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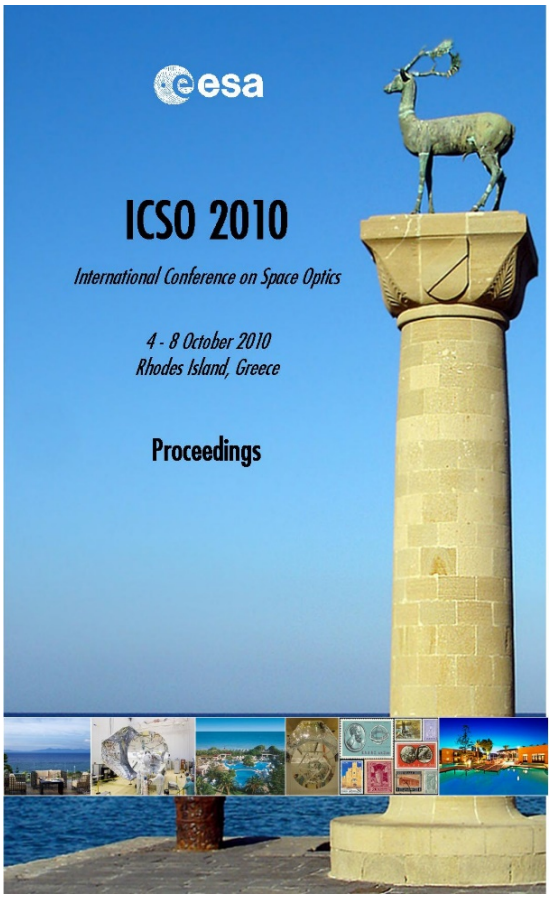

Edited by Errico Armandillo, Bruno Cugny, and Nikos Karafolas

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THE BRAZILIAN MULTISPECTRAL CAMERA (MUX) FOR THE CHINA - BRAZIL EARTH RESOURCES SATELLITE - CBERS 3 & 4

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This paper aims to present the optical system of the Multispectral Camera MUX that is part of the payload for the CBERS 3 & 4 satellite (China Brazil Earth Resources Satellite). The CBERS program was created by Brazil and China for the development of Earth remote sensing satellites. The MUX camera is being developed by the Brazilian company OPTO ELETRÔNICA S.A. and consists of a multispectral camera with four spectral bands covering the wavelength range from blue to near infrared (from 450nm to 890nm) with a ground resolution of 20m and a ground swath width of 120 km. Besides MUX camera (optical system, signal processing electronics and mechanical frame), this company is also developing the Ground Support Equipment – GSE of this camera and is responsible for structural and environmental tests. At the moment, the project is in the Qualification Model (QM). During this phase of the development, the camera shall be submitted to several tests, including environmental, optical and structural tests with the objective of qualify the project and start the flight models manufacturing.

INTRODUCTION

The partnership between Brazil and China for the development of satellites applied to remote sensing of the Earth started in 1988 through the CBERS program. So far, this program has already launched 3 units - CBERS 1, 2 and 2B. The next two satellites CBERS 3 and 4 are slight different from the previous launched and represent an evolution of the previous satellites. These satellites will carry four cameras on board. Two of the cameras (panchromatic and the IRMSS) are being built in China and the other two are being built in Brazil [1].
For these two Brazilian cameras (MUX and WFI), Opto Eletrônica S.A.[2] is in charge of their development, considering that this company participates in a consortium for the development of the WFI Camera (Wide Field Imaging Camera) and is responsible for the complete development of the MUX Camera (Multispectral Camera) and its Ground Support Equipment (GSE). The MUX-GSE equipments consists of an assemblage of equipments that perform on ground optical and electronic tests of this MUX camera. It includes a collimator, a scene simulator, an integrating sphere, a power supply, an oscilloscope, an image display system, etc. Fig. 1 exhibits some of the equipments of the MUX-GSE.

THE MULTISPECTRAL CAMERA - MUX

The MUX Camera will image a ground swat of 120Km with 20m of resolution. This camera consists of three equipments: RBNA, RBNB e RBNC. Fig. 2. shows the RBNA equipment of the MUX Camera.
The RBNA is responsible for the image acquisition and is composed by the optical system (entrance mirror and lens assembly), optical housing and the focal plane assembly. The RBNB consists of the electronics responsible for the thermal control, the focus adjustment and the internal calibration system control. The RBNC is responsible for generating the CCD reading clocks, processing the CCD analog outputs to digital signal and encoding the data into a serial data stream. This data is transmitted to the satellite.
The sensor of this camera has four lines, each one with 1 x 6000 pixels of 13x13µm in size. Spectral thin films deposited over a window that covers the photosensitive elements of the CCD are responsible for the four spectral bands separation.

OPTICAL DESING

A. Optical Requirements

Table 1 shows the main requisites of the optical system design for the MUX camera. Although the optical system meets its basic requirements, the system must be compliant with dimensional conditions such as mass and envelope, and support an internal calibration system between the adjustable lens and the focal plane. Other requirement of the optical system is to enable focus adjustment to allow the air compensation for the performance evaluation on ground. The entrance mirror should have a surface quality better than $\lambda/10$. The

system must withstand environmental requirements and to reach these performances specifications some theoretical analysis and vibration and thermal tests are performed.

Fig. 1. Some of the equipments of the Ground Support Equipments: collimator, integrating sphere, GSE controller, and image display system (Courtesy Opto Eletrônica S.A.).

Fig. 2. RBNA equipment (Courtesy Opto Eletrônica S.A.).

Table 1 . Optical System Requirements [3].

Characteristics	***Requirements***
Effective Focal Length – EFL	505.8 mm
Relative aperture	4.5
Field of view – FOV	±4.4º
Spectral bands	B05: 450 – 520nm; B06: 520 – 590nm; B07: 630 – 690nm; B08: 770 – 890nm;
Modulation Transfer Function – MTF	> 0.65 at 38.5lp/mm
Distortion	< 0.1%
Polarization Sensitivity	< 7.0 %
Field Illumination	Constant within ± 3.0%
Band-to-band registration	< 3.9µm
Mean Temperature of Operation	17.5ºC
Temperature Range	15ºC - 20ºC

B. Optical System Characteristics

Fig. 3 presents the layout of the optical system developed. The optical system consists of a refractive system with 14 components: an entrance mirror, a window, 11 fixed lenses and a moving lens. The total length of the optical system is 653mm. The weight of the optical components (excluding the mirror) is about 4.7kg and the system is athermal in the temperature range from 0ºC to 40ºC. Fig. 3 exhibits the manufactured optical system aligned in its optical housing and during optical test.

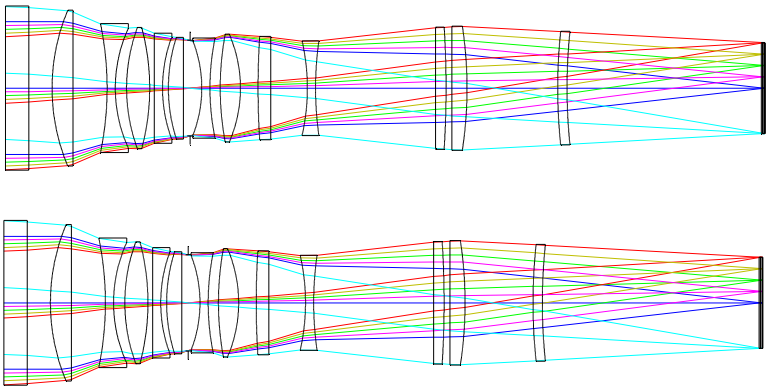


Fig. 3. Collecting lens system with focal adjust lens.

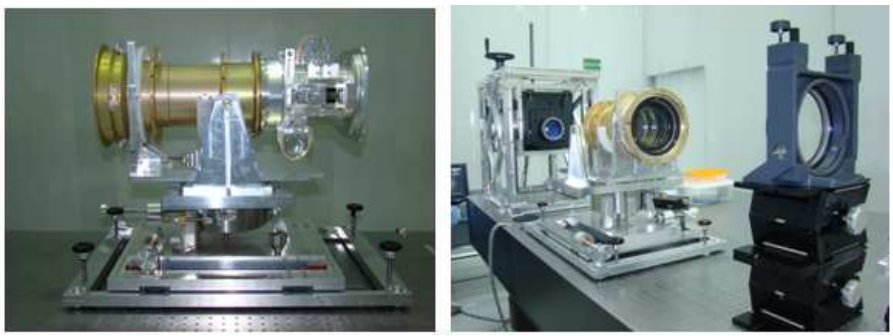
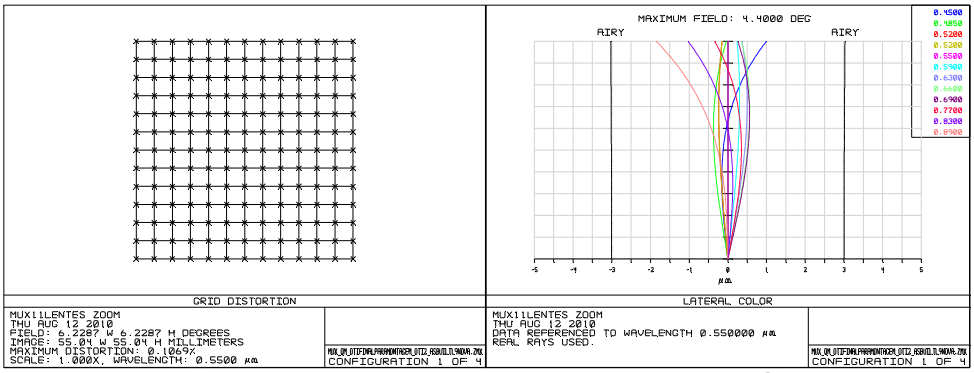


Fig. 4. Collecting lens with focus adjust lens assembled in alignment stage.

C. Theoretical Performance

The Fig. 5 shows graphics of grid distortion (<0.107%) and graphics of lateral color at the mean temperature operation (17ºC). Fig. 6 shows the graphics of the Modulation Transfer Function (MTF) for the four spectral bands all together at the overall temperature range (0ºC, 17.5ºC and 40ºC) in the air and vacuum positions. It shows that the MTF is > 0.7 at 38.5lp/mm. Fig. 7 shows Through Focus MTF for all spectral range (from 450nm to 890nm) in the overall temperature range (0ºC to 40ºC) in the vacuum and in the air.



a) b)

Fig. 5. a) Grid Distortion, b) Lateral Color.

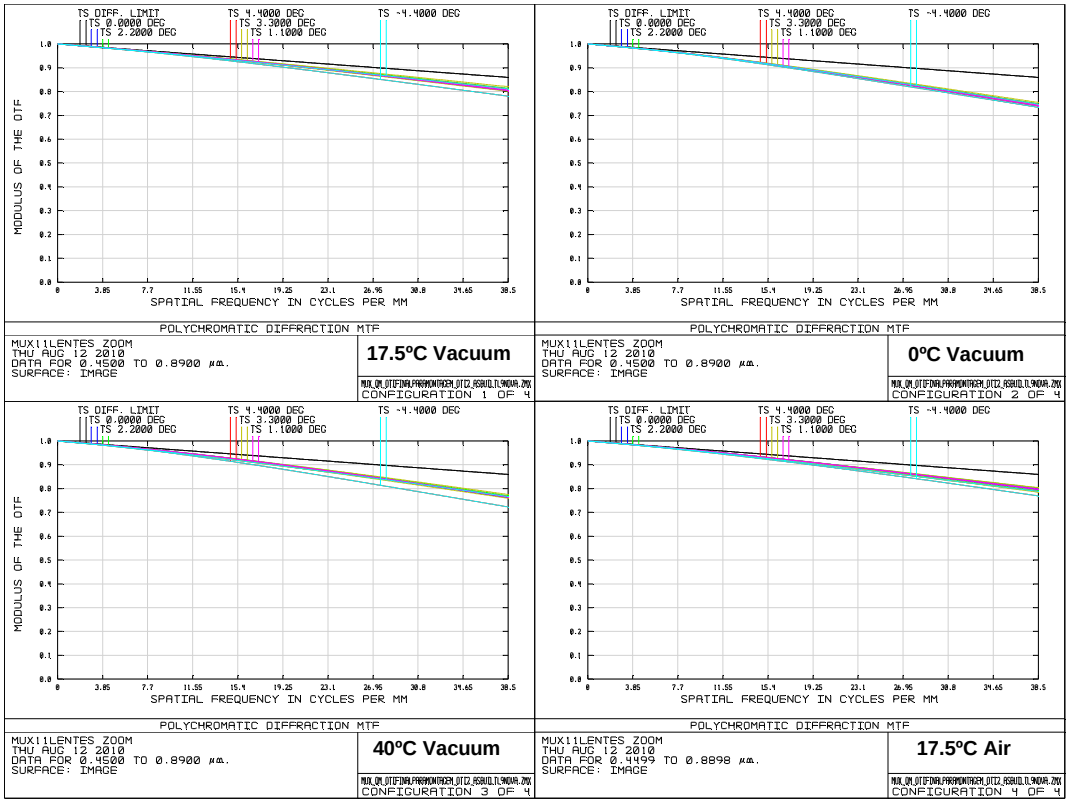


Fig. 6. Modulation Transfer Function in the four spectral bands, all together, at 17.5ºC, 0ºC and 40ºC in the vacuum and at 17.5ºC in the air.

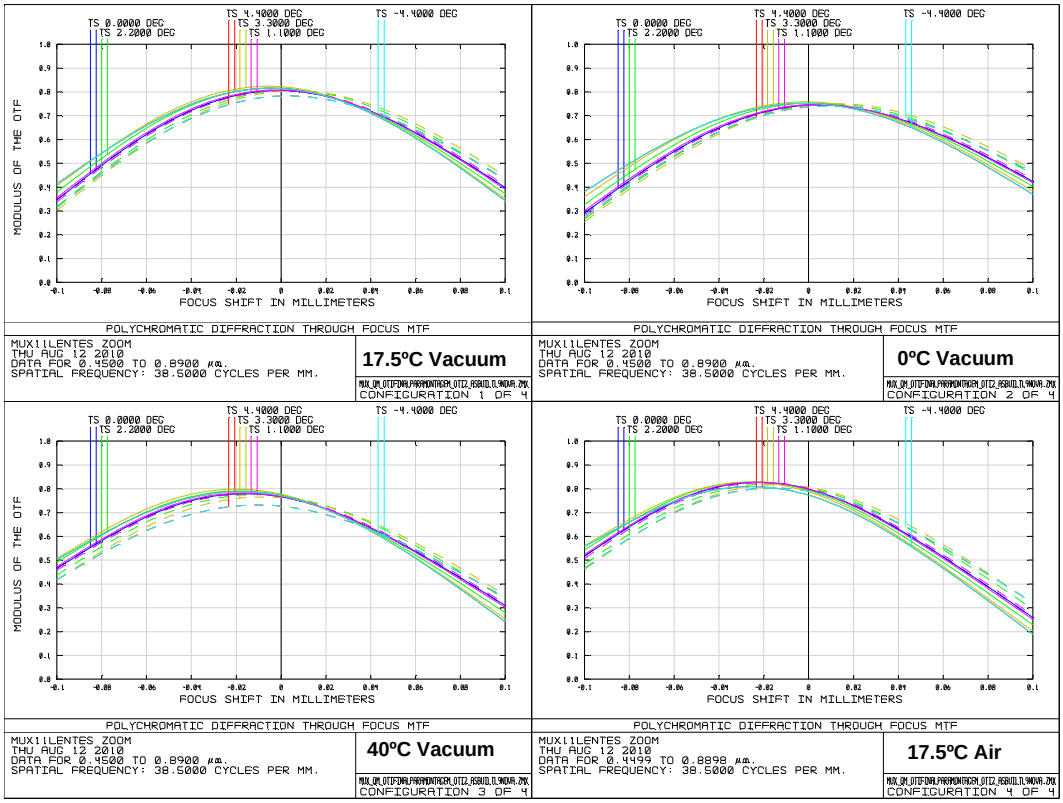


Fig. 7. Through Focus MTF for the overall wavelength range in the temperatures: 17.5ºC, 0ºC and 40.0ºC.

FLAT MIRROR

The entrance mirror must be manufactured with high superficial quality. The fabrication and mounting were performed at Opto Eletrônica S. A. Fig. 8 shows the schematic mounting draw and a picture of the mirror before it received the reflexive coating.

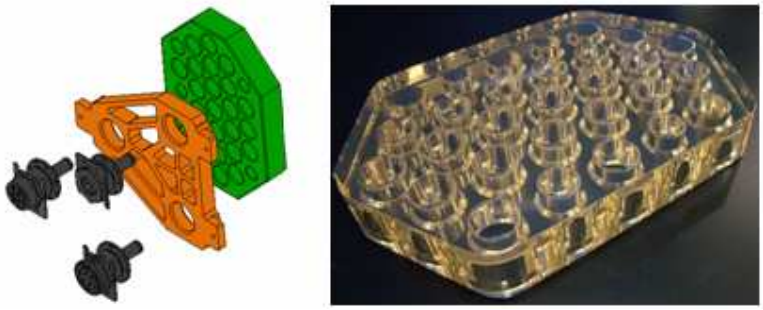


Fig. 8. MUX Camera entrance mirror.

CONCLUSIONS

The MUX camera is being developed to allow high quality performance images. This camera is the first one of this type to be developed, manufactured, mounted and tested in this country. The project is now on the Qualification Model (QM). The previous phases allowed the refinement of the project by means of analysis and tests. This phase foresee environmental and optical tests.
The QM unit is already aligned and the optical tests are being taking place. The preliminary results were very satisfactory.

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