Istituto Nazionale di Geofisica e Vulcanologia – Laboratorio di Geodesia e Telerilevamento

FASA

In progress status report

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Galileo Avionica

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Definitions

BB	Black Body
CPC	Central Processor Controller
CU	Calibration Unit
EB	Electronic Box
FBD	Functional Block Diagram.
IB	Interface Box
MP	Main Plate
MPC	MIROR PC
MS	Mechanical Structure
PID	Proportional Integral Derivative
PM	Parabolic Mirror
PS	Power Supply
TB	Thermal Box

Introduction

The FASA (Fire Airborne Simulator Arrangement) project in collaboration with the DLR and the financing of ASI, was started in order to Combine bi-spectral imager and high-resolution FTIR-spectrometer (MIROR) for airborne remote sensing and gas analysis of high temperature events such as volcanoes and wild fires.

In order to mount MIROR and the camera on the Dornier 228, a specific interface consisting of three part was developed: an optical interface (Galileo Avionica, Florence), a mechanical support structure (IROE, Florence) and a calibration unit (INGV, ROME).

In this report we present the whole mechanical configuration development, the software acquisition package implementation and the preliminary test results.

1. General instrument description

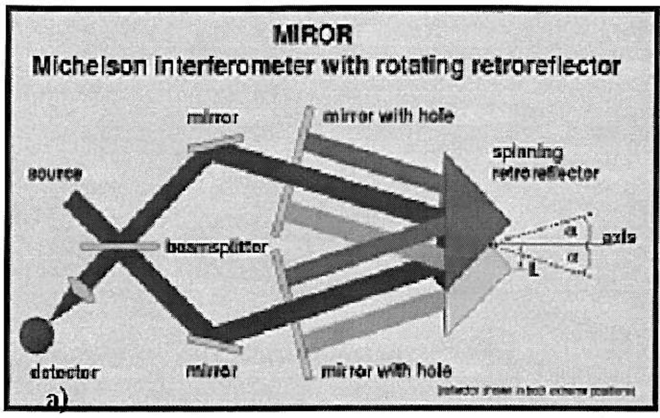
MIROR is a Michelson interferometer realized at the DLR, that splits incoming radiation into two beams, generates a path difference between them, and recombines the beams again. Because of the introduced path difference both beams have different phase when they interfere.

The path difference is generated by a spinning retroreflector, mounted off-axis to the driving axle (figure 1 a). The reflector consists of three mirror surfaces, which are arranged perpendicularly to each other (corner cube).

The interference pattern is focused onto a detector and read into the memory of a computer (MIROR, Personal Computer, MPC)

The spectrum of the incident radiation, in the infrared range **2.5 - 18 µm**, is obtained as the Fourier transform of the detector signal (P.Haschberger and E. Lindermeier).

Table 1 lists the optics specifications and the operational features.



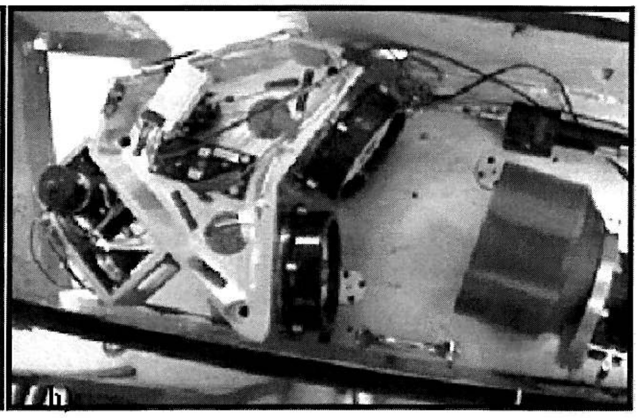


Fig.1: a) MIROR ray trace scheme *(Haschberger)*; b)MIROR set-up *(DLR ref.http://pid.da.op.dlr.de/1_org-einheit/IMF-EV/Infrastruktur/Hardware/miror/miror_engl.html)*.

PARAMETERS	
Detector	HgCdTe/InSb
Sectral range	2.5 ... 18 μm
Beam splitter	Ge on KBr
Max. optical path difference	11.6 cm
Spectral resolution	0.12 cm^{-1} (FWHH)
Optical throughput	2.0×10^{-3} cm^2 sr
Laser reference system	He-Ne, 633 nm
NESR	7×10-8 W/(cm^2 sr cm^{-1})
Aquisition system	19" PC/486
ADC	16 Bit
NESR	(with reference to single HgCdTe: 0.24 μW/(cm²srcm^{-1}) @ 1000 cm^{-1} measurement) InSb: 0.08 μW/(cm²srcm^{-1}) @ 2000 cm^{-1}
Measurement time/interferograms	0.25 s
Measurement rate	180interferograms/min

Tab.1: MIROR optics specifications and operational features.

2. Mechanical configuration

In order to install the MIROR on the Dornier 228 airplane, has been necessary built specific mechanical support structure. Moreover we added a calibration unit (CU) in order to have three different reference Black Body (BB) temperatures. The presence of a CU implies the existence of an optical interface consisting mainly of a parabolic and a plane mirror folding the light beam coming from the BB towards the MIROR pupil. In figure 2 we show a total 3D view of the system.

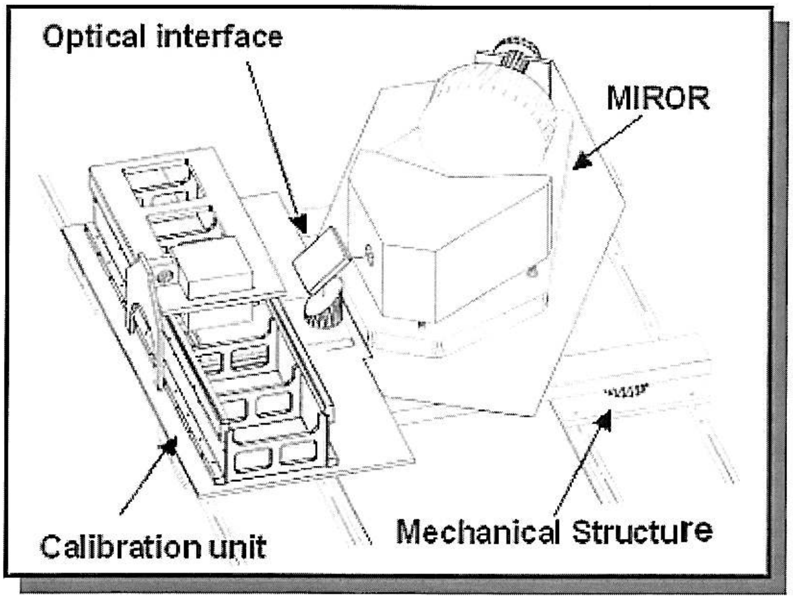


Fig.2: complete view of the system.

2.1 Optical interface

The optical interface consists of three folding BK7 mirror: a parabolic coated mirror, a calibration flat gold coated too and an aluminum treated mirror mounted on the flange linked on the MIROR.

2.2 Calibration Unit

It is an aluminum structure that contains three Black Bodies (BB) at different temperatures (100 °C, 150 °C, and 200 °C) in order to realize the radiometric calibration (figure 2). A motor remote controlled by the MPC (software tool) allows to place the BB in calibration position or to set the unit in acquisition mode (MIROR looks at the target). A thermal box will be put over the system with a double intent: first of all to maintain constant the temperature of the system and secondly to protect it .
The CU, as the complete mechanical structure, has been realized on Dott. Ing. Di Stefano G. draw, at the INGV workshop (figure 2). The CU is motorized in order to position the BB in the calibration or acquisition mode.
The Black Bodies (figure 3), realized by DLR, are CU spheres of a diameter 80mm with two solenoids that cover each hemisphere and are used to heat them. They are lodged put inside aluminum box an blocked on the CU.

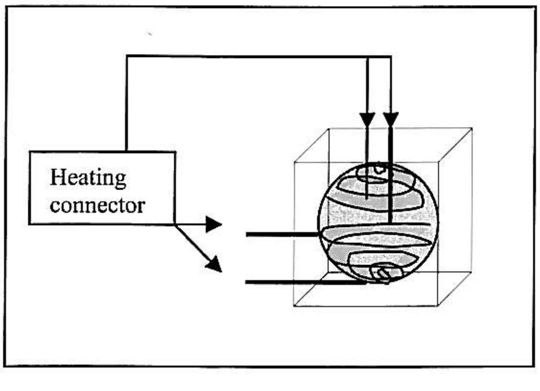


Fig.3: Black Body scheme.

2.3 Mechanical Structure

The bars structure is the connection between the MIROR plus Calibration Unit system and the aircraft guides. The structure was realized on the Dot. Ing. Di Stefano Giuseppe (INGV) draw by Galileo Avionica – IFAC in Florence.
The structure bars consist of a truss of Aluminum (100x50mm) fixed to the airplane by four interface plate (figure 4); between the main plate and structure are present 4 shock mount in order to reduce the vibrations. The mass of the FASA Structural Model results to be 174.97 Kg.

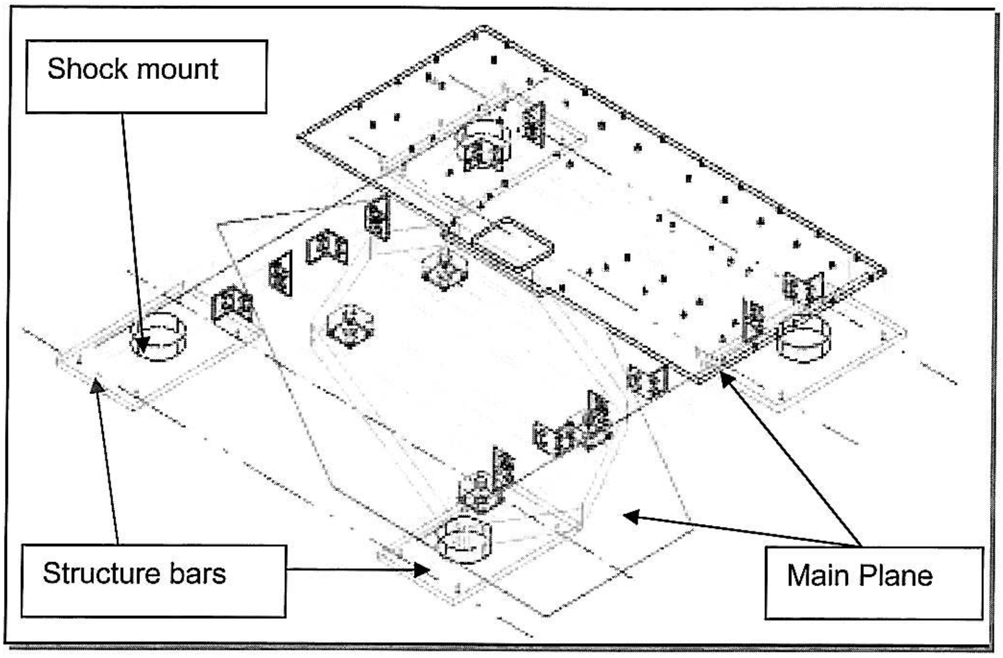


Fig.4: FASA main structure.

Aluminium alloy Al 6060-T6		
Module of elasticity	E = 66.000	Mpa
Density	d = 2700	Kg/m^3
Poisson's ratio	$\nu = 0.33$	
Thermal Expansion	$\alpha = 0.24 \cdot 10^{-4}$	K^{-1}
Yield Tensile Stress	$\sigma_y = 165$	MPa
Ultimate Tensile Stress	$\sigma_u = 205$	MPa

Aluminium alloy Al 6082-T6		
Module of elasticity	E = 69.000	MPa
Density	d = 2700	Kg/m^3
Poisson's ratio	$\nu = 0.33$	
Thermal Expansion	$\alpha = 0.24 \cdot 10^{-4}$	K^{-1}
Yield Tensile Stress	$\sigma_y = 240$	MPa
Ultimate Tensile Stress	$\sigma_u = 300$	MPa

Tab.2: Truss components features.

3. Bench structural analysis

The modelling and structural analyses were performed by Galileo Avionica by using the ANSYS program rev. 5.6. The item was that to evaluate the mechanical strength of the interferometer truss when the static loads, transmitted by airplane structure, in terms of accelerations are applied on all the three axes. The analysis were carried out on two step: By means of model check analysis we check: dynamic, gravity loading, mass and inertia, static stress analysis valuating the acceleration in the three direction.
The detailed description of the test and the results (positive and within the requirements) are in the OGF-AN-001 document of the 01/08/2002 Galileo Avionica.

4. Central Processor Controller

The Central Processor Controller (CPC- Rome INGV laboratory) consist of a REC 19 inches, a PIII 866 MHz, a 800 GBytes double disk in mirroring configuration and a resistive touch screen. Five controlling boards are mounted but it is possible to reach 14.

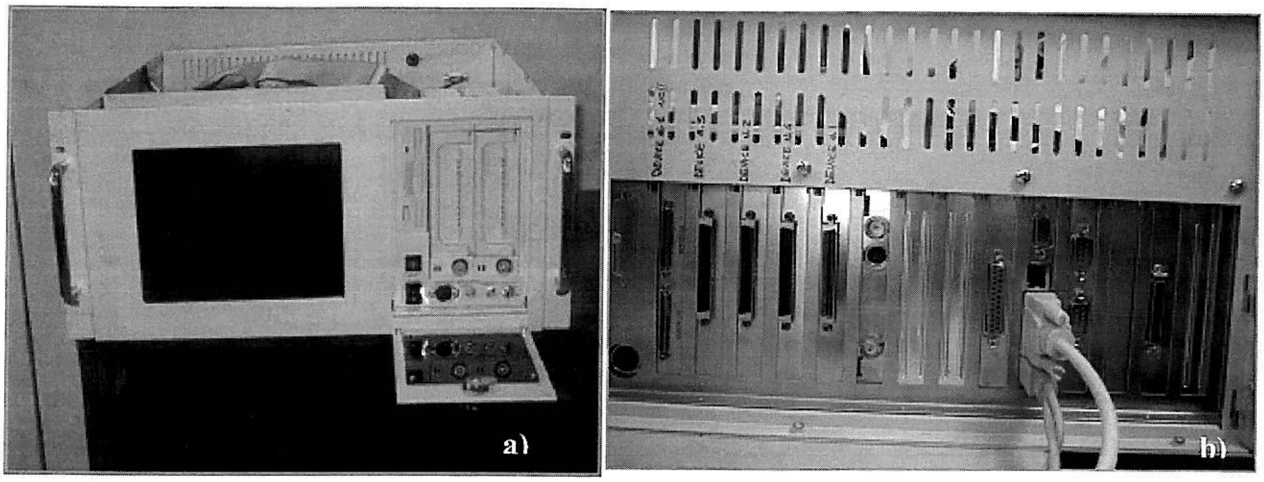


Fig.5: a) CPC hardware unit (front view); b) connectors details (back view).

5. Control software procedure

The software tool for the in ground and in flight test is implemented by using Labview 6.00.
It uses object oriented philosophy allowing the development of different object according to different functions.
In order to give an idea of the complete procedure, that will be described in detail in a proper document, we show the Functional Block Diagram (figure 6).

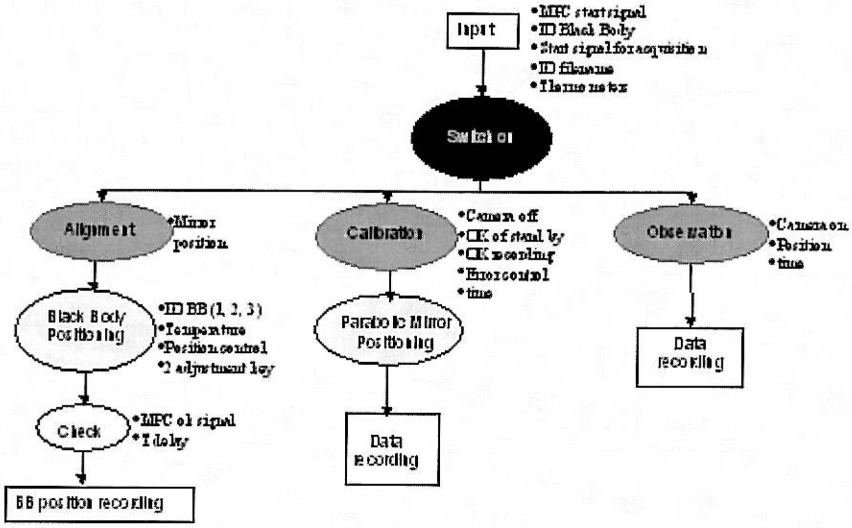


Fig.6: Functional Block Diagram.

6. Test activities

We realize different kind of test in two different periods. At first we need to verify the interfaces and the assembling of the mechanical parts. Secondly we tested the software procedures (file *.vi) for the camera and the thermal control.
For each kind of test we present the test results pointing out the goal, the date, the participants and the results.

6.1 RACK vs CPC and Interface Box

Test Date: <u>July 30, 2002 - DLR</u> Test Result: Accept (OK!) Reject_

Technician: Di Stefano G., Buongiorno M.F., Amici S., Lindermeier E.

Equipment:

MIROR, CPC, BB0.

General Test Procedure:

The first test consisted in verifying the correct positioning of INGV-CPC unit on DLR- RACK. The CPC fitted quite well with RACK and only the position of some holes for screws need to be adjusted.

Test Procedure: Black Body temperature control

Labview Program: Real_ PID.VI

Directions:

1. The first step consisted in construct the cable connection between the BB and the CPC (OK!)
2. The connection to the board was adapted. (OK!)
3. Attach power supply connector.
4. The right functioning of the was verified. (OK!)
5. The RTD procedure was implemented in order to convert the signal into temperatures (Celsius degree). (OK!)
6. The BB temperature stability was tested by performing a series of heating cycles. (to be completed).

Test Procedure: Test on the frame grabber of camera

Labview Program: grabber_cam.vi
Directions:

1. The camera was connected to the CPC.
2. The frame grabber procedure was tested (OK!)

Test Procedure: Interface box

Directions:

1. The interface box will remain at the DLR in order to install the electronic box.

6.2 CPC MIROR interface TEST

Test Date: <u>July 31, 2002- DLR</u> Test Result: Accept

Technician: Di Stefano G., Buongiorno M.F., Amici S., Lindermeier E.

Equipment:

MIROR, CPC, MPC, BB0
CPC has a temporally NI5911 board which will be replaced by faster one.

1. We implemented a preliminary procedure to acquire the MIROR signal and the clock signal
2. We implemented the procedure to record a sample of the MIROR signal and the Clock signal.
3. We implemented the procedure to record a sample of MIROR and clock signal

Test Procedure: MIROR

Directions:
1. MIROR temperature
2. Parabolic Temperature control.

6.3 Preliminary assembly test

Test Date: <u>September 12, 2002 - Galileo Avionica –IFAC</u> Test Result: Accept

Technician: Di Stefano G., Buongiorno M.F., Amici. S., Cherubini G., Pippi I. and Marcoianni P.

Equipment:

Calibration Unit, Main Plane, Bench Structure and Parabolic Mirror.

General Test Procedure:

The morning was devoted to look the results of the "FASA bench Structural Analysis" (DOC: OGF-AN-001) Galileo Avionica. The results point out that the design is critical because of the negative values of the stresses. However the structure is not broken off when is under a 11G acceleration.
The afternoon was devoted to the assembly test of the structure, main plane, calibration unit and the flange.

Test Procedure: Bench structure

Direction:
The assembly of the structure took 3 hours, in fact the holes of the screws were not perfect realized so was necessary to adapt them.

Eight holes have been realized in the correct position.
The Calibration Unit box was connected successfully with the plane
The flange and the parabolic mirror were mounted on the plane.

Comment:
The main plane and the structure were leaved at IFAC in order to be mounted perfectly in plane.

6.4 Starting the assembly

Test Date: <u>September 23, 2002 - DLR</u> Test Result: Accept

Technician: Di Stefano G., Buongiorno M.F., Amici S., Badiali L. and E. Lindermeier

Equipment:

Calibration Unit, Main Plate, Bench Structure and Parabolic Mirror and Flange .

General Test Procedure:
During the morning meeting we have analyzed the results of the "FASA bench Structural Analysis" (DOC: OGF-AN-001) Galileo Avionica. The results point out that the design is critical because of the negative values of the stresses. So we decided to run again the program with detailed weight of MIROR and the other components. The afternoon was devoted to start with the assembly.

Component	Weight Kg
MIROR	74
Calibration Unit (+BB)	27
Plate	10

Tab.3: weights' evaluation.

Comment:
The screws of the truss are not the right one.
We have to reduce the total weight that excides the broken weight (95 kg).

6.5 Assembly

Test Date: September 24, 2002 - DLR **Test Result**: Accept

Technician: Di Stefano G., Buongiorno M.F., Amici S., Badiali L. and E. Lindermeier

Equipment:

Calibration Unit, Main Plate, Bench Structure and Parabolic Mirror, Flange.

General Test Procedure:

We started to mount the different components in the following order: the structure the shock mounts, the main plate, the MIROR, the calibration unit (with the BB0) the parabolic mirror, the flange on MIROR, the pins and the plane mirror, the camera on the MIROR and then the connection to the CPC and the MPC. In the following pictures are showed the different phases.

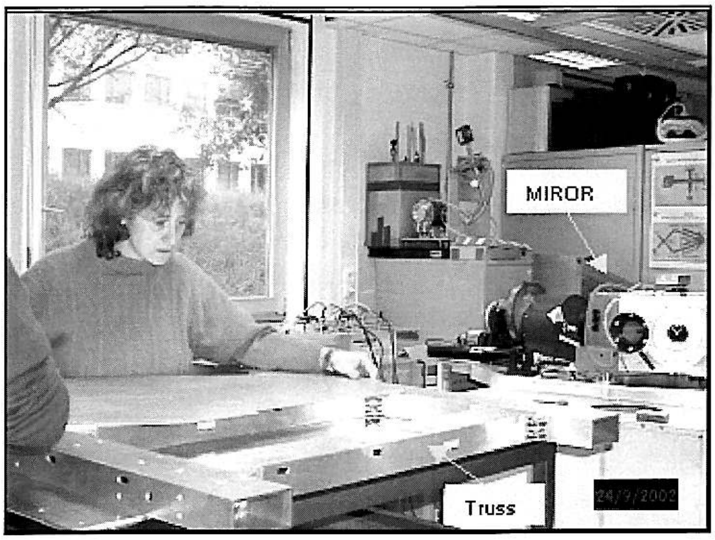


Fig.7: Plate dimension control.

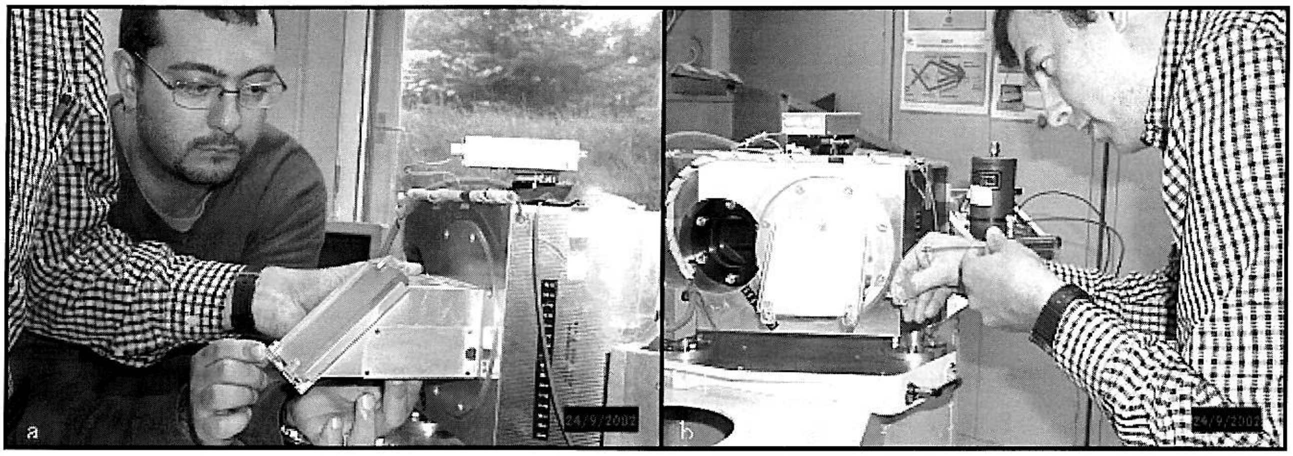


Fig.8: a) verification of the Germanium Flange and MIROR interface; b) Flange assembly.

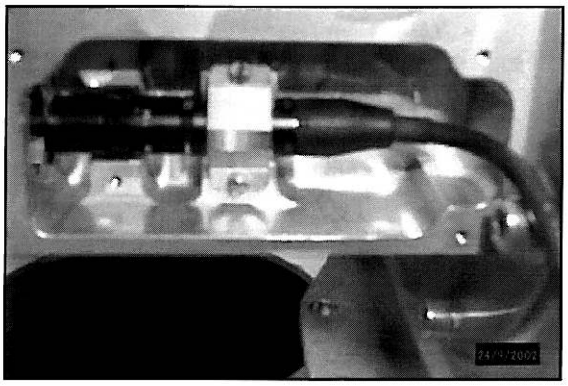


Fig.9: camera assembly details.

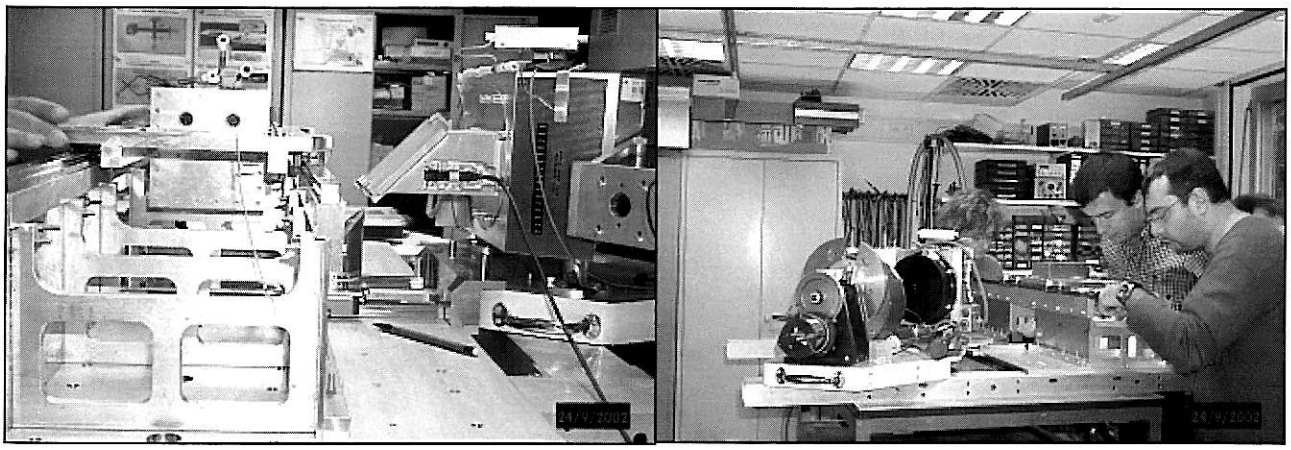


Fig.10: a) BB positioning; b) BB0 height evaluation.

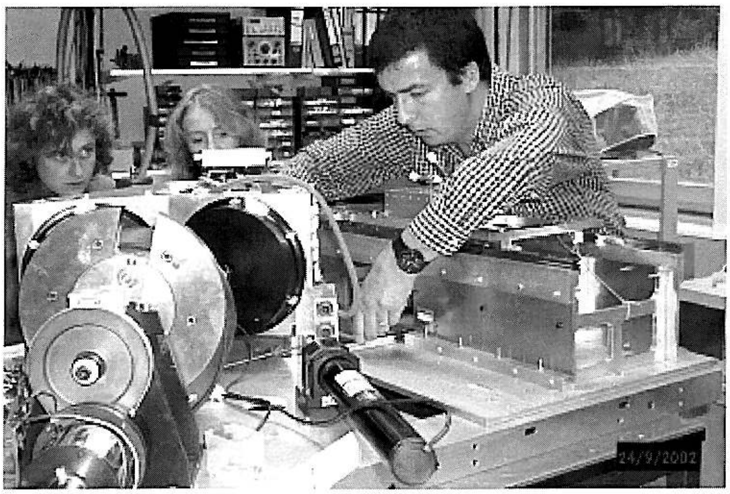


Fig.11: parabolic mirror positioning details.

Comment
The Black Body results to be not in the perfect position so we have to lower the BB0 position.

6.6 Camera test

Test Date: <u>September 25, 2002 - DLR</u>   Test Result: Accept

Technician: Di Stefano G., Buongiorno M.F., Amici., L. Badiali and E. Lindermeier

Equipment:

Calibration Unit, Main Plate, Bench Structure and Parabolic Mirror, Flange.

Labview Program: camera_grab.vi

General Test Procedure: camera procedure acquisition.

We launched the camera procedure and verified the camera signal as showed by the figure.

Fig.12: graphic interface.

6.7 BB signal measurements

Test Date: **September 25, 2002 - DLR** **Test Result**: Reject

Technician: Di Stefano G., Buongiorno M.F., Amici S., L. Badiali and E. Lindermeier

Labview Program: temp_control.vi

Equipment:

Calibration Unit, Main Plate, Bench Structure and Parabolic Mirror, Flange.

General Test Procedure:
The measurements of the BB0 radiation was not realized because of the bad alignment of the system. The not removable Germanium window didn't allow to perform the alignment test.

6.8 BB heating control.

Test Date: **September 25, 2002 - DLR** **Test Result**: Accept

Technician: Di Stefano G., Buongiorno M.F., Amici., L. Badiali and E. Lindermeier

Equipment:

Calibration Unit, Main Plate, Bench Structure and Parabolic Mirror, Flange.

Labview procedure: temp_control.vi

General Test Procedure:
The measurements of the BB0 heating was successfully realized according to the time requirement of 15 min in order to reach the working temperature.

Comment
Will be realized test in order to characterized the BB parameter in order to maintain the constant temperature with a precision of ± 1K. Figure 13 shows the complete BB calibration mode se-up.

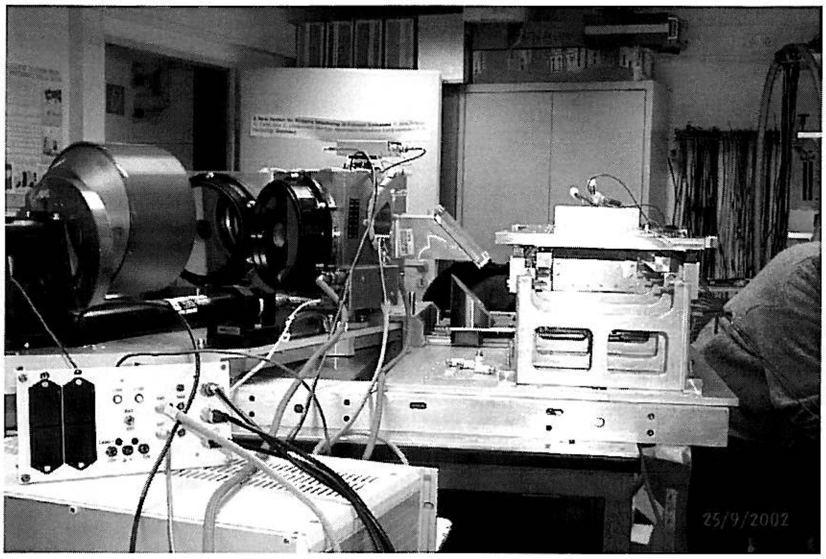


Fig.13: Set-up.

Reference

Haschberger P., Impact of the Sinusoidal Drive on the Instrumental Line Shape Function of a Michelson Interferometer with Rotating Retroreflector, *Applied Spectroscopy* 48 (1994), 3, 307-315.

Haschberger P., Tank V., Optimization of a Michelson interferometer with a rotating retroreflector in optical design, spectral resolution, and optical throughput, *J. Opt. Soc. America* A 10 (1993), 11, 2338-2345.

Haschberger P., Entwicklung eines Fourierspektrometers mit rotierendem Retroreflektor. PhD Thesis at the Fakultät für Elektrotechnik und Informationstechnik, *Technical University München/Germany*, 1992 .

Haschberger P., Mayer O., Tank V., Dietl H., Ray tracing through an eccentrically rotating retroreflector used for path-length alteration in a new Michelson interferometer, *J. Opt. Soc. America* A 8 (1991), 12, 1991-2000.

Haschberger P., Mayer O., Tank V., Dietl H., Michelson Interferometer with a rotating retroreflector: a laboratory model for environmental monitoring, *Applied Optics* 29 (1990), Nr. 28, 4216-4220.

Lindermeir E. , Haschberger P. Tank V. and Dietl H, Calibration of a Fourier transform spectromiter using three Black body source, *Applied Optics*, august 1992 Vol. 31, No. 22.

Lindermeir E. and Tank V., The spectral emissivity of natural surfaces measured with a Fourier transform infrared spectrometer. *Elsevier – Measurement* 14 (1994) 177-187.

Lindermeir E., Evaluation of infrared emission spectra of aircraft exhaust with the FiFas software. *Ann. Geophysicae* 12, 417-421, 1994.

Wolters F., Haschberger P., Tank V., Korn A., Innovative FTIR Spectrometry for Real Time NIR Industrial Process Control, 2000 *Annual AWMA Conference,* Salt Lake City/USA, June, 18-22, 2000.

Spectrometric inflight measurement of aircraft exaust emissions:First results of the June 1995 campaign, P. Haschberger and E. indermeier, *J.G.R.* vol. 101, NO D20, pages 25, 995-26, 006, November 20,1996.

Petrini M., Tonetti N., Cherubini G., FASA bench structural analysis, *OGF-AN-001* document of the 01/08/2002 Galileo Avionica.