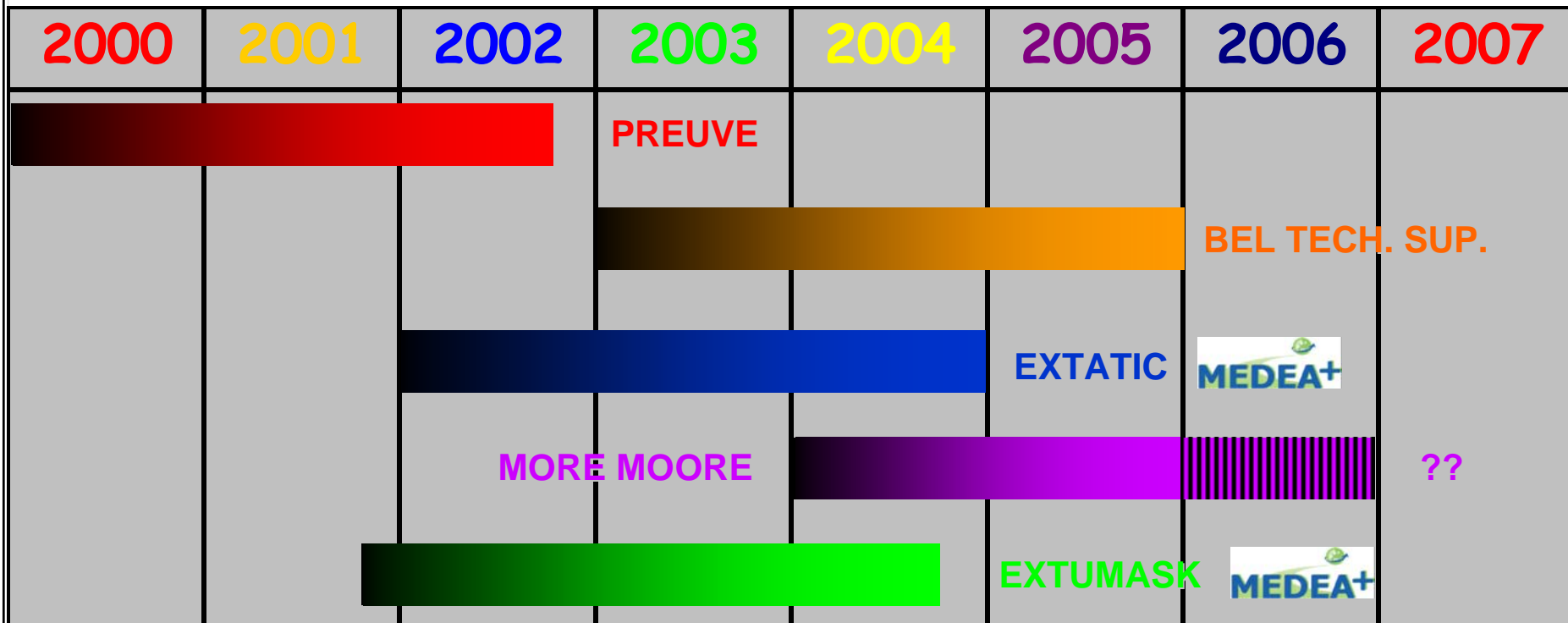


EUV projection optics and active mirror development at SAGEM

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EUV Programs at SAGEM



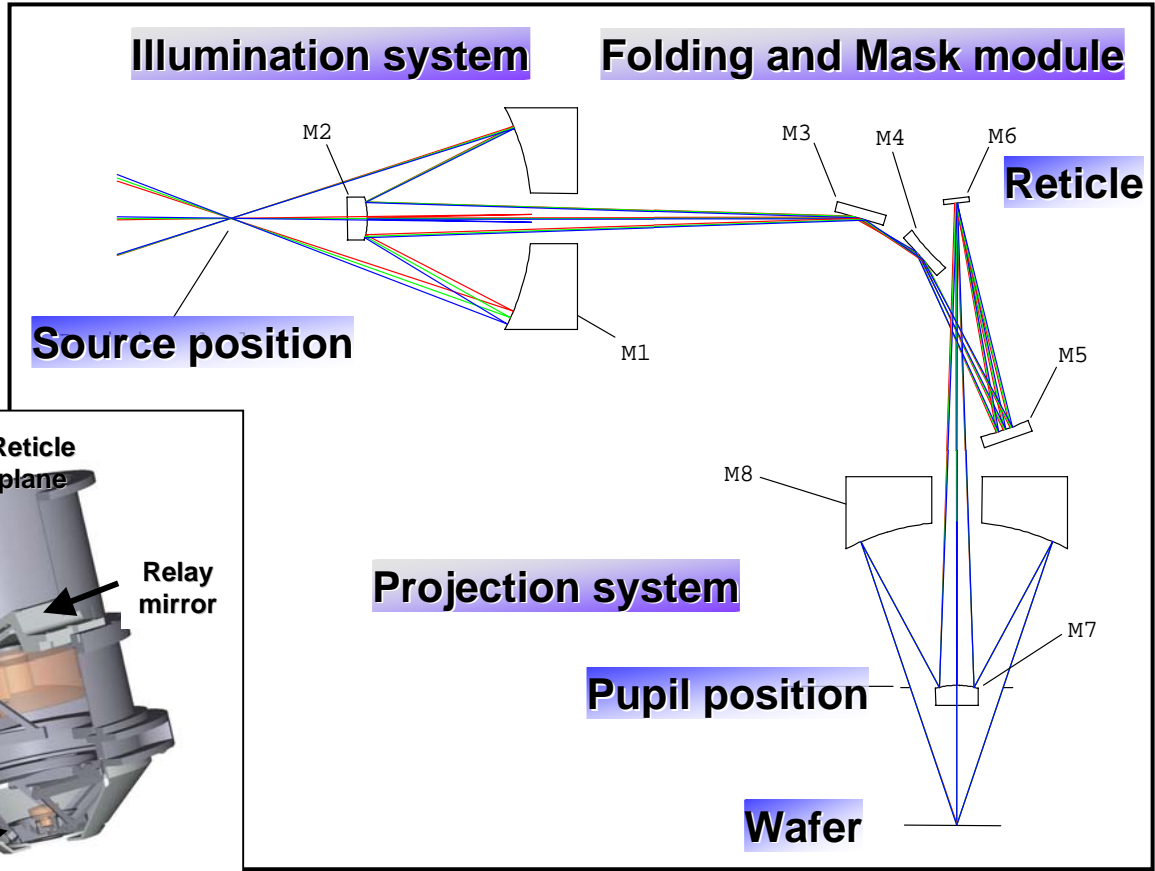
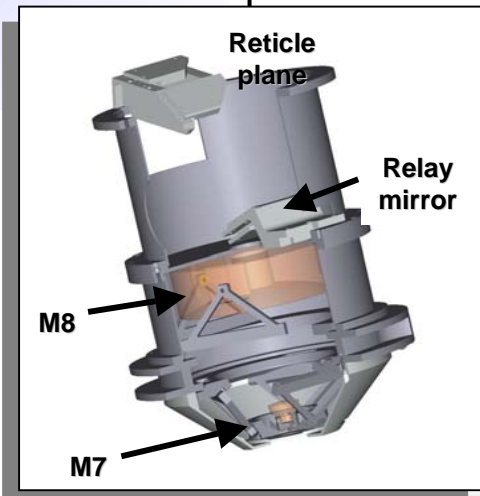
See Poster #37

SAGEM Contribution to PREUVE

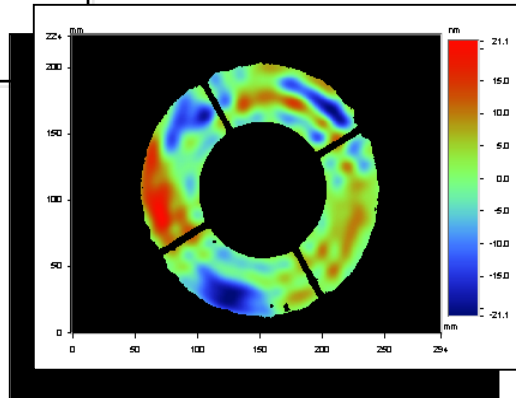
- SAGEM has manufactured the complete set of optics for the BEL (Banc d'Essai de Lithographie)

Characteristics

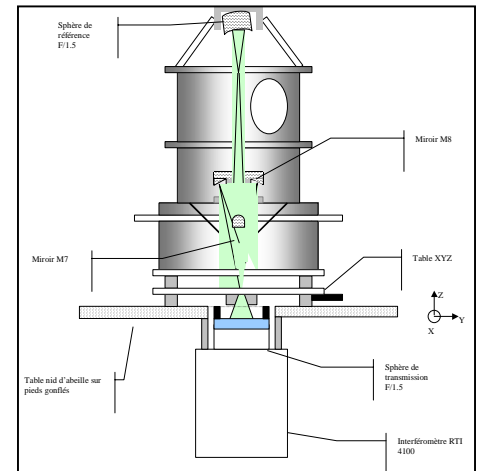
- x10 Magnification
- NA 0.32
- M7 & M8 aspherized for perfect quality over curved field.
- M8 $\varnothing = 220$ mm
- M7 $\varnothing = 50$ mm



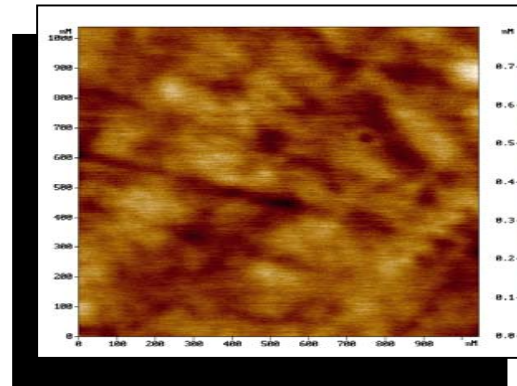
BEL Optics Performance



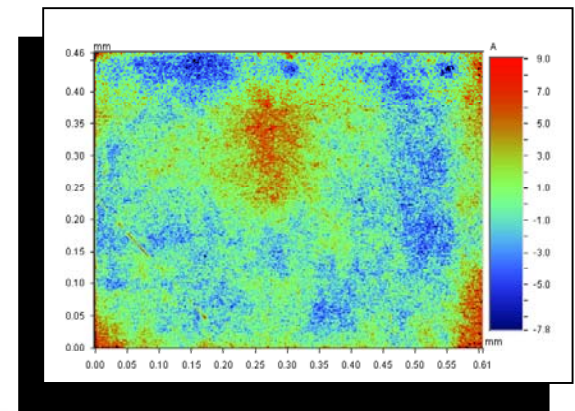
Wavefront error < 3.5 nm RMS
(simple path)



HSFR Roughness < 1.5 Å RMS
(AFM measurements)

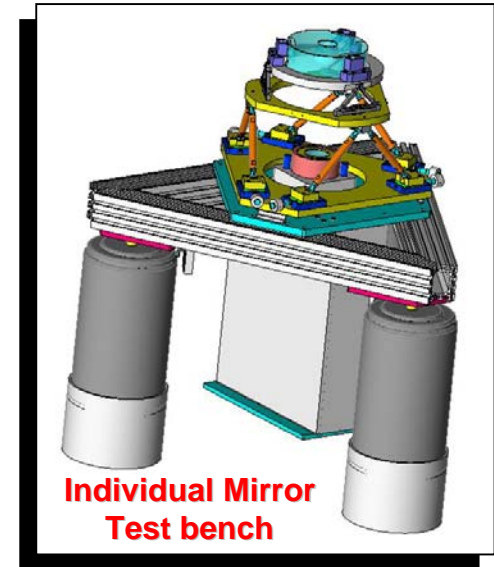


MSFR Roughness < 1.5 Å RMS
(Interferometric microscope measurements)



BEL Optics product line

- Complete set of optics installed in BEL at CEA LETI since Q4/2002.
- SAGEM provides support to the CEA LETI for BEL operations
- Metrology capabilities reinforced for individual mirrors / global performance measurement.
- New test benches to be installed in C100 integration room for optics alignment and evaluation.

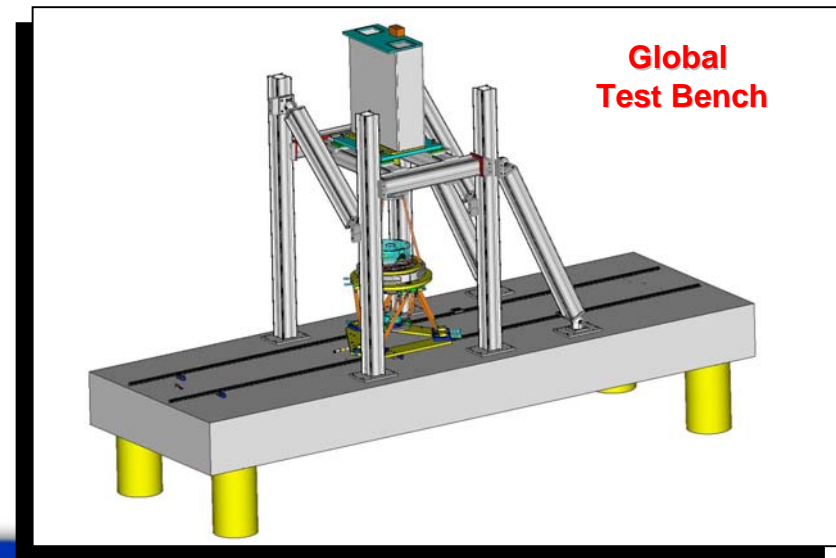


EUV Schwarzschild optics is now a new SAGEM product line

**BEL at CEA
LETI lab**

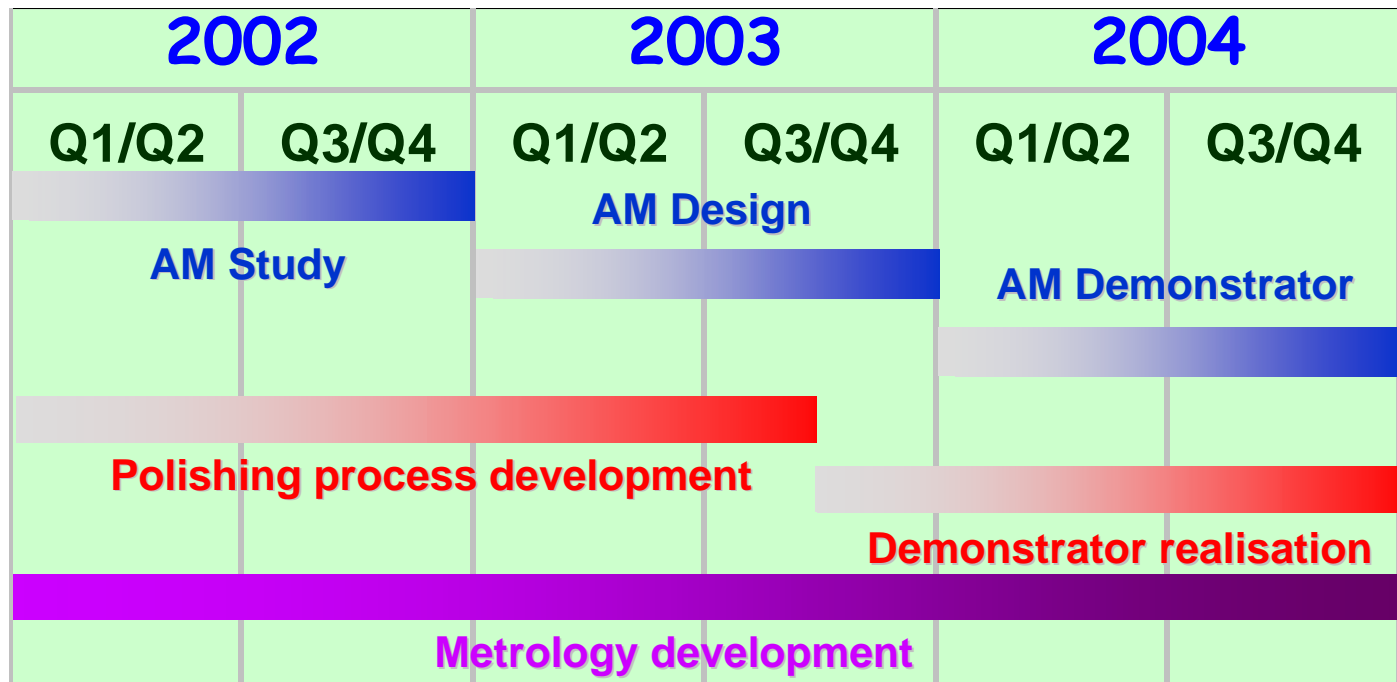


SAGEM SA



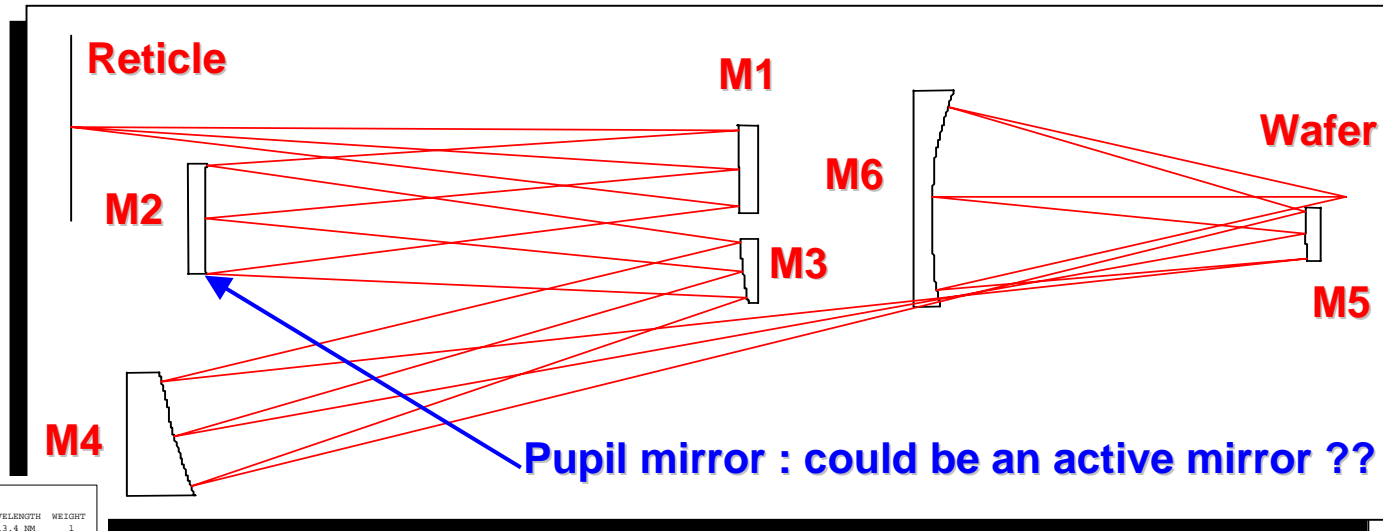
EXTATIC Program

- Through the EXTATIC program, the aim of SAGEM is to develop alternative strategies for projection optics manufacturing.
- 3 development axis have been highlighted
 - ❖ Active mirror (AM) study and design
 - ❖ Polishing process development for aspheric optics
 - ❖ Associated metrology technology improvements

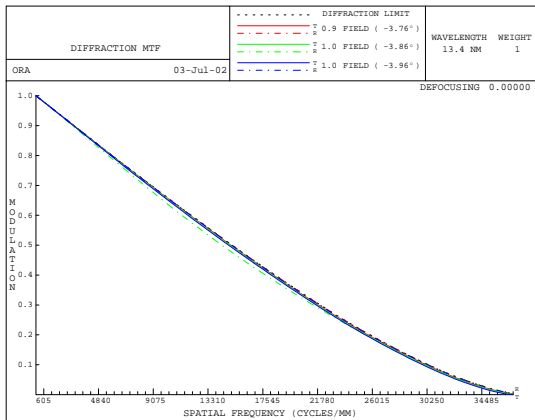


An Active Mirror could help within an EUV PO Box

■ Analysis of a PO box design



PO Box MTF



■ Active mirror function :

Quasi-static correction of tilt, decenter, radius and some Zernike surface deformations

■ Active mirror advantages :

Relax mirror manufacturing tolerances

Keep performances through operational life

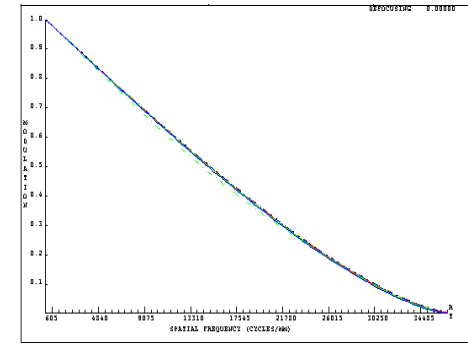
=> Reduces Cost of Ownership

SAGEM SA

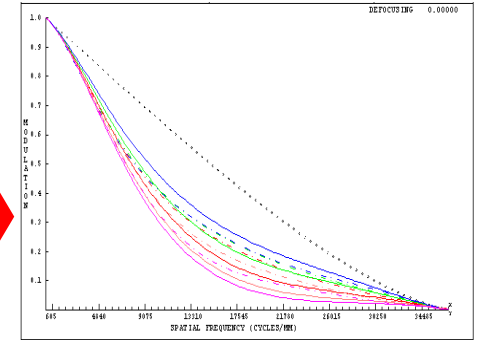
An Active Mirror reduces effects of mirrors loss of position

Example of simulated case :

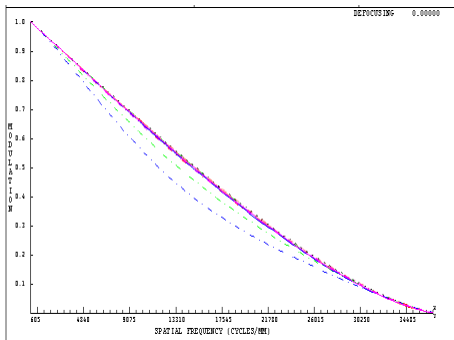
	dX (μm)	dY (μm)
M1	0.8	0.0
M3	-0.5	0.7
M4	0.3	0.8
M5	0.0	-0.8
M6	-0.9	0.3



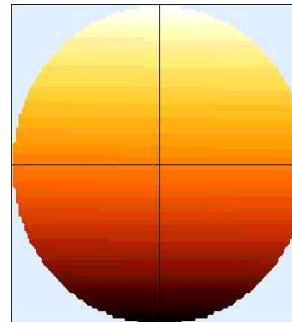
Perfect PO Box



Loss of performance



Quality is well restored

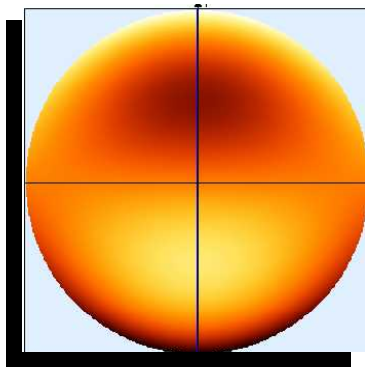


Active mirror command :

Tilt	1300 nm
Focus	1.7 nm
Astig	2.6 nm
Coma	2.6 nm
Sphere	0.13 nm

Efficiency of the Active Mirror

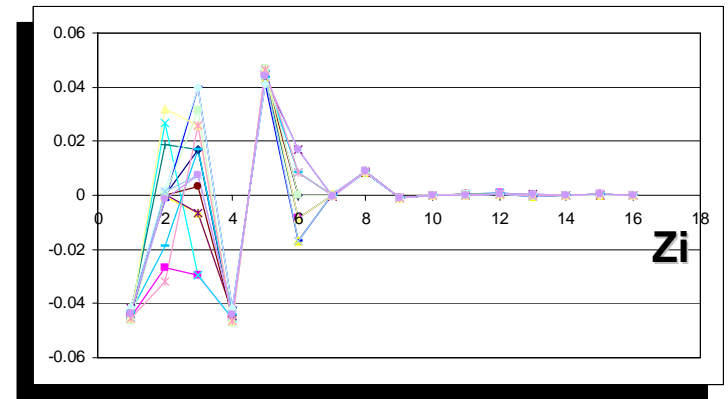
■ Surface figuring correction



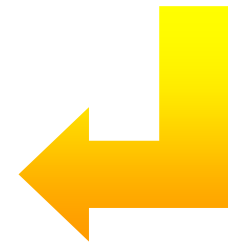
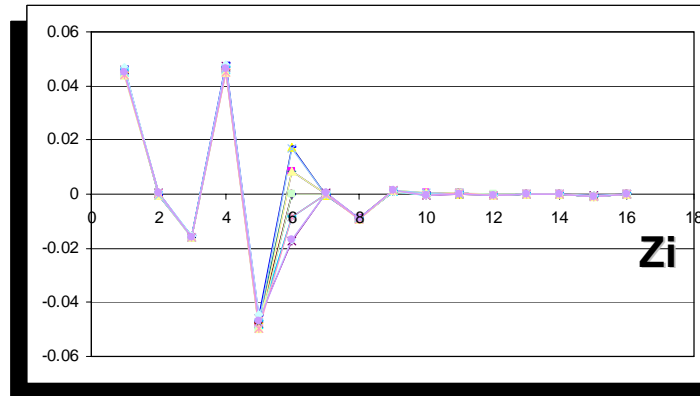
Coma on M3 mirror (Z8)



Computation of the defects generated for different zones of the ring field



Computation of the performance including active correction



Computation of the AM correction for all the zones of the ring field

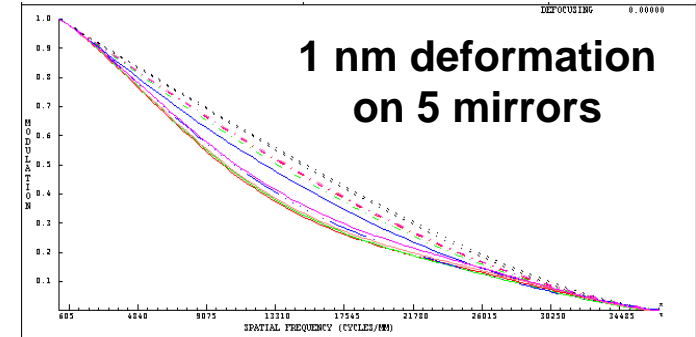
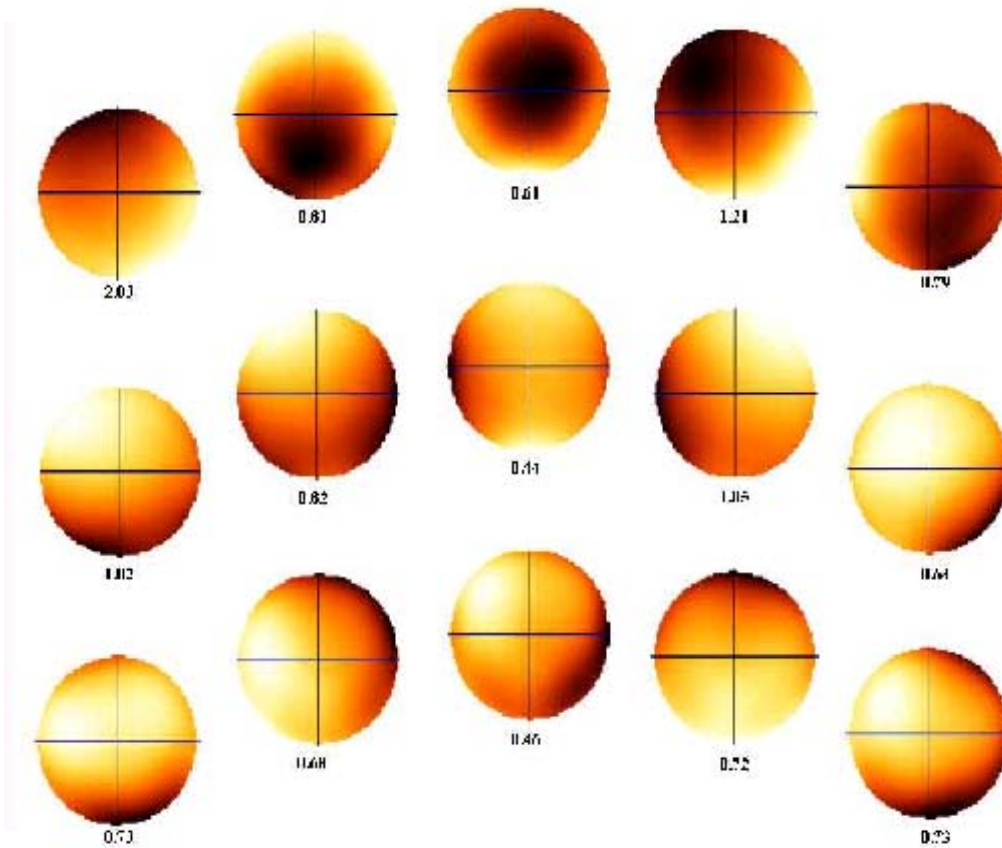
Efficiency of the Active Mirror

■ Example of mirror deformation correction

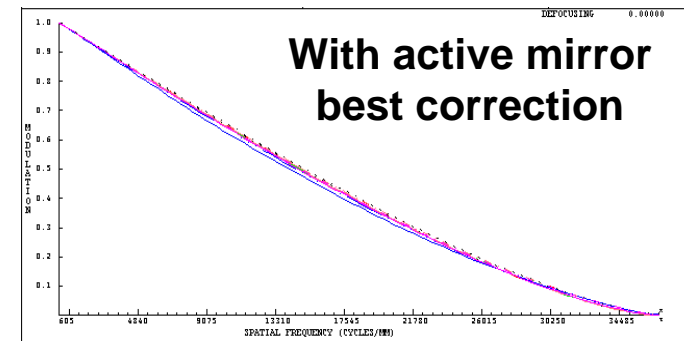
	M1	M3	M4	M5	M6
Z5	0.5	0.5	0.5	0.5	0.5
Z6	0.5	0.5	0.5	0.5	0.5
Z7	0.25	0.25	0.6	0.25	0.25
Z8	0.12	0.12	0.5	0.12	0.12
Z9	0.05	0.05	0.1	0.05	0.05
Z10	0.25	0.25	0.6	0.25	0.25
Z11	0.12	0.12	0.3	0.12	0.12
Z12	0.5	0.5	0.5	0.5	0.1
Z13	0.05	0.05	0.1	0.05	0.05
Z14	0.06	0.06	0.06	0.06	0.06
Z15	0.05	0.05	0.05	0.05	0.05
Z16	0.025	0.25	0.025	0.025	0.025
Total (nm)	0.95	0.98	1.35	0.95	0.82

Table of mirror surface errors

An Active Mirror reduces effects of mirrors loss of figure



Max : 4.11 nm RMS
Mean : 3.2 nm RMS



Max : 2.03 nm RMS
Mean : 0.85 nm RMS

The active mirror reduces

SAGEM SA image degradation by a factor 4

Efficiency of the Active Mirror is demonstrated

- Synthesis of the gains thanks to the active mirror on component manufacturing, P.O. box alignment and in-use stability requirements.

	Relaxation of manufacturing tolerances thanks to the active mirror
Centring	x4
Tilt	x4
WFE	x3 à x5
Curvature radius	x4

- ➔ Review active mirror technologies
- ➔ Selection of the technology
- ➔ Go ahead for EUV active mirror demonstrator manufacturing

Active Mirror demonstrator

■ Requirements

- The main requirements of the demonstrator are :
 - ❖ Correction of the first 10 Zernike polynomials (Z_i)
 - ❖ Correction accuracy < 0.3 nm RMS for the first 15 Z_i
 - ❖ Correction accuracy < 0.2 nm RMS for $Z_i > 15$
 - ❖ Correction stability < 0.1 nm RMS
 - ❖ Tilt stability < 0.1 μ rad
 - ❖ Dimensions : diameter 200 mm and useful aperture 180 mm

■ Progress

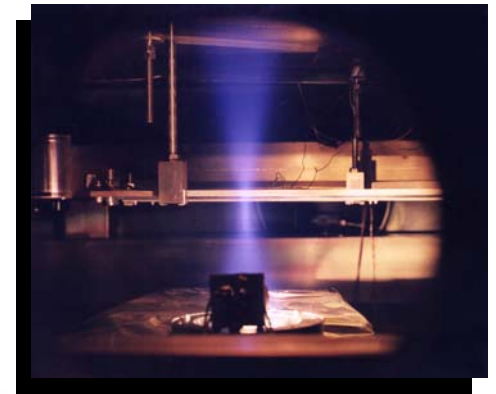
- ❖ Demonstrator design is in progress as well as elementary technological validations.
- ❖ To reduce cost, actuator pattern optimisation computations have been carried out.
- ❖ Manufacturing phase is expected to start at the end of 2003.

Polishing process development

- Mirrors for EUV PO box are off axis aspherics with stringent requirements
 - ❖ Aspherical sag $10\ \mu\text{m}$, slope $1\ \mu\text{m}/\text{mm}$
 - ❖ HSFR and MSFR $< 0.15\ \text{nm RMS}$
- These specifications require development of polishing technologies for reaching the surface error as well as the roughness values.
- BEL optics manufacturing have proved that the used polishing process allows to reach a $0.15\ \text{nm RMS}$ roughness.
- We are working on polishing tools and more particularly on ion beam figuring improvement.



New Ion beam facility

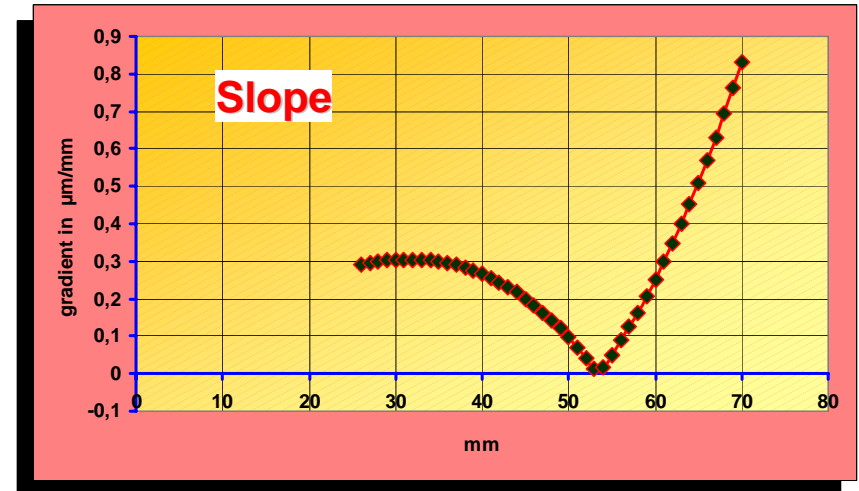
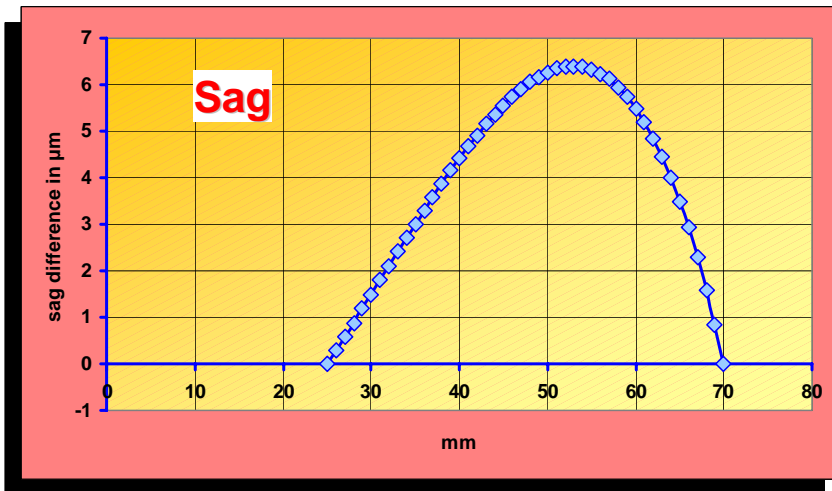


Ion beam figuring

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Polishing activities

- To demonstrate its ability to produce mirrors of a PO box optics, we have started the manufacturing of a representative aspherical specimen.
- The characteristics of this mirror are :
 - ❖ Maximum aspherisation $7 \mu\text{m}$
 - ❖ Slope $0.8 \mu\text{m}/\text{mm}$
 - ❖ Ellipsoid shape (for metrology facilities)



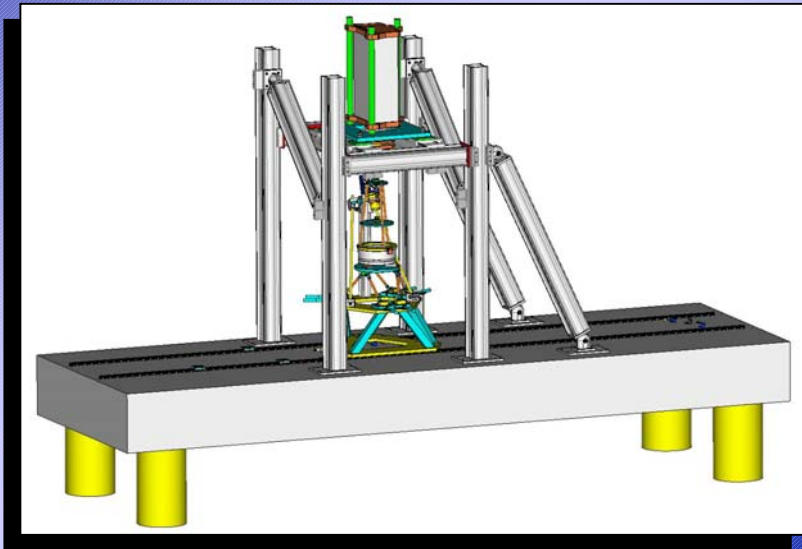
- Manufacturing of this mirror is in progress. First results expected before end of 2003

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Metrology activities

- Development of metrology test benches for measuring the aspherical demonstrator.
- Two complementary technologies will be mainly used :

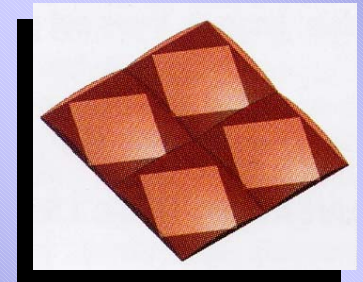
HeNe Interferometry with a specific test bench



Shack Hartmann metrology

Partnership with Imagine Optic for implementing a high accuracy S.H

Use of patented rotated micro lens matrix → cross talk reduction between pixels



Classic microlenses Rotated microlenses

Conclusions

- Through the different EUV programs, SAGEM
 - ❖ has realised a first set of optics for an EUV micro exposure tool (BEL) installed at CEA LETI since dec. 02
 - ❖ provides support to CEA LETI for BEL setup and improvement
 - ❖ has demonstrated the interest of active mirror module within an EUV PO box
 - ❖ has engaged the development of an active mirror demonstrator
 - ❖ is pursuing its efforts in polishing and metrology technologies for EUV optics (and photomask substrates)

- Thanks to CEA / LETI, MinEFi and MEDEA+