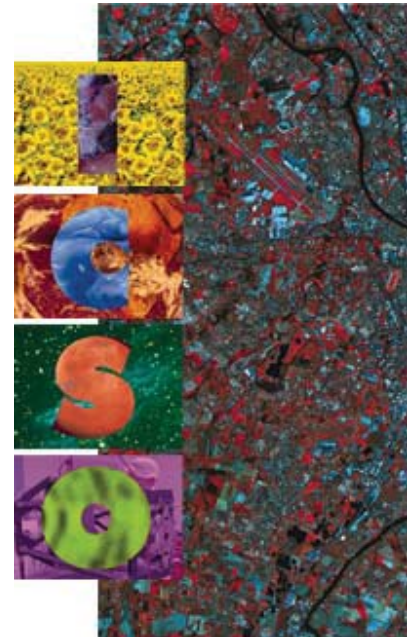


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## *Space optics technology at SAGEM*

*Roland Geyl, Luc Thepaut*



ics0 proceedings



## SPACE OPTICS TECHNOLOGY AT SAGEM

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### 1 – INTRODUCTION

Space optics is continuously pushing its suppliers like SAGEM towards new limits. In this paper, latest developments of state of the art space optical equipment will be presented through SAGEM, and its REOSC Products family, contribution to several projects presently running in the company. These are :

The Infrared Atmospheric Sounding Interferometer (IASI). Ultra lightweight hollow corner cubes, wide spectral band beam splitter and compensator plates have been developed and enter presently in flight model fabrication phase.

The IRS P5 (Cartosat) large aperture three mirror anastigmat optics is presently developed for the Indian Space Research Organization.

### 2 – IASI

**2.1 The project :** Onboard METOP, CNES and EUMETSAT have decided to install the Infrared Atmospheric Sounding Interferometer dedicated to establish precise vertical temperature and humidity profiles of the earth atmosphere. Launch of the first flight model is scheduled for 2003. Alcatel Space Industries is the Prime Contractor for the instrument conceptually designed by CNES. It is based on a Fourier Transform interferometer including several critical elements like the hollow corner cubes, the beam splitter and the cold optics units made by SAGEM.

**2.2 The optics made by SAGEM :** The IASI interferometer has two main difficulties. The first one is the radiometric performance requiring a high transmission over the broad spectral range of 3,6 $\mu$ m to 15,5  $\mu$ m. This require new coatings to be developed, especially for the extension up to 15.5  $\mu$ m. The second difficulty is the so called ‘interferometric’ performance. Optically the two arms of the interferometer must be as identical as possible. Their difference in wavefront error should remain below 1.5  $\mu$ m PTV WFE error. This request the highest mechanical stability of all optical surfaces, especially the reflective one.

The IASI Michelson interferometer has two arms of 88 mm clear diameter ending with a hollow corner cube. As one of these corner cubes is permanently moving onboard, they must exhibit a low mass of less than 170 gr., a first natural frequency higher than 400 Hz. A high reflectivity of 94% is also requested.

The beam splitter and beam compensator plates of the beam splitter unit are two thin ZnSe discs of 110 mm diameter and 5 mm thickness. The assemblies should weight no more than 1.3 kg and the flatness of all optical surfaces should stay below 0.5  $\mu$ m. Reflection and transmission toward the two arms should stay at 50%  $\pm$  10% over the spectral band.

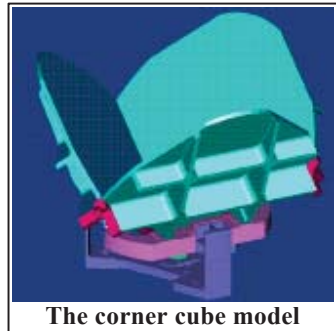
The Cold Optics Unit (COU) separates the three spectral bands and focuses them on the detectors. The unit works at 100 K. The 11 different coatings developed for the COU have top maximize optical throuput over the broad spectral range and at the operational temperature. Mechanical deformation and displacements during cryogenic temperature descent shall be minimized or taken into account during room temperature fabrication and assembly.

**2.3 Project status :** The project ask for 1 breadboard model, 1 STM, 3 flight models plus 1 spare. After two years development, the critical hollow corner cube assembly technique has been validated and a breadboard model successfully realized. The first flight model undergoes final qualification.

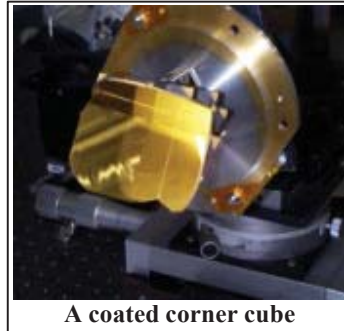
Polishing and coating of the beam splitter and compensating plates have been well mastered. Coating of all flight elements has been done within specifications. The qualification model has been assembled and fully mechanically and thermally tested. Work continues on other flight models.

The development of the broadband coatings at low temperature remains a critical point. IR performances required limit strongly the choice of thin film materials. The material qualified during previous projects (MIPAS experiment on ENVISAT) could not be re-used due to the extension of the IR spectral band up to 15  $\mu\text{m}$ .

In term of 'interferometric' performance the breadboard model went well with a wavefront difference lower than 1.2  $\mu\text{m}$  between the two arms.



The corner cube model



A coated corner cube



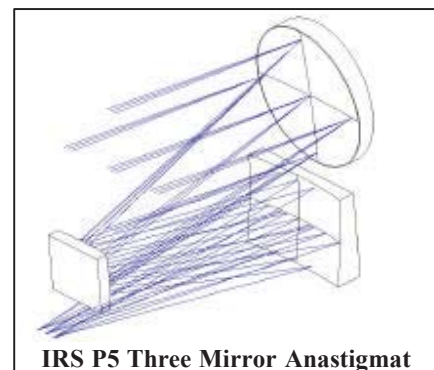
A mounted compensator plate

## 4 – IRS P5

**4.1 The project :** The Indian Space Research Organization (ISRO) is developing an operational infrastructure for natural resources management from space with its series of Indian Remote Sensing (IRS) satellites. The IRS P5 – Cartosat mission will take onboard a high resolution, wide field camera, the fabrication of which has been awarded to SAGEM. Launch of the satellite is scheduled by 2002.

**4.2 Optics specification :** The IRS P5 optics is a Three Mirror Anastigmat (TMA) system with the following main characteristics and requirements :

Focal Length	1945 mm
Entrance aperture	500 mm
Field of view	2.6 x 0.4 degrees
Spectral band	0.5 – 0.85 $\mu\text{m}$
Image quality	Diffraction limited @ 633 nm over the whole flat field



IRS P5 Three Mirror Anastigmat

All three mirrors are to be made from Zerodur. Their weight has to be reduced by more than 60% through pockets machining from the rear side without sacrifice on stiffness and gravity sag.

M1 and M3 mirrors are off axis conics with higher order aspheric coefficients. M2 mirror could be left spherical as per the design option already chosen for the IRS 1C optics made 8 years ago by the company for ISRO too.

Their optical surfaces have to be polished to highest specification in order to reach the full system image quality requirements and leave some margin for alignment and lack of position stability during operational life.

Testing the off axis elements requires state of the null lens design, fabrication and alignment. Computer Generated Holograms (CGH) are now routinely used through our optical shop and are specifically designed to make more easy their alignment and certification.

**4.3 Fabrication status :** SAGEM undertook the mechanical design of the three mirrors lightweight structure reducing both gravity sag during optical tests on ground and optical surface quilting under polishing pressure.

Fabrication of the elements is done according to different strategies :

The M1 circular mirror requires a too big parent mirror to be produced economically. Therefore it is manufactured “**direct off axis**”

The M3 mirror can be more efficiently cut from a reasonable size parent mirror. Therefore the option of “**cutting after polishing**” has been selected for this piece. Photo SAGEM

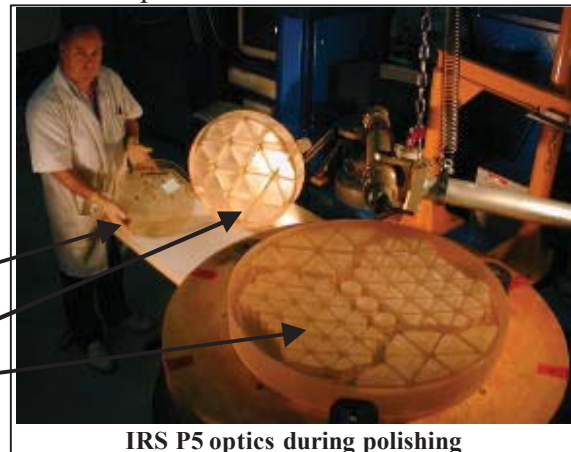
The M2 spherical mirror is not a major manufacturing issue.

The mirrors have been lightweighted successfully and undergo now the polishing operation with computer controlled polishing and Ion Beam Figuring in the final stage.

Spherical M2 mirror

Direct off axis M1 mirror

M3 parent mirror



IRS P5 optics during polishing

## 5 – CONCLUSION

SAGEM pushes its efforts to make space optics, within its REOSC Products family, being a more and more mature, affordable and reliable, for the benefit of all its customers entering in today’s competitive commercial space business. But, at the same time, innovation and imagination remain the stimulating characteristics of this challenging activity.

This is reflected by the various optical configurations designed and fabricated as well as the new material or mirror technology explored. However, when budget is driving, proven solutions are available. SAGEM thanks all its customers for placing their confidence in his engineers and technicians and is proud to contribute to science progress and development of remote sensing applications.