

Progress in EUV Optics at SAGEM

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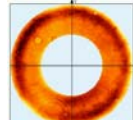
This poster presents SAGEM various line of R&D effort toward precision optics for EUV applications. Generic background, design and manufacture of high NA Schwarzschild optics, Active Optics with Deformable Mirrors, mask substrates, high magnification microscope, EUV collectors and mandrels are highlighted.

SAGEM Background in EUV Optics

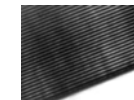
- SAGEM participates to the European EUV R&D effort**
 - 2000-2002 PREUVE project with Leti - Manufacture of the BEL
 - 2002-2004 EXTATIC program within EU MEDEA+ frame
 - 2002-2004 EXTUMASK program within EU MEDEA+ frame
 - 2004-2006 More Moore program within EU ISTframe
- Optical manufacturing Technology development**
 Within PREUVE SAGEM initiated EUV optical manufacturing technology development and demonstrated basic capability of :
 - 0.1 nm High Spatial Frequency Errors (HSFE) over large area up to 10" diameter
 - 0.2 nm Mid Spatial Frequency Errors (MSFE) smoothing
 - 1 nm Low Spatial Frequency Error (LSFE) correction capability (figuring)
- Optical metrology development**
 Metrology tools were developed and adapted to the various ranges of spatial frequencies
 HSFE are evaluated thanks to AFM with 0.01 nm sensitivity
 MSFE are checked with our Wyko micro interferometer with 0.05 nm sensitivity
 LSFE, the most difficult, are evaluated with HeNe interferometry with 0.2 nm accuracy
- Multilayer coating development**
 ML coating are developed by our PREUVE and MEDEA+ partners
 UDESAM at Marseille University
 XENOCs in Grenoble
 The Mo-Si bilayers are deposited with magnetron sputtering and IBS.
- Effort is continuing within EXTATIC**
 Within EXTATIC SAGEM-REOSC is pursuing its efforts to better master the manufacturing process along various line of progress :
 - Aspheric surfaces with a 10 μm asphere departure demonstrator
 - Better controlled shop environment
 - Metrology of individual components and full system
 - Introduction of Schack Hartman technology from Imagine Optic



Imagine Optic patented microlens arrangement



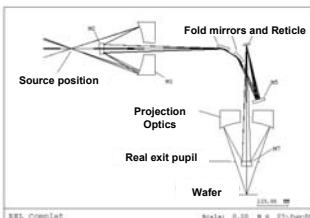
Asphere figured to 1 nm



Test bench

The BEL Schwarzschild Optics

- The BEL Micro Exposure Tool**
 PREUVE program was aimed to federate French capabilities to develop an EUV Laboratory Exposure Bench, the BEL, now installed at CEA Leti in Grenoble.
 It consists in :
 - A vacuum exposure Bench
 - A source (3 were developed)
 - An Illumination and Projection optics
 SAGEM undertook the design and manufacture of the whole BEL optics set within PREUVE.



- The BEL Optics Design**
 The BEL design is based on two main ideas :
 - 10X Schwarzschild optics for the PO
 - Critical illumination with identical optics
 The Schwarzschild has NA = 0.32 and has its two mirrors slightly aspherized to enhance image quality over 100 μm image field.
 Large mirror diameter is 220 mm.
 Small mirror diameter is 50 mm.

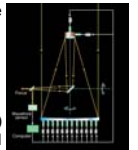
- Towards a BEL 2**
 Leti is now working to make print tests with the BEL system.
 In parallel, a second set of BEL optics has been launched to benefit from latest progress in manufacturing technology.
 We place our efforts on flare and hope to deliver BEL 2 optics by end of this year.



The BEL Optics and mechanics

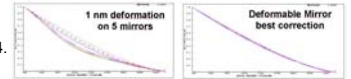
Active Optics in EUVL - A Real Plus

- What is Active Optics ?**
 Large astronomical telescopes made big jump in performances thanks to Active Optics and SAGEM believes EUVL can much benefit from this technology :
 - Image quality is analyzed
 - Main telescope mirror is deformed thanks to some actuators
 - A slaving loop keep telescope performance optimal through time
 The net result is a reduction of manufacturing costs (substrate, polish, mount) and a capability for the system to respond to aggressions (gravity, aging, thermal load, stress relieve, ...) for optimum Cost of Ownership.

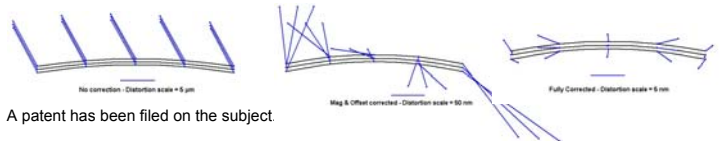


Active Optics concept

- EXTATIC demonstrated the efficiency of one Deformable Mirror**
 Within EXTATIC SAGEM explored the concept of one DM within a typical 6 mirror EUV projection optics and demonstrated that :
 - Effects of mirror movements are well reduced
 - Effects of mirror deformations are reduced by 4.
 A prototype of DM has been designed to correct several nm of the first 10 Zernike polynomials.
 This hardware is under manufacturing and functional tests are to be run before end of 2004 to demonstrate the real feasibility of the Active Optics concept.
 However, with one DM it is not possible to restore at the same time image quality and overlay. As node is going down from 70 nm to 35 and 22 nm, overlay errors become more and more critical.



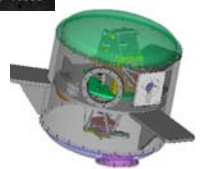
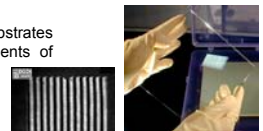
- More Moore is demonstrating the benefit of two Deformable Mirrors**
 This is why, within the More MOORE IST project focused on the 22 nm node, SAGEM is working on a more elaborate Active Optics concept including two DM dedicated to restore at the same time Image Quality and Distortion.
 Deep and complex optical modeling studies have been made to optimize a 2 DM configuration and to determine its efficiency. Remarkable results have been obtained so far with :
 - A 50 X better correction capability with respect to any "mobile rigid body mirrors" option
 - A 50 X better correction capability with respect to the 1 DM active optics option
 The capability to well compensate some very damageable mirror deformations like :
 - Astigmatism resulting for example from mirror mounting stresses,
 - Spherical aberration resulting for example from thermal load,
 - Trefoil astigmatism caused by gravity or bad mounting, etc
 For example a random case of 10 μm mirror displacements, 20 nm astigmatism, 5 nm trefoil and 2.5 nm spherical aberration is very well corrected from more than 3 λ wavefront error to 0.03 λ and distortion reduced to 3 nm as shown below :



A patent has been filed on the subject.

Other EUV Activities

- EUV Masks**
 Within EXTUMASK SAGEM is exploring a mask substrates manufacturing strategy that could meet the severe requirements of flatness, roughness and especially defect quality.
 Good results were obtained so far with flatness, parallelism and roughness specification all met. For the defects, we reached the level of 1 defect > 300 nm / cm². Efforts are pursued.
- EUV Microscope**
 Within EXTUMASK SAGEM is working on metrology and developing a 500 X EUV microscope based on a Schwarzschild 12X main module followed by a second 40 X module.
 This instrument has been designed and is presently under manufacturing in our plant of Saint Pierre du Perray.
 First light is planned for early 2005.



- Collector mandrels and collectors**
 SAGEM had also the opportunity to apply its precision polishing skill to the case of EUV collector optics mandrels for electroforming process.
 Diamond turned ellipsoids or Wolter mirrors can be post-polished to low 1 nm microroughness and improved surface figure errors.
 Electroforming process to produce collectors from the mandrels can also be offered by SAGEM.
 Collaboration with source makers on this subject is welcome.

