of a X Tool in the beam and corresponding wavefront**



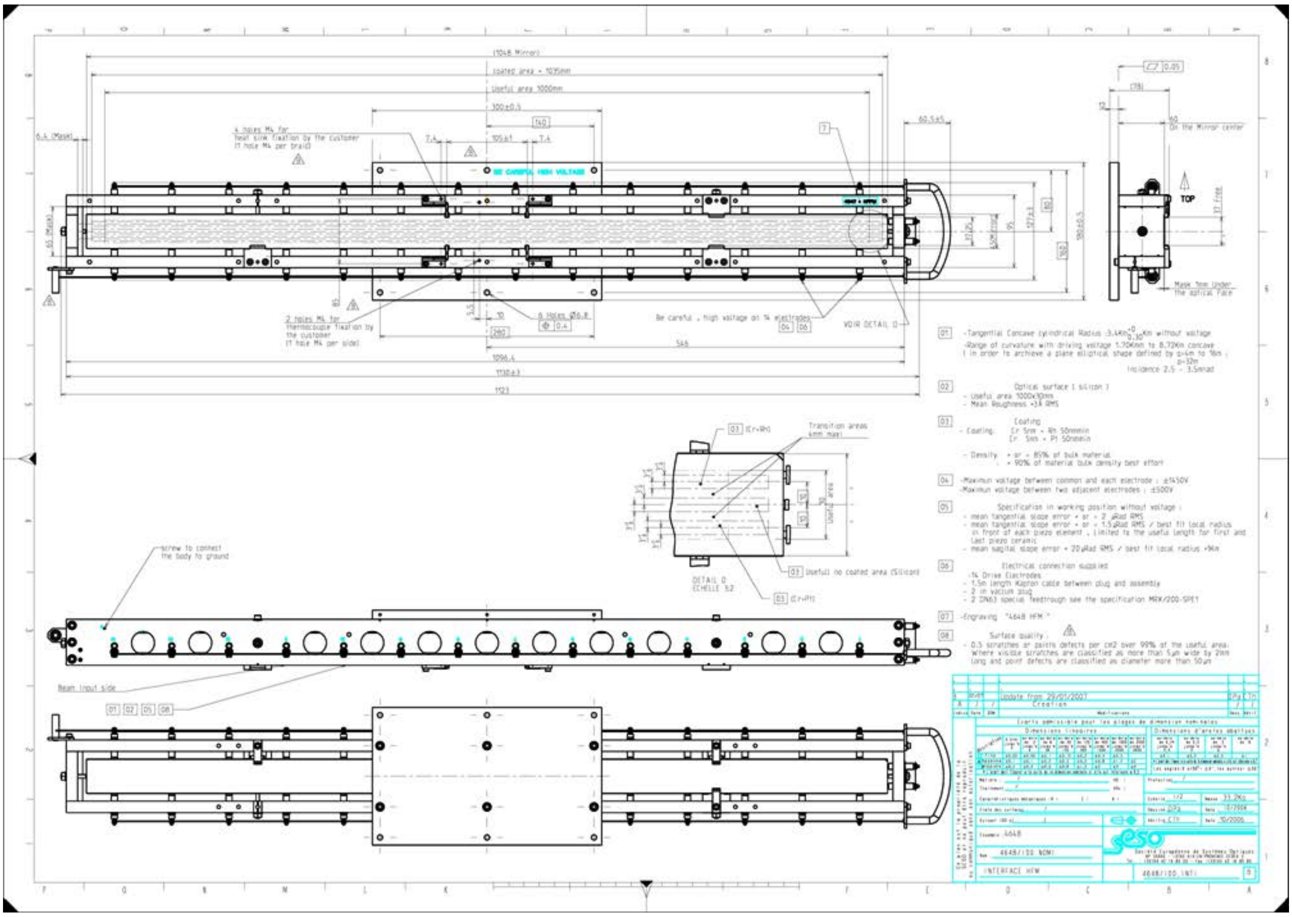


- **Spot achieved after correction Spot achieved after**

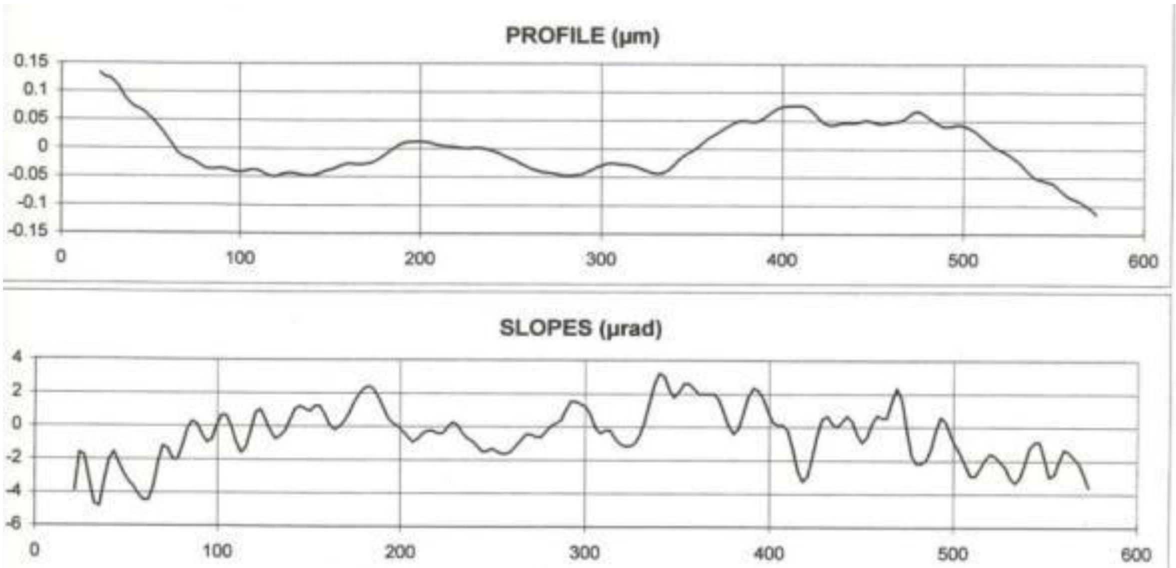


DATA COLLECTED BY Dr. Riccardo SIGNORATO

Drawing of an 1000 mm Bimorph Mirror



Slope error on a 600 mm length Bimorph Mirror

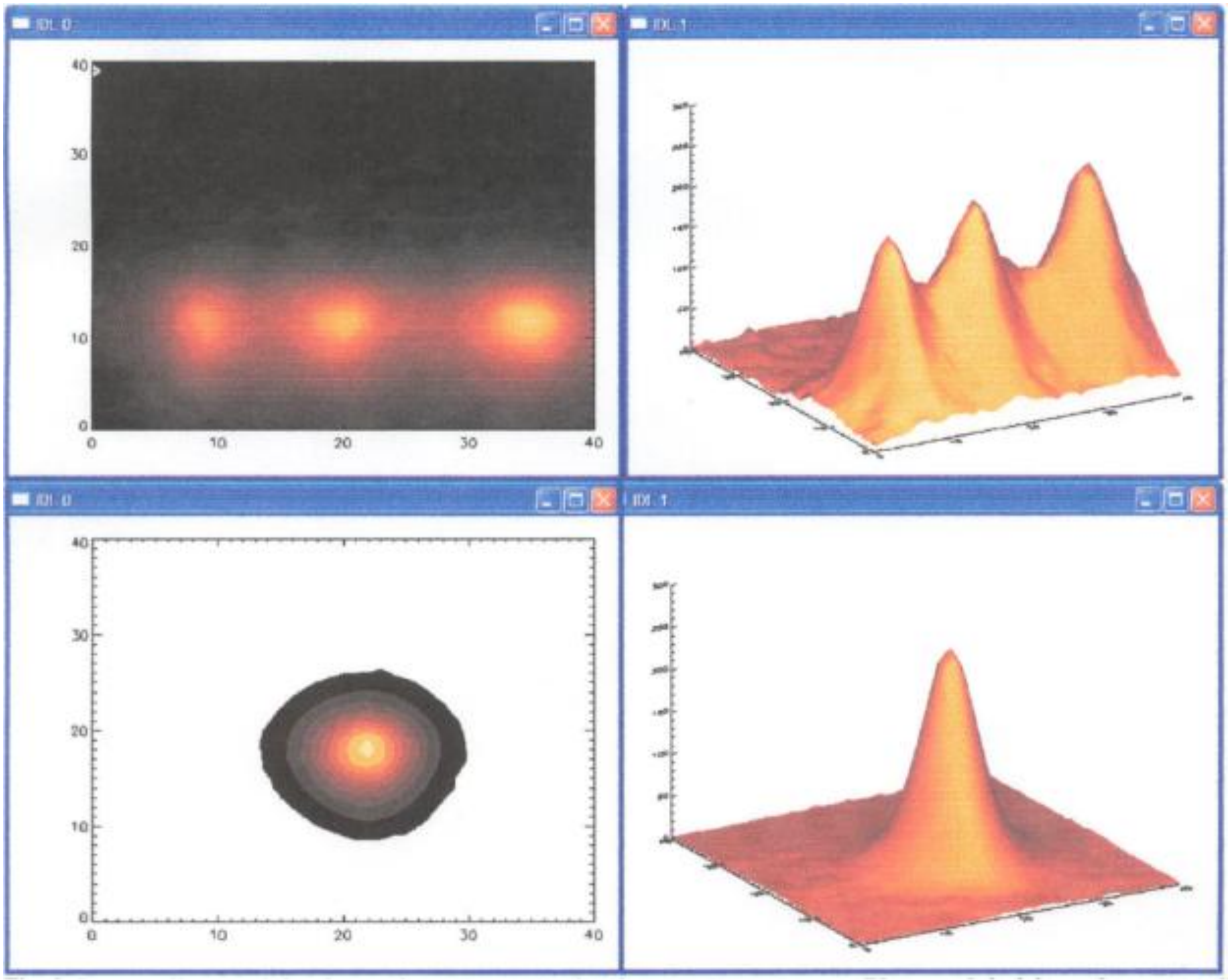


- ✓ Unbent: 1.8 µrad rms
- ✓ Radius = 3 km
- ✓ On each segment: < 1.5 µrad

THALES

Beam profiles recorded at the sample position

Units: lengths in µm, intensity in a.u. (upper row)

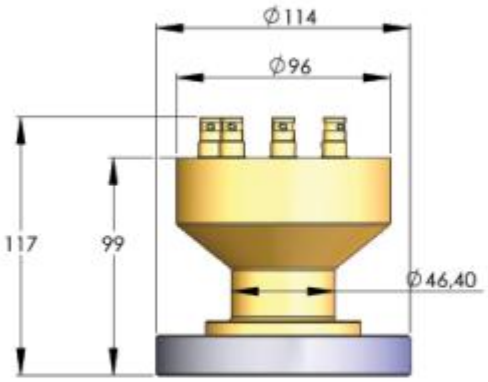


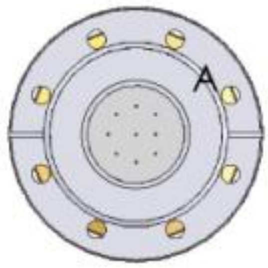
	***Bimorph Mirrors for Nanofocalisation*** **Length 150 mm** **16 Electrodes** **Possible minimum radius of about 40 m**

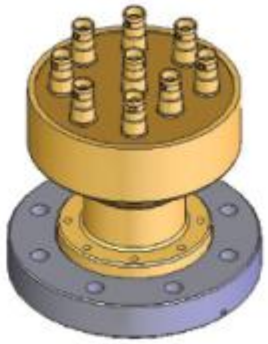
Vacuum electrical feed-through 9 circuits

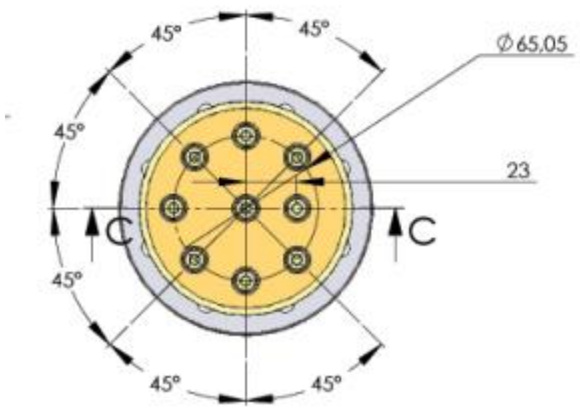
Specifications

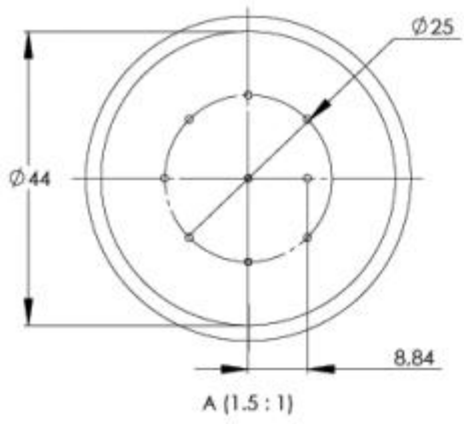
- Stainless steel flange DN 63 CF
- 9 circuits with female BNC SHV on airside, golded pins 1mm diameter on vacuum side
- Insulation for 2000 V pick between mass and pins, 4000 V between pins
- Applicable vacuum 1E-9 mbar
- Max bakeout temperature 100 °C
- He leak rate lower than 2E-9 mbar.l/s
- Total of the partial pressures < 1E-9 mbar for molecular mass M>= 46
- Total of the partial pressures < 1E-9 mbar for M = 19, 35, 37, 41, 55 and 57
- Partial pressure <=5E-10 mbar for each M = 19, 35, 37, 41, 55 and 57





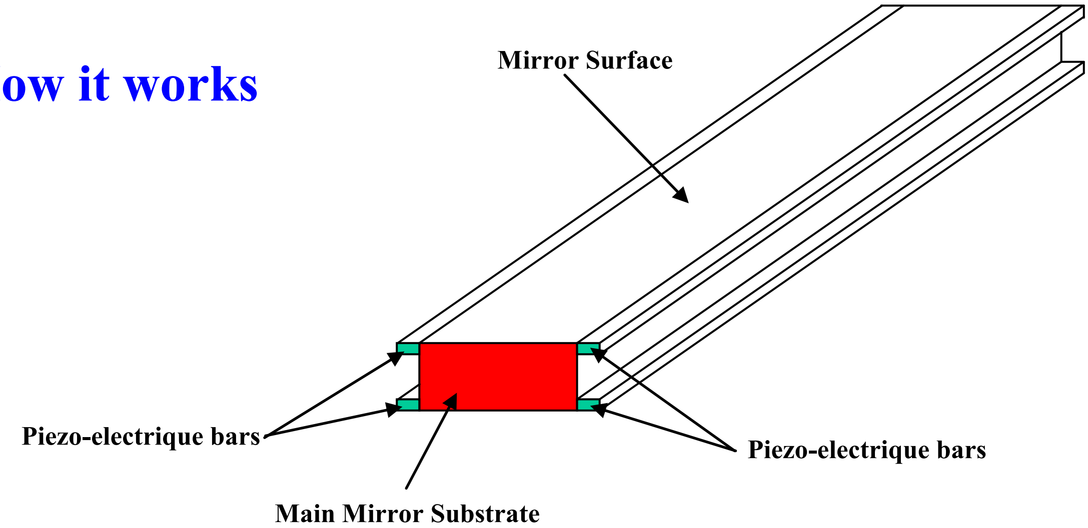




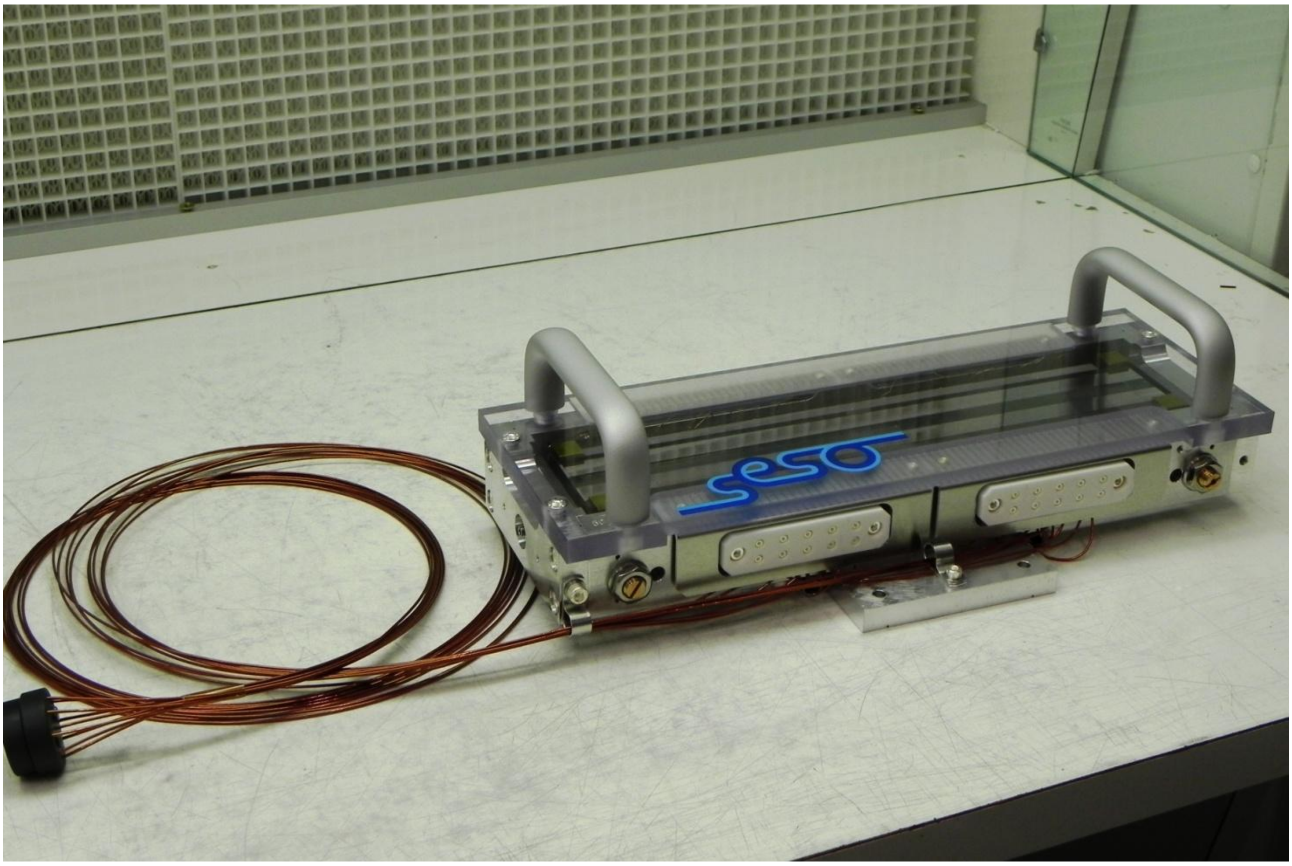


NEW ADAPTIVE OPTICS

How it works

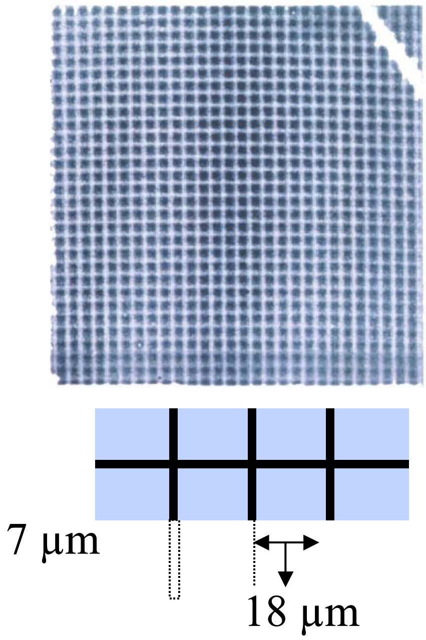


Patent 1000471-05/02/2010



CHAPTER 4
WOLTER - K B

X-RAYS MICROSCOPE



- ✓ **Resolution: 3 µm**
- ✓ **Field of view ≥ 0.4 mm x 1 mm**
- ✓ **Collecting angle: 1 mrad**
- ✓ **Magnification: x17 to x40**
- ✓ **Energy bandwidth: 1 to 5 keV**

KIRKPATRICK-BAEZ DESCRIPTION

Mirrors:

- Length 100 mm to 300 mm
- Focusing distance 0,8 m to 1,5 m
- Elliptical shape
- Slope error < 0,2” RMS to 0,5” RMS
- Roughness < 5 Å RMS

Different possibilities are implemented:

- Focusing adjustment
- Adaptation of elliptical profile

Adjustment can be made from outside of the vacuum chamber by actuators:

- Manual
- Driven by stepper motor

Equation of the elliptical profile is:

$$f(x) = A_1x^2 + A_2x^3 + \varepsilon (x)$$

ε (x) = error between elliptical profile and approximation by x2 and x3 development

A_1 = focusing term
A_2 = elliptical term

Manufacture of the mirrors:

- They will be polished with a radius greater than the maximum value of the range,

- Higher order terms will be corrected as follow :

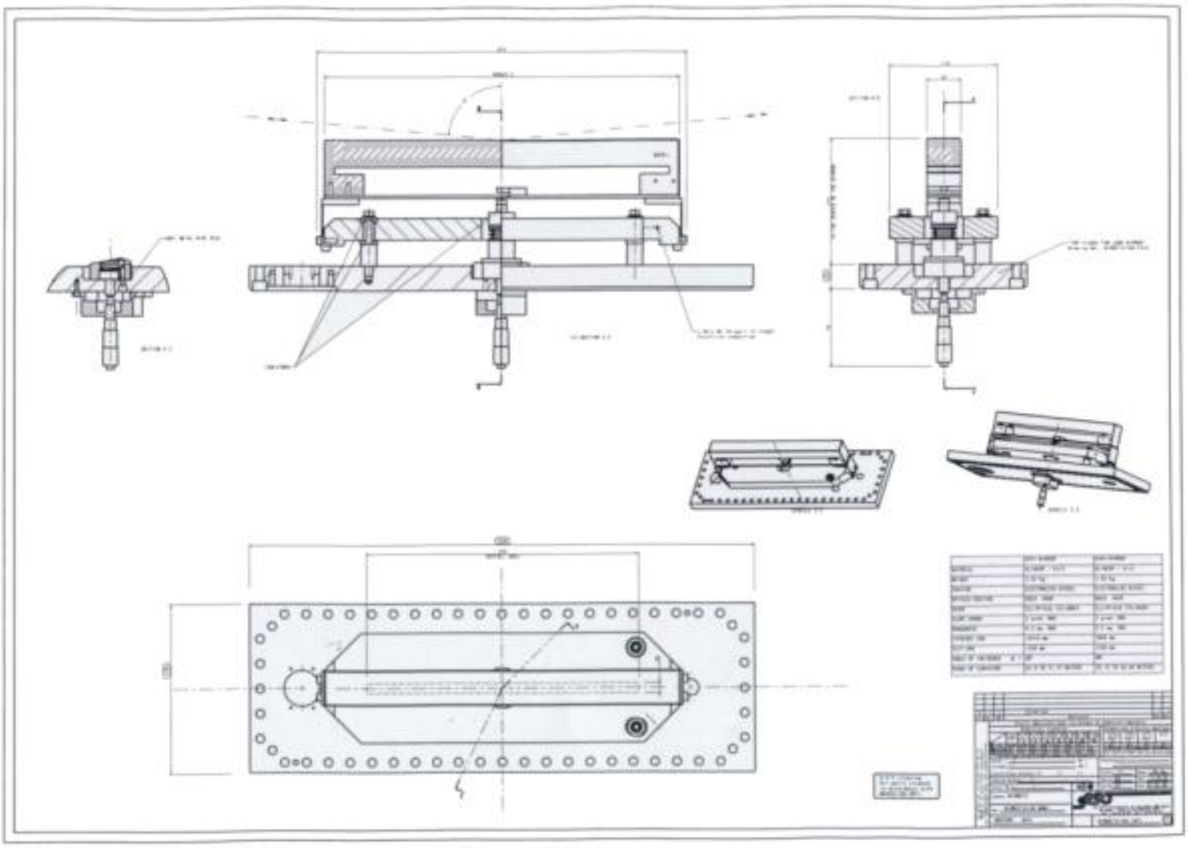
  - If A_2 is variable

    - A_2 term will be obtained through actuator
    - Higher order by polishing

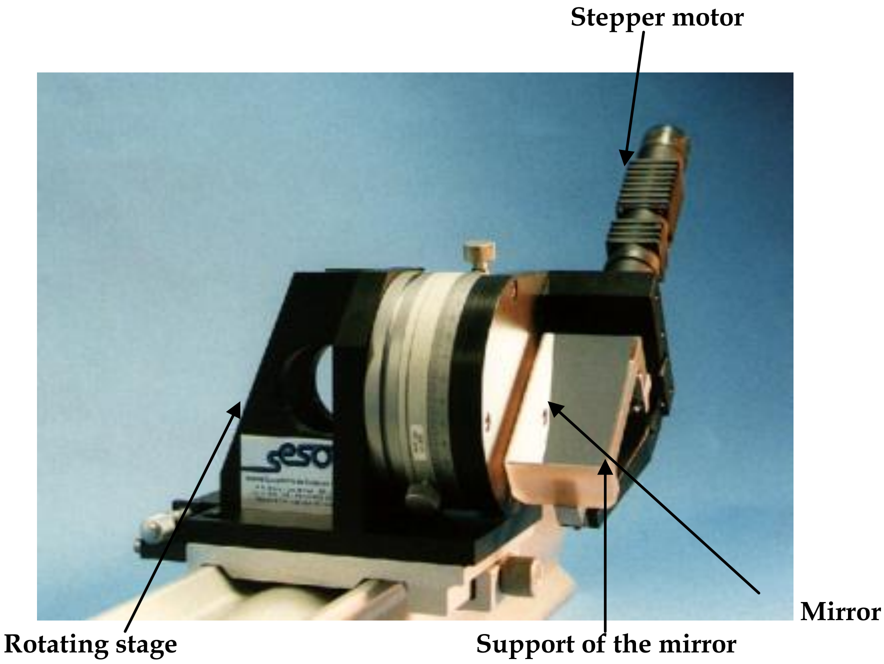
  - If A_2 is not variable

    - A_2 and higher terms will be obtained by polishing.

Manual Adjustment of Focusing (A1 term)



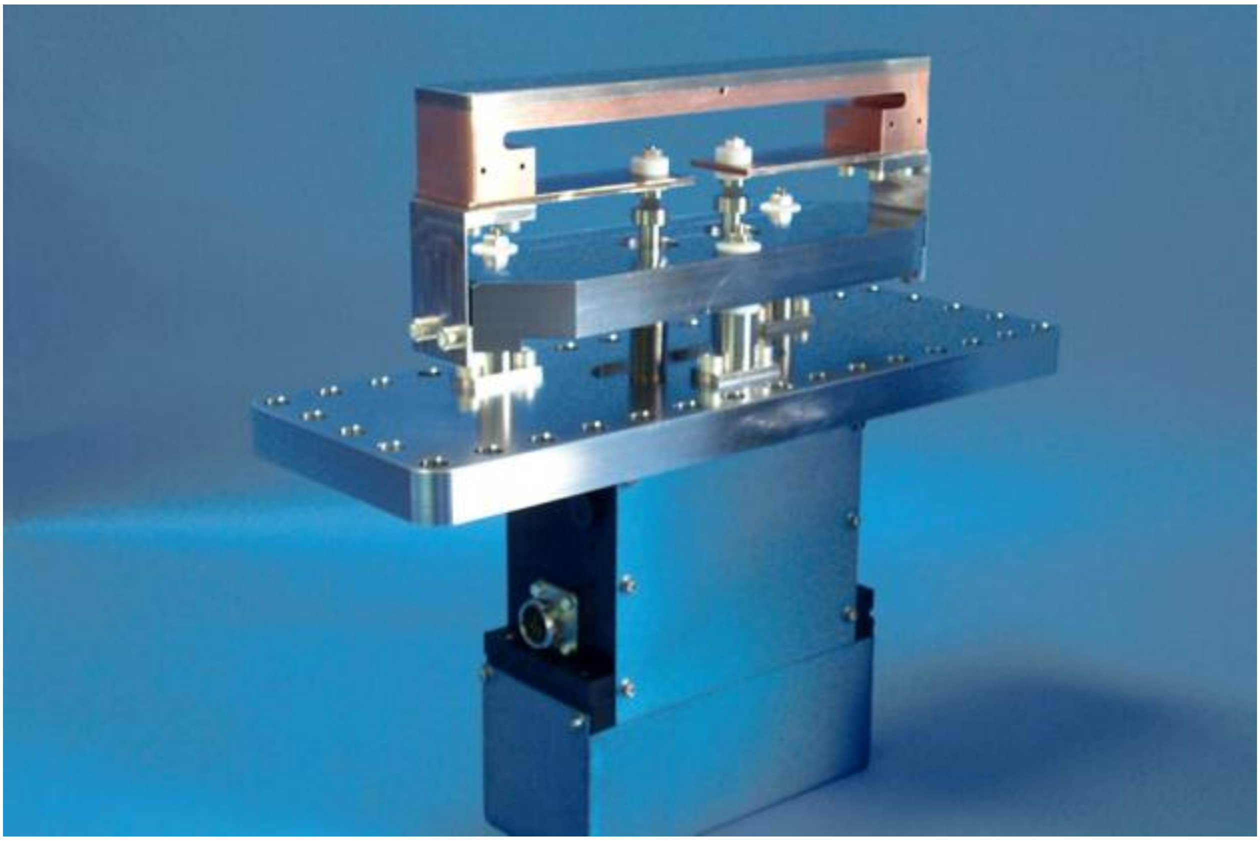
100 mm U Bender:



The fixture of the mirror has been designed in order to not stress the mirror.

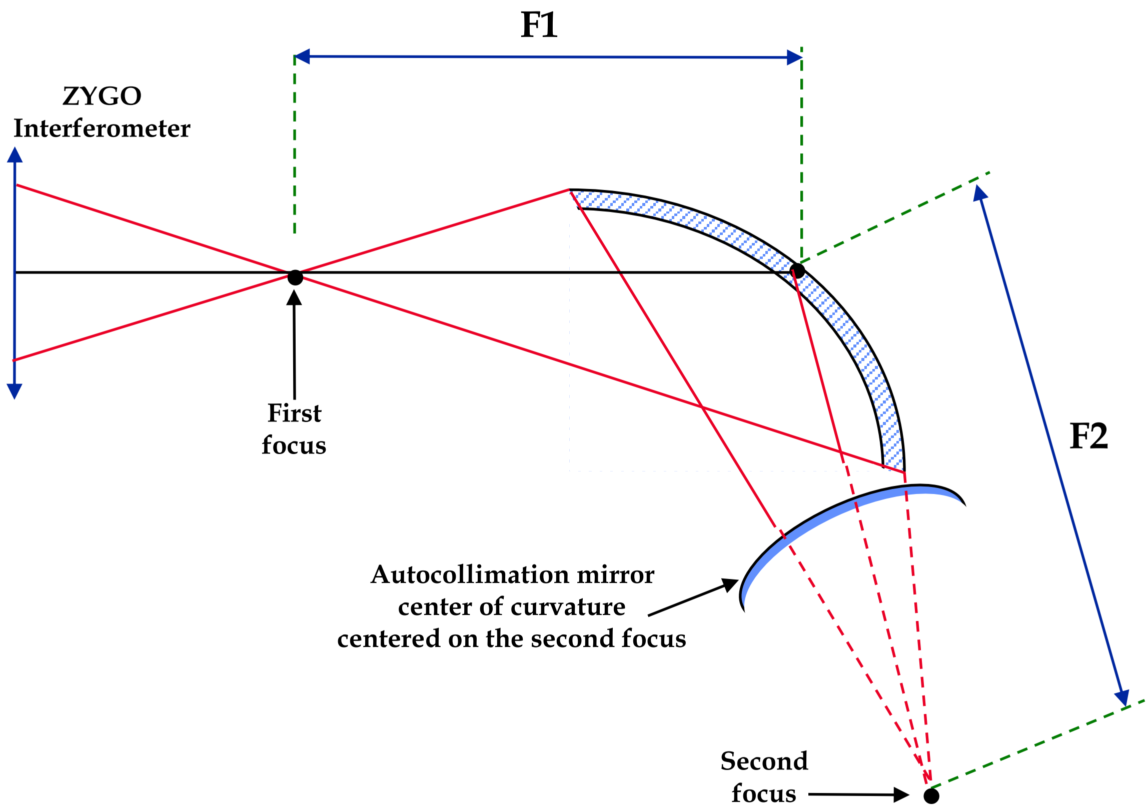
KB Mirror (A_1) with focusing and elliptical (A_2) shape driven by stepper motors:

KB (A1) with focusing and elliptical (A2) shape driven by stepper motors



Test method:

We are checking the mirrors by grazing incidence interferometry:



We compare the shape of the mirror with the elliptical profile including all higher order terms.

Example of some manufactured mirrors:

F1 (m)	F2 (m)
1,35	10,41
1,16	7,85
0,8	15,45
0,61	12,89
1,685	3,25
0,65	3,25
1,185	3,75
0,15	3,75

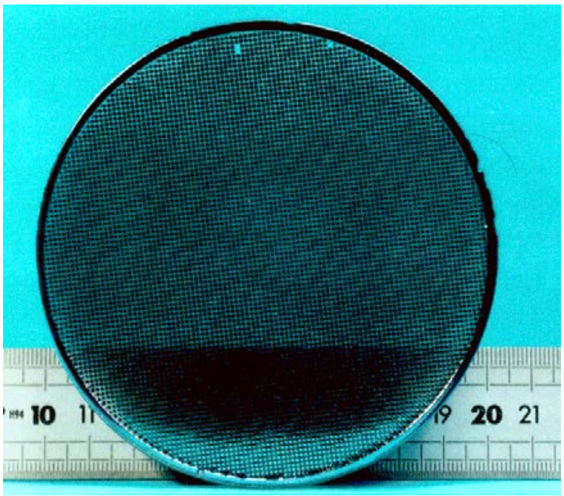
CHAPTER 5
CRYSTAL ANALYSERS
EUV COLLECTOR
MANDREL

ESRF Crystal analysers for inelastic x-ray scattering from phonons

THALES SESO can provide:

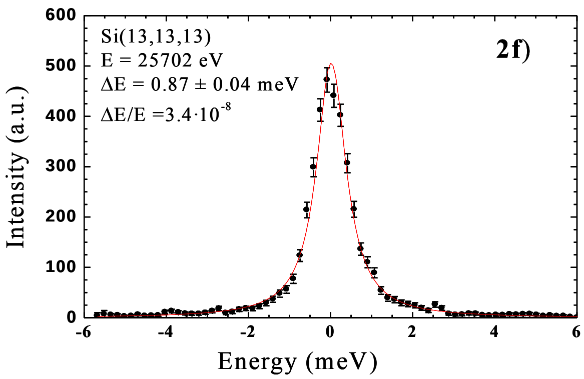
Components	⇒ Concave substrate diameter 100mm in Silicon Radius 1m ; 2m ; 6m ; 10m ⇒ Parallel flats in Fz Silicon diameter 100mm Thickness 3mm ; Roughness 2 Å
Integrated crystal analysers [Orientation 1-1-1)]	⇒ With continuous Crystal ⇒ With cross grooved patterned Crystal for best efficiency ⇒ 1/1 Rowland geometry

Our references: ESRF R. Verbini, M. Krisch, G. Monaco



Reflection	Energy [keV]	ΔE [meV]
(7 7 7)	13.840	7
(8 8 8)	15.819	5.5
(9 9 9)	17.794	3
(11 11 11)	21.747	1.5
(13 13 13)	25.704	0.9

Best Resolution so far obtained:



EUV COLLECTOR

Principle

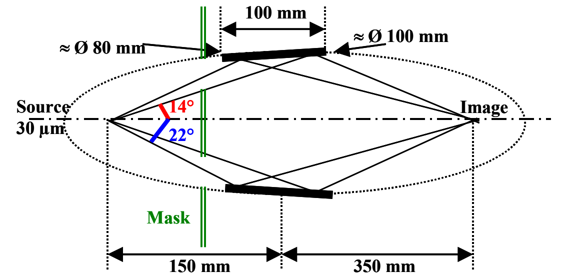
- ✓ Elliptical surface

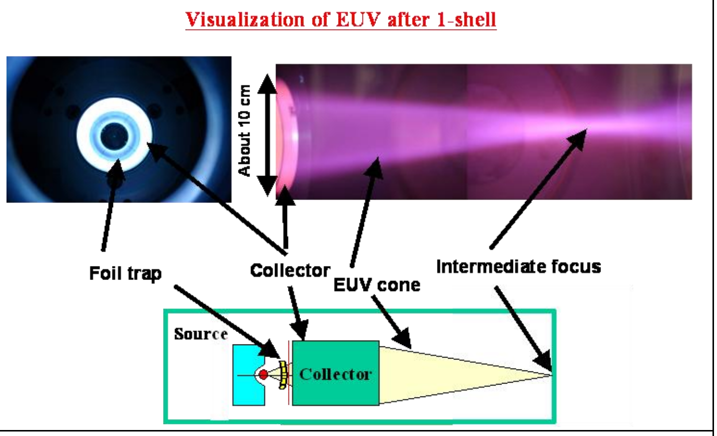
Characteristics

- ✓ Reflective diameter: about 100mm
- ✓ Major axis: 255mm
- ✓ Minor axis 50mm
- ✓ Magnification factor: 3

Performances

- ✓ Collecting angle between ± 14° to ± 22°
- ✓ Image quality: better than 400 microns
- ✓ Reflecting surface roughness: lower than 1nm rms (optical measurements by Micromap)
- ✓ Coating: gold





Results presented with courtesy of ASML EUV Laboratory

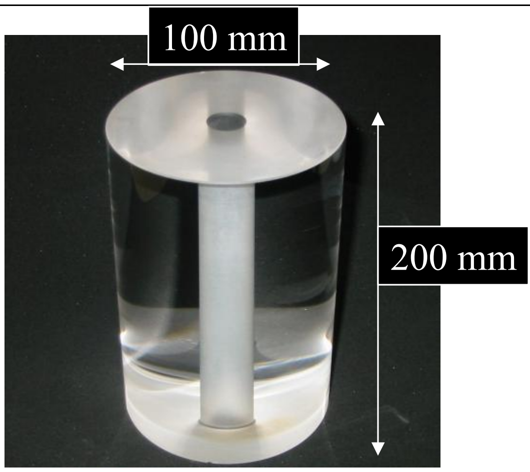
MANDRELS FOR X-RAY TELESCOPES

Telescopes are mainly based on Wolter design. Mirrors used in these optics are generally made by replica.

Circularity 3 µm
Slope error < 1" rms
Roughness < 3 Å rms

Our capabilities:

- ✓ **Up to 600mm diameter**
- ✓ **Up to 1500mm length**



Constellation X Mandrel

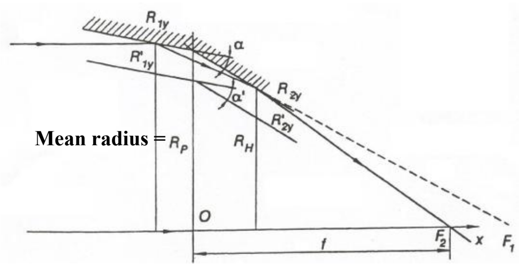
Bendable off-axis Mandrel for Wolter Telescope (THALES SESO patent No. 99 403263.9)

With one mandrel, possibility of moulding 5 different shells.
Example based on XEUS Telescope:

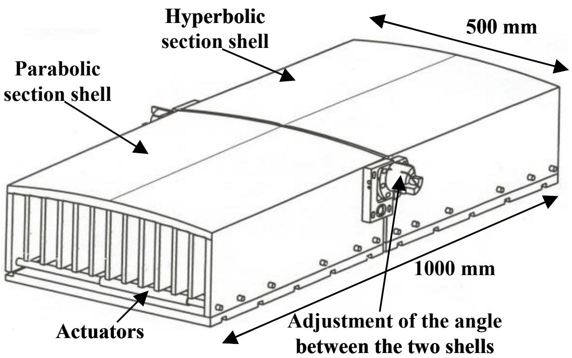
Mean radius (Rp)	Image quality due to bending
1889 mm	0.8 arc second RMS
1894 mm	0.4 arc second RMS
1900 mm	0 (mandrel realised for this diameter)
1906 mm	0.4 arc second RMS
1911 mm	0.8 arc second RMS

- **Parabola and hyperbola moulded at the same time**
- **Can also be used for one shell production (simpler)**

Theoretical parameters



Design of the mandrel



CHAPTER 6
X B M

X-RAY BEAM MONITOR

XBM camera

System includes: Optics (fluorescent coated radiation-hard glass), CCD Camera, Software, Frame Grabber, 5m Cables (up to 25m total length allowed).

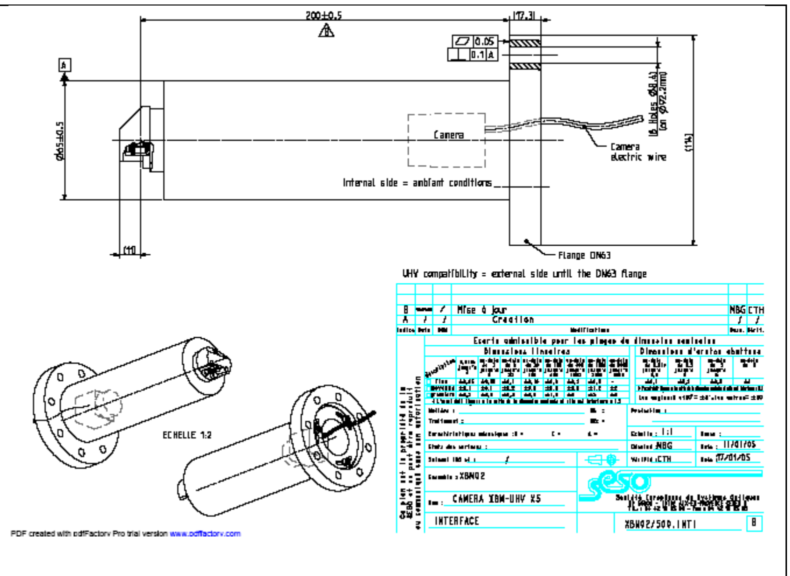
Specifications (all specifications valid for X ray beam dimension)				
Magnification	1x	2.4x	5x	x10
Image Resolution	648 x 494 pixels			
Pixel Size (µm squared)	7.4	3.1	1.5	0.74
Field of View (mm²)	5.8 x 4.9	2.4 x 2.0	1.1 x 0.9	0.6 x 0.5
Point spread function	12 µm	12 µm	6 µm	2 µm
Frame Rate	10 Hz max, depends on integration time			
Sensitivity	Better than $1x10^6$ ph/mm^2/s at 13 keV			
Spectral Response	From 5 keV to 50 keV			
Dynamic Range	Integration time from 5 µs to 0.25 s - software adjustable			
Accuracy of position measurement	< 1/100 to 1/1000 of pixel (position monitoring within 0.1 µm)			
Size	(L) 100 to 140 mm x Ø 48			
Power Supply	From the frame grabber.			

Applications

- Beam Visualisation
- Beam Displacement Monitoring and Control
- Cross calibration of non destructive detectors
- Test and Measurement
- Synchrotron Experiments

Features

- High precision
- Fast response (several Hz)
- True 8-bit digitisation
- Progressive scan readout
- High performance specifications
- Fully integrated system
- Small Size
- Light Weight
- Distance host real time communication



CHAPTER 7
SUPPORT & VESSEL

SUPPORT

- ✓ Subassembly with 3 electrical screw jacks in air
- ✓ Vertical translation and two rotations
- ✓ Linear and angular stoke limited by electrical switches
- ✓ Angular resolution: 2 µrad
- ✓ Linear resolution: 1.5 µm
- ✓ Measurement by optical encoders and inclinometers

VESSEL

- ✓ Type inversed
- ✓ Very good access to the mirror, the bender and the cooling (if fitted)
- ✓ Vacuum up to 10-9 mbar with metal gasket
- ✓ Bake-out up to 200°C
- ✓ Several feedthrough foreseen for the actuators thermal measurement, etc …
- ✓ Several portholes if needed
- ✓ Flanges for the primary and the ionic pumps (THALES SESO can deliver these equipments)

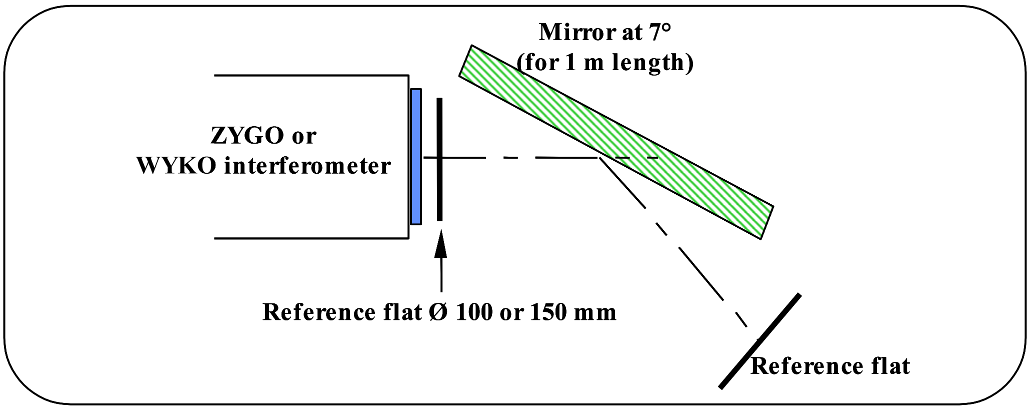
2 Mirror systems LURE H10 Beamline

CHAPTER 8
CONTROL

THALES

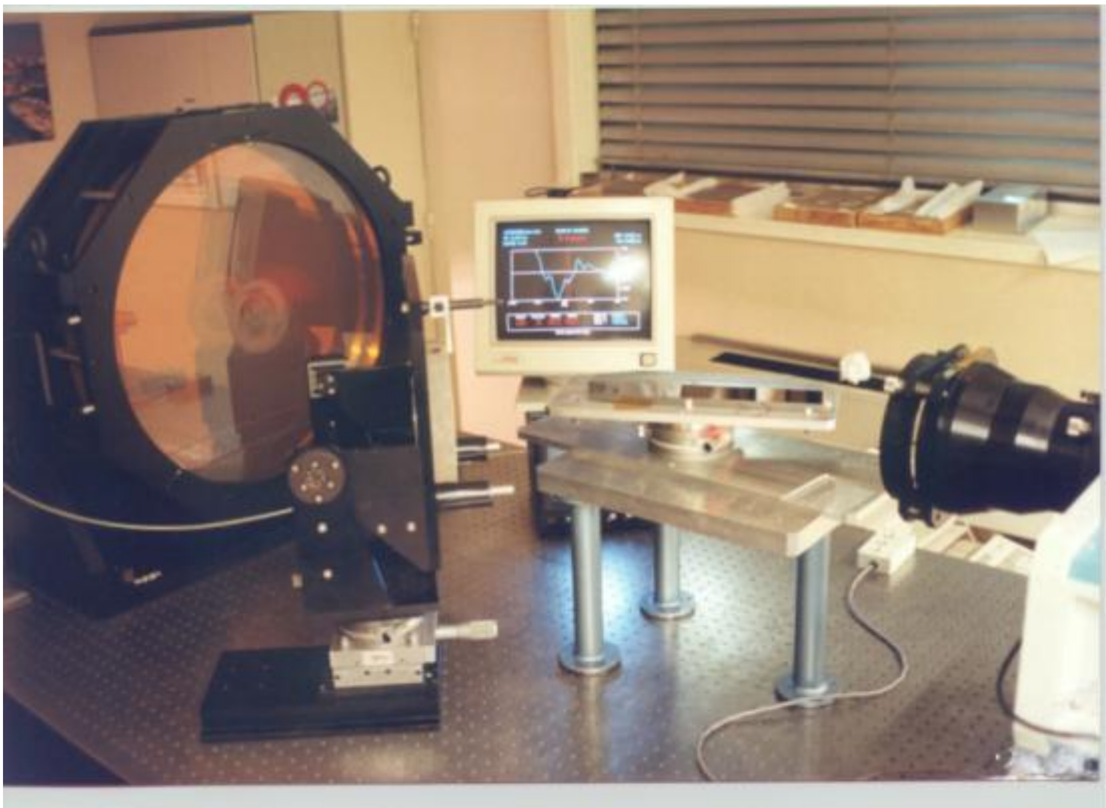
HOW WE CONTROL OUR MIRRORS

SURFACE QUALITY : With optical interfometry (ZYGO interferometer) and grazing incidence of some degrees to control longitudinal profile.



A special analysis software allows to obtain the slope error.

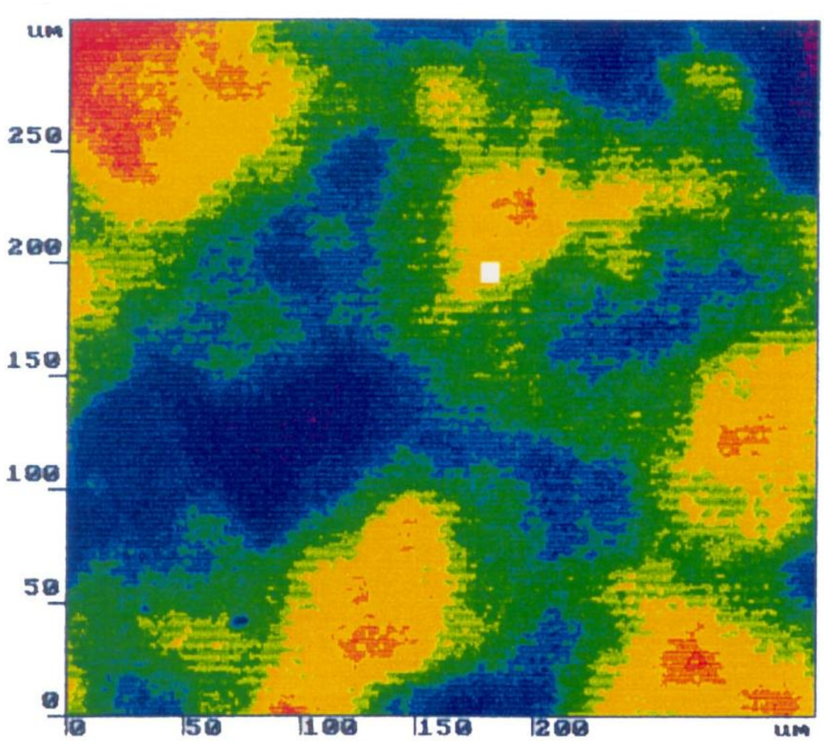
Advantage:
- **measurement in 2 or 3 seconds**
- **check of real influence of gravity (horizontal or vertical position of the bench)**
- **analysis from spatial frequencies between length of the mirror and 1/200 to 1/400 of the mirror length (2 mm to 1 m)**



ROUGHNESS

With Micromap 512 interferometer equipped with a 10x objective.

Frequencies 5µm to 1mm.



RMS : 1.70 A
Ra : 1.34 A
P-V : 12.29 A
322 µm x 309 µm

CHAPTER 9

SCIENTIST ARTICLES

Available on request:

1991	2- 4 September *(ESA SP-328)*	Cannes - France	Proc. Int. Symp. On Radars and Lidars in Earth and Planetary Sciences	LIRA a new Rayleigh Lidar System	Michel DETAILLE
1997	24- 27 June *(SP-408 August 97)*	ESTEC, Noordwijk, The Netherlands	Proc. of the Third Int. Symp. on Environmental Testing for Space Programmes	SOLAR SIMULATOR	Michel DETAILLE Alain AUCLAIR
	27 July- 1st August	San Diego, USA	SPIE 3152-12 - Optical Science, Engineering and Instrumentation	New improvements in bendable mirrors	Jean-Jacques FERME
1998	19-24 July	San Diego, USA	SPIE 1998 Proceedings, 3447-12	BENDABLE MIRROS	Jean-Jacques FERME Dr. Gilbert DAHAN
1999	18- 23 July	Denver, USA - Colorado Convention Ctr	SPIE Conférence Optical Science, Engineering and Instrumentation	Microfocusing between 1 and 5 keV with Wolter type optic	Jean-Jacques FERME
2000	21- 25 August	Berlin, Germany	7th International Conference on Synchrotron Radiation Instrumentation	An advanced KB mirror pair for microfocusing	Jean-Jacques FERME
2001	11- 14 June	Marseille, France	Proceedings - ETTC Conference	SOLAR SIMULATORS	Michel DETAILLE
2002			Proc. SPIE 4501, pp 76-87, 2002 "Xray mirrors, crystals and multilayers"	Performance of the Spring-8 modular piezoelectric bimorph mirror prototype	Ricardo SIGNORATO Jean-François CARRE
2003	August 2003		SPIE 2003	Performance of an adaptative µ-focusing KB for high pressure studies at the APS	Ricardo SIGNORATO Jean-François CARRE
	29 Sept. - 3 October	St Etienne, France	Optical Systems Design 2003	LIL fused silica lenses and thin flat plates production	Jean-Jacques FERME
	29 Sept. - 3 October	St Etienne, France	Optical Systems Design 2003	Optical Contacting	Jean-Jacques FERME
	29 Sept. - 3 October	St Etienne, France	Optical Systems Design 2003	R and AR coatings for high power laser and for X, DUV, VIS, IR wavelengths	Serge DUMARTIN Patrick ROBERT Laurent HAYER
	13-15 October	Biarritz, France	Applications for High Field and Short Wavelength Sources X	Status of the art in EUV-X optic manufacture	Jean-Jacques FERME

2004	21-25 June	Glasgow, United Kingdom	SPIE 5494-14 - Astronomical Telescopes and Instrumentation	Criterion to appreciate difficulties of aspherical polishing	Christian du JEU
	21-25 June	Glasgow, United Kingdom	SPIE 5494-32 Astronomical Telescopes and Instrumentation	New improvements in reflecting-absorbing coatings for astronomy	Denis FAPPANI
	12-13 October	Rochester, USA	Conférence OPTIFAB 88th OSA 2004 - 04-C-1091- OFT	Criterion on aspherical manufacturing used as guideline for design	Christian du JEU
2005	28 August- 2 Sept.	Warsaw, Poland Warsaw University of Technology	Optics and Optoelectronics	Large dimension optics	Jean-Jacques FERME
	24-27 October	Marseille, France	1st International Conference on Optical Complex Systems & Technical Exhibition	Adaptative x-ray mirrors for synchrotron facilities	Jean-Jacques FERME
	24-27 October	Marseille, France	1st International Conference on Optical Complex Systems & Technical Exhibition	WIND LIDAR SPECTROMETER	Christian du JEU
2006	28 May - 3 June 2006	Daegu, Korea	The Ninth International Conference on SRI 2006	Adaptive X-Ray Mirrors for Synchrotron Facilities	Jean-Jacques FERME Gilbert DAHAN
	27-30 June 2006	Noordwijk, The netherlands	6th international conference on Space Optics ESTEC	Engineering tool for the qualification of optical coatings	Marilyne DAVI Daniel PERRIN Michel LEQUIME Dominic DOYLE
	14-15 December 2006	Synchrotron Soleil France	Workshop: "X-Ray and XUV Active/Adaptive Optics manufacturing and design"	Theoretical Model of Bimorph Mirror Bending	Jean-Jacques FERME
2007	26-30 August 2007	San Diego, USA	SPIE Optics and Photonics Conference	Manufacturing & Control of the aspherical mirrors for the telescope of the French Satellite Pleiades	Denis FAPPANI Hélène DUCOLLET
2008	23-28 June 2008	Palais des Congrès Marseille	Astronomical Telescope and Instrumentation	Light and lightened mirrors for Astronomy	Denis FAPPANI
	14-17 Oct 2008	Toulouse, France	ICSO 2008	High Stability Hollow Cube Corner	Jean-Jacques FERME
	14-17 Oct 2008	Toulouse, France	ICSO 2008	Manufacturing & Control of The Aspherical Mirrors For The Telescope Of The Satellite Pleiades	Hélène DUCOLLET Christian du JEU Jean-Jacques FERME
	14-17 Oct 2008	Toulouse, France	ICSO 2008	Innovative lightweight baseplate solution for stable optical benches in space programmes	Elisabetta Rugi Grond Andreas Herren Stève Mérillat Jean-Jacques FERME
	14-19 Sept 2008	KONSTANZ Germany	ESCP 08 (8th European Space Power Conference)	Multi-source Solar Simulator characterization for establishing AM0 equivalent conditions	A. Gras J.M. Fernandez-Marin J.M. Aguilar Patrick Robert C. Baur

2010	29 June to 02 July 2010	San Diego, USA	SPIE Astronomical Instrumentation	Recent Achievements with a Cryogenic Ultra-Lightweighted HB-Cesic® Mirror	Matthias R. Krödel Peter Hofbauer Christophe Devilliers Zoran Sodnik Patrick Robert
	01 August to 05 August 2010	San Diego, USA	SPIE Optics + Photonics 2010	Design and Development of the Laser Retroreflector Array (LRA) for SARAL	Vincent Costes Karine Gasc Pierre Sengenes Corinne Salcedo Bernard Passier Christian Du Jeu Laurent Escarrat
	4 October to 08 October 2010	Rhodes Island, Greece	ICSO 2010 - International Conference on Space Optics	Design and Development of the Laser Retroreflector Array (LRA) for SARAL	Vincent Costes Karine Gasc Pierre Sengenes Corinne Salcedo Bernard Passier Christian Du Jeu Laurent Escarrat
2011	05-09 September 2011	Marseille, France	SPIE Optical design and systems	Manufacturing and testing of the large lenses for Dark Energy Survey (DES) at SESO	Denis FAPPANI Julien FOUREZ

THALES

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