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IASI-NG development status

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ABSTRACT

The Infrared Atmospheric Sounding Interferometer New Generation (IASI-NG) is a key payload element of the second generation of European meteorological polar-orbit satellites (METOP-SG) dedicated to operational meteorology, oceanography, atmospheric chemistry, and climate monitoring.

It will continue and improve the IASI mission in the next decades (2020-2040) in the field of operational meteorology, climate monitoring, and characterization of atmospheric composition related to climate, atmospheric chemistry and environment. The performance objective is mainly a spectral resolution and a radiometric error divided by two compared with the IASI first generation ones.

The measurement technique is based on wide field Fourier Transform Spectrometer (operating in the 3.5 - 15.5 µm spectral range) based on an innovative Mertz compensated interferometer to manage the so-called self-apodisation effect and the associated spectral resolution degradation.

We present here the design of the instrument, the development status of the main units, critical technologies and sub-systems and the first test results performed on engineering models.

Keywords: Fourier Transform Interferometer, IASI, KBr, infrared

1. INTRODUCTION

IASI-NG (Infrared Atmospheric Sounding Interferometer New Generation) is the follow on mission of IASI. It shall provide operational meteorology data such as temperature and humidity atmospheric profiles and also monitor other gases like ozone, methane or carbon monoxide on a global scale.

The IASI-NG instrument performs spectral measurement in the infrared between 3.6 µm and 15.5 µm using Fourier Transform interferometry. Compared to IASI, the new generation instrument shall improve the radiometric signal to noise ratio and the spectral resolution by a factor two. Table 1 gives the main instrument requirements:

Table 1. IASI-NG main requirements

Characteristic	Requirement	Value
Geometry	sounding point size spatial sampling geolocation error	≈ 12 km ≈ 25 km 0.5 km
Radiometry	radiometric calibration error NedT@280K	0.25 K @ 280 K 0.1 to 0.4 K within the spectrum
Spectral	continuous spectral covering spectral resolution spectral sampling spectral calibration error	From 3.6 µm to 15.5 µm 0.25 cm^{-1} 0.12 cm^{-1} $5\ 10^{-7}$

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Due to volume and mass constraints it was not possible to improve IASI radiometric performances by increasing the pupil size. The chosen solution is to increase the Field Of View (FOV) size and thus the integration time. The resulting FOV is in the order of 100 x100 km². The spectral resolution and sampling are divided by two by doubling the Optical Path Difference (OPD) of the interferometer to about 8 cm in total (± 4 cm).

Unfortunately Michelson interferometers present a so called self-apodisation effect which reduces the signal level when one increases the FOV and the OPD range. Contrarily to the previous IASI instrument, this effect would reduce the signal to null before reaching the extreme OPD with the IASI-NG parameters. It is thus mandatory to compensate this effect to get a sufficient signal level. The chosen solution was proposed by Mertz and consists in putting in the optical path a refractive material which thickness changes with the OPD. This is made by having two opposite KBr prisms moving synchronously with the OPD change. A patented mechanism allows performing simultaneously the OPD scan and the compensation using a single actuator.

2. INSTRUMENT DESCRIPTION

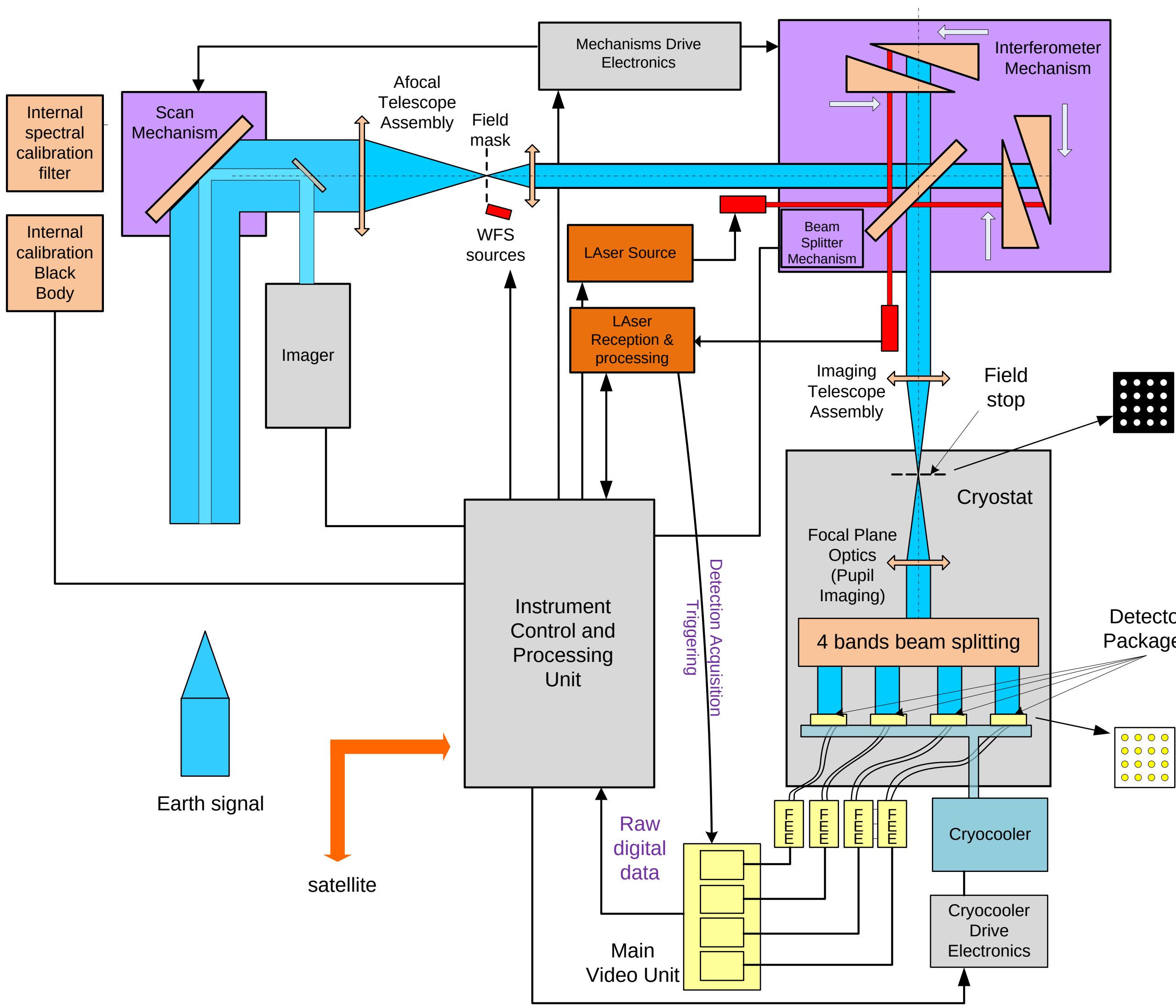

Figure 1. block diagramme of the IASI-NG instrument

The beam coming from the observed point on Earth enters the instrument via a reflection on the pointing mirror: the scan mechanism provides the desired target direction and compensates for satellite velocity during the interferogram acquisition. The 90 mm diameter beam then enters the Afocal Telescope Assembly which reimages the entrance pupil inside the interferometer, providing a beam diameter reduction ratio of 2.25: the pupil size is reduced to 40 mm at interferometer level.

The interferometer is a modified Michelson type interferometer: in the Mertz concept the field apodisation compensation is performed simultaneously with the Optical Path Difference scan thanks to a dedicated interferometer mechanism principle. This mechanism moves in synchronization the two couples of Internal and External Prisms. The beam reflection is made at the outer face of the External Prisms.

The optical path difference resulting of the interferometer mechanism motion is monitored by the Laser Metrology. A frequency stabilized laser source sends five beams into the interferometer: these beams undergo interferences in the interferometer in the same way as the science beams and five detectors receive the resulting metrology interference signals. The Laser Reception Electronics acquires and processes these data. The computed OPD is used to synchronize the detector acquisitions so that interferogram data are acquired at constant OPD intervals. The five signals are also used to derive the tilt of the differential wavefront which is used for on ground correction of the instrument spectral response function.

The beam outgoing the interferometer is then focused by the Imaging Telescope Assembly onto a field stop located at the cryostat input port: this stop consists in pattern of four by four holes that define the sounder pixels size and relative positions. The cryostat includes the focal plane optics and the detectors. The focal plane optics send the signal to the arrays of four by four detectors in a pupil imaging mode. These optics also include three spectral beam splitters in order to separate the beam into the four IASI-NG spectral bands. The cryostat allows cooling down of the detectors at the operating temperature of 75 K by means of a pair of redounded cryo-coolers.

For each of the four spectral bands, an array of 4x4 detectors receives the signal from the Sounder Pixels. The signals from the detectors are digitized in the Main Video Unit and sent to the Instrument Control and Processing Unit.

The Instrument Control and Processing Unit is the control electronics of the instrument. It provides the power distribution function, the TM/TC interfaces and the interface with the satellite Spacewire bus. It also performs the instrument FDIR management, the thermal control and the sequencing of the activities.

Beside the nominal Earth target acquisition, the instrument includes three calibration systems, using dedicated pointing directions:

- The radiometric calibration, with one internal black-body and two possible deep space views.

- The spectral calibration, with a Fabry-Perot filter. The spectral calibration is periodically performed by looking at the cold space through this filter which provides a reference spectrum comb that is used to check the calibration law of the instrument.

- The interferometer wavefront calibration, termed Wave Front monitoring System. It uses a dedicated source beam sent from the edge of the field mask located in the entrance telescope towards the pointing mirror. This latter is used in auto-collimation mode to send back the WFS beam into the instrument. Processing of the data acquired with the nominal detectors of one spectral band allows measuring the interferometer wavefront. These wavefront data are taken into account for ground processing of the metrology. This operation is performed during commissioning and a few times during the mission to check the long-term stability of the interferometer.

The instrument performs continuous data acquisition throughout the mission lifetime. The swath is covered during a so called Basic Repeat Cycle which is repeated along the orbit. A typical observation sequence within this Basic Repeat Cycle consists in pointing the scan mirror successively towards the 14 Earth views to cover the required swath. It is then switched towards two successive radiometric calibration positions, one aiming at a reference Blackbody and one aiming at the cold space.

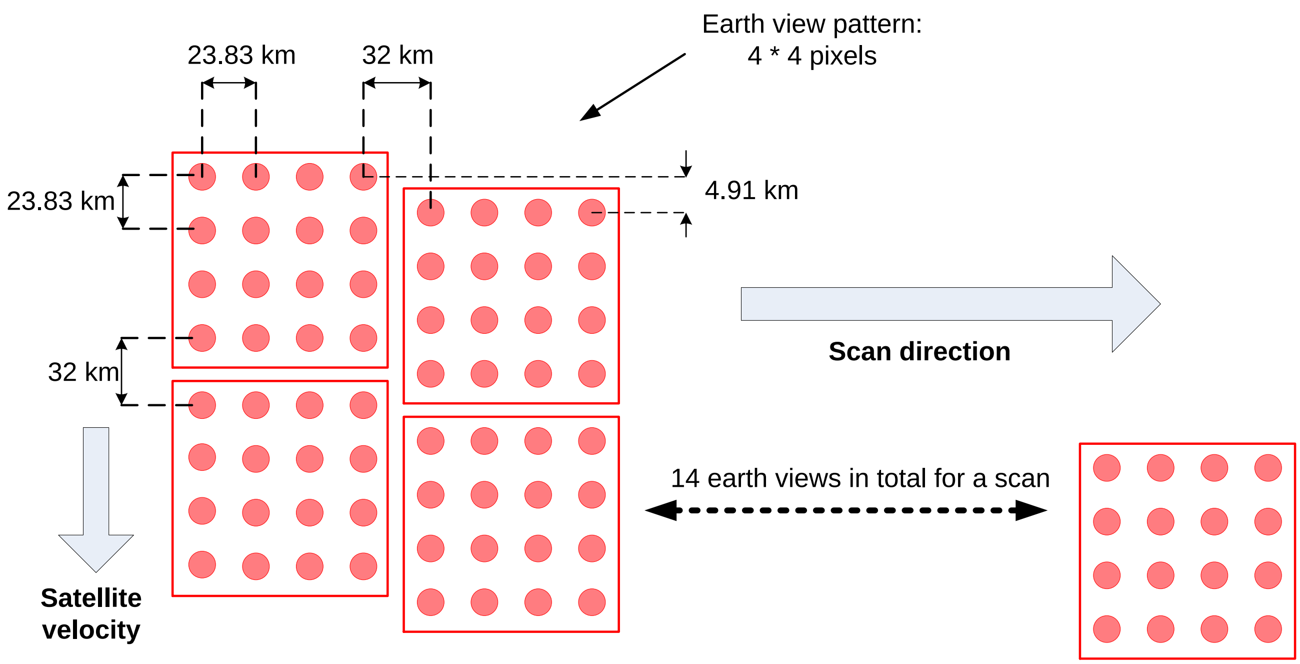

Figure 2. Instrument FOV footprint on ground and spatial sampling

3. INTERFEROMETER

3.1 Principle

The interferometer is a Mertz interferometer, i.e. a Michelson interferometer modified to compensate for the self apodisation effect. This is obtained by the interposition of a refractive plate which thickness is changed according to the OPD value.

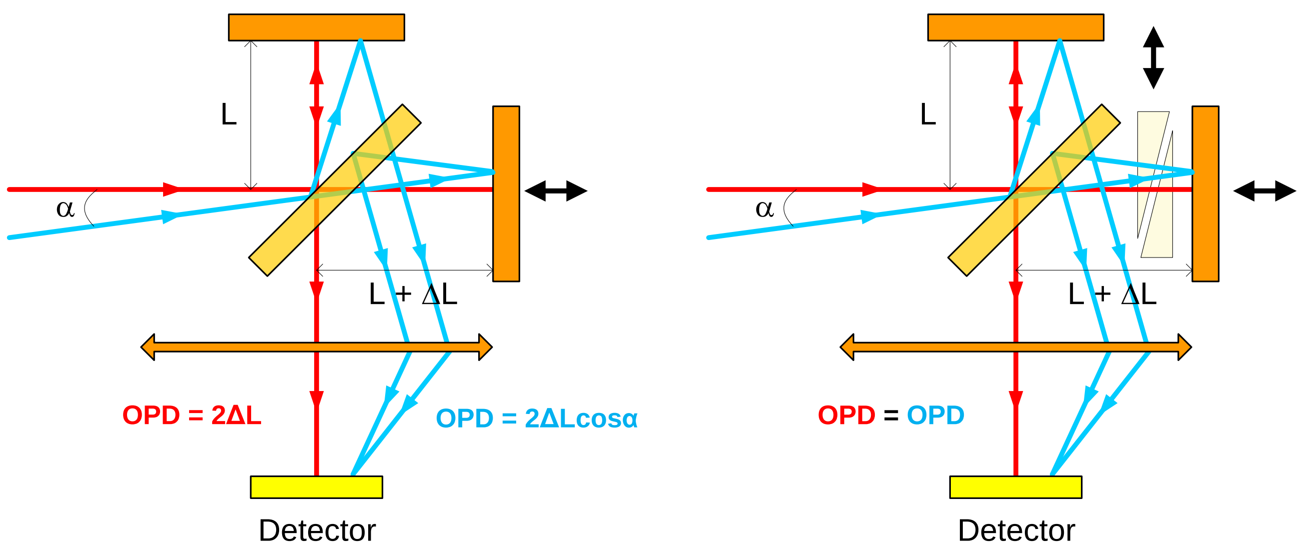

Figure 3. The OPD variation in the FOV is compensated for by a variable thickness KBr plate

In the actual interferometer the two arms are symmetrical and the reflecting surface is the external surface of one moving prism. The internal and external prisms are mounted on two frames linked by a deformable parallelogram. This parallelogram is composed of two pairs of lever arms. The deformation of this parallelogram creates differential translations of the prisms ensuring the variation of the OPD and the variation of the optical thickness created by each pair of prisms. The relationship between the two is ensured by the accuracy of the lever arms and thus in a purely mechanical way. The deformation of the parallelogram is ensured by a single rod actuated by a motor.

3.2 Development

A breadboard model of the mechanism has been developed. It has allowed demonstrating the capability to compensate the self-apodisation at about 4 µm, thus validating the alignment tolerancing.

An Engineering Model is being built to be soon equipped with optics. Mechanical alignment has been made with accuracies in the range of a few microns. This model will be tested with a representative laser metrology to validate the end to end measurement and the correction process of the interferograms.

The prisms and beam splitter components are made of KBr which is a material with very poor mechanical properties and sensitivity to humidity. A full qualification program has been successfully passed to demonstrate the capability to mount the optical components, to ensure their long term stability and to verify that they can withstand the ground environment throughout the whole integration and test process.

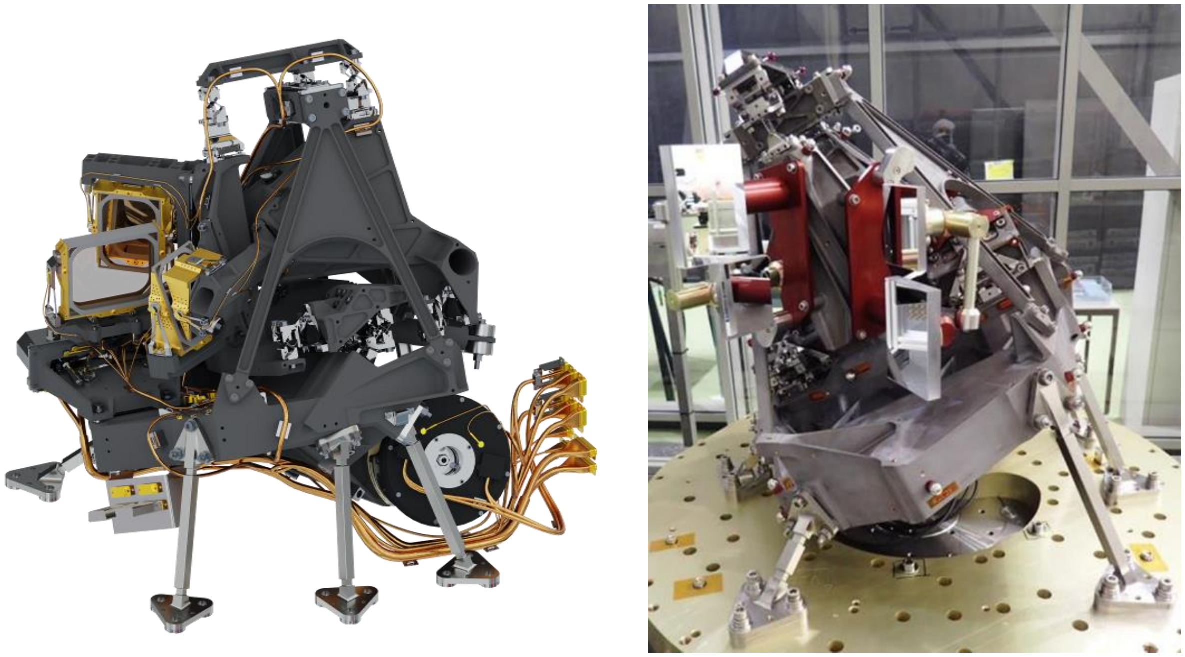

Figure 4. CAD model and actual IASI-NG interferometer mechanism

4. FOCAL PLANE AND CRYO-COOLER ASSEMBLY

4.1 Principle

The Focal Plane and Cryo-cooler Assembly (FPCA) is composed of an optical bench located inside a cryostat. The focal plane includes the optics of the four spectral channels (mainly dichroics, folding mirrors and pupil imaging optics) and the four detector packages. The temperatures inside the cryostat vary from 75 K at colder detector interface to about 80 K at optics level. The equipped cryostat has a mass of 22 kg and the heat link to be extracted by the cold tip of the cooler is 3.35 W. The cryo-cooler is a Liquid Pulse Tube Cooler manufactured by ALAT.

4.2 Development

The optics inside the focal plane are made of materials including ZnSe, CdTe and silica. Airbus has developed all the mounting techniques in order to align these optics at ambient temperature and ensure their stability in cold operating vacuum conditions with accuracies in the order of 10 microns. The mounting system also ensures that the wavefront error of these optics is not degraded by the constraints linked to the temperature change.

A cryostat with a representative internal heat load has also been tested with a cryo-cooler in representative thermal conditions. We have shown that the required temperatures were indeed attained even with margins on the nominal power provided by the cooler.

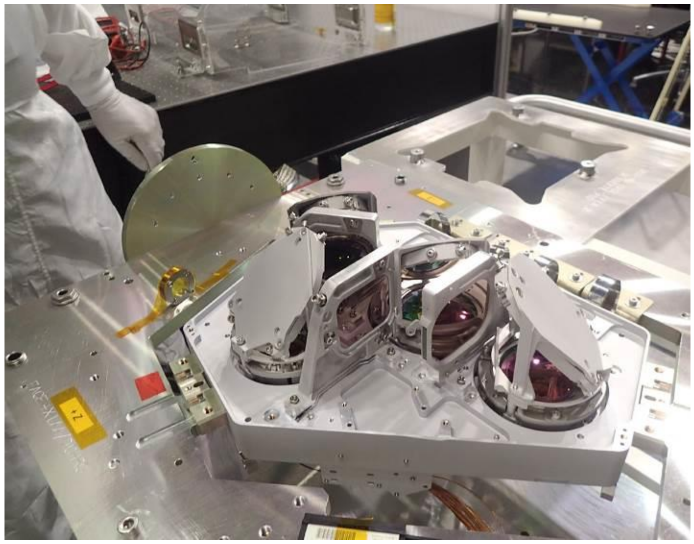

Figure 5. folding mirrors and dichroic plates on the cold optical bench

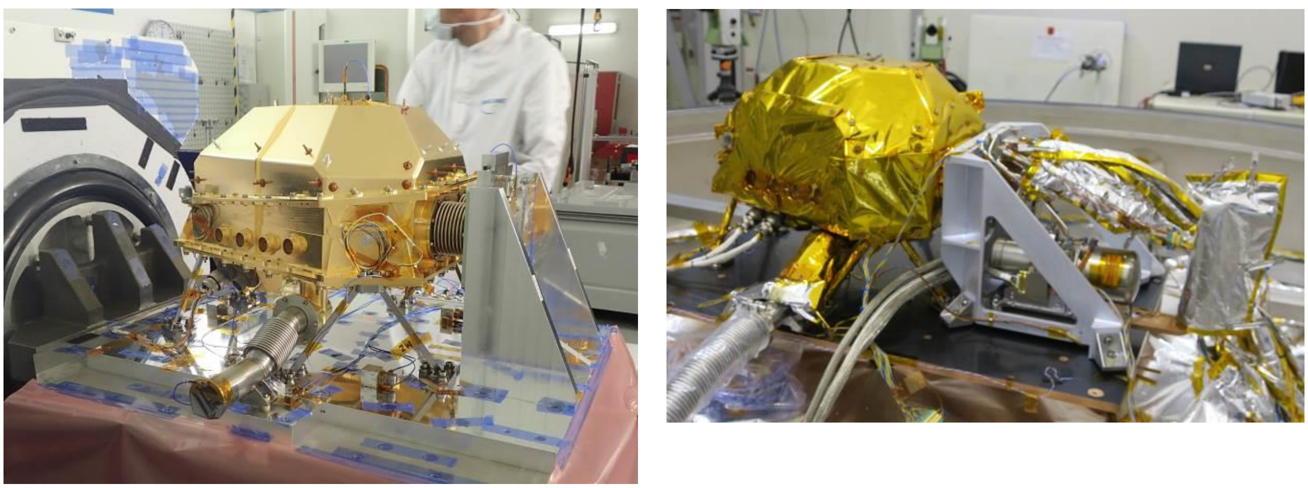

Figure 6. IASI-NG cryostat during vibration test and prior to thermal vacuum test

5. INFRARED IMAGER

5.1 Principle

IASI-NG includes an infrared imager used to perform the co-registration of IASI-NG observations. It includes an optical system covering the IASI-NG FOV and working around 10 microns. The detectors are micro-bolometer arrays used in warm redundancy.

5.2 Development

The objective is manufactured by SODERN. It is under qualification which should be completed end 2018. The detectors are off the shelf components manufactured by ULIS which have been qualified by ADS. The electronics has been qualified by its manufacturer EREMS. The vibration and thermal vacuum tests of the complete Imager are started at ADS and should be finished around end 2018 year.

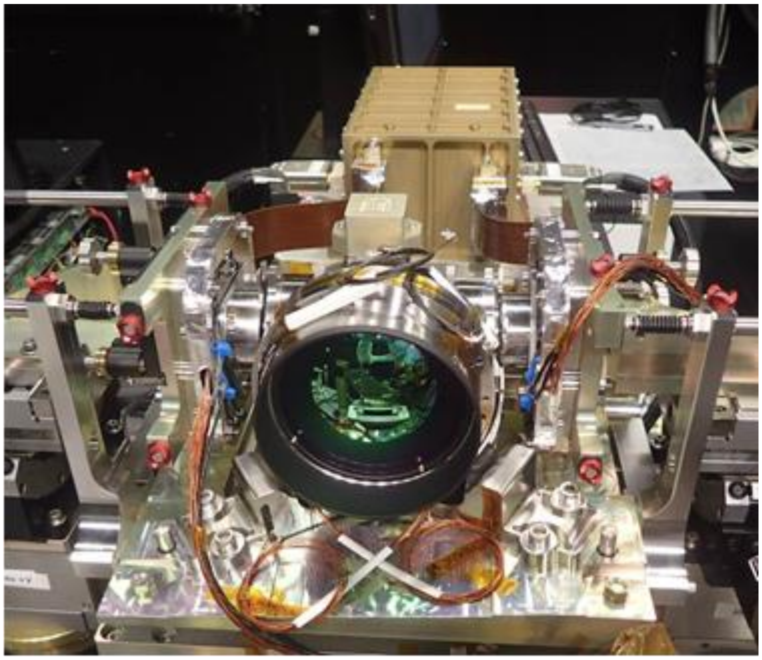

Figure 7. Alignment of the micro-bolometer detectors on the optics of the Imager

6. FUTURE ACTIVITIES

The Critical Design Review of the instrument is foreseen in 2019.

This year will also see the complete test of the Engineering Model (EM) of the interferometer coupled with the laser metrology and a detection system. Such test will demonstrate the capability to acquire an interferogram at constant OPD intervals and to process the data using the metrology measurements.

The other important system test will be made with the complete aligned EM focal plane. This test will allow measuring the alignment and geometric performances in thermal vacuum.

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