International Conference on Space Optics—ICSO 2012

Ajaccio, Corse

9–12 October 2012

Edited by Bruno Cugny, Errico Armandillo, and Nikos Karafolas

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International Conference on Space Optics — ICSO 2012, edited by Bruno Cugny, Errico Armandillo, Nikos Karafolas
Proc. of SPIE Vol. 10564, 105640B · © 2012 ESA and CNES · CCC code: 0277-786X/17/$18 · doi: 10.1117/12.2309151

PMS Camera For ZY-1(02C) Satellite

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***Abstract*—PMS (panchromatic/multi-spectral) camera is one of the main payloads of the ZY-1(02C) satellite. It is a new generation camera of multi-spectral bands, which is developed by Beijing Institute of Space Mechanics & Electricity (BISME). PMS camera has one panchromatic band with 5m GSD, 3 multi-spectral bands with 10m GSD at nadir. The swath of camera is 60 km. It also has the sight capability of ±32°.**

On the December 22nd in 2011, ZY-1(02C) satellite was launched up successfully. PMS camera operates well and the image is good.

This paper gives the design and verification in the laboratory of the PMS camera. The test results show that the PMS camera satisfies the requirements.

Keywords: ZY-1(02C); PMS camera; Image Quality; Design and Verify.

I. INTRODUCTION

ZY-1(02C) satellite was built by Chinese Academy of Space Technology (CAST), which was customized by Ministry of Land and Resources of China to satisfy the urgent demand of land remote sensing data.

The satellite will cover the earth except the northern and southern polar region. It can provide the dynamic remote sensing data of usage of land, minerals and other data for the Ministry of Land and Resources of China and other ministries of China.

On the December 22nd in 2011, ZY-1(02C) satellite was launched successfully. The mass of the satellite is about 2000 kg. The power of the satellite is 2400W. After launch, the satellite was adjusted to run on the 780Km sun-synchronous orbit with 98.5° inclination angle. The satellite has two Hyper Resolution cameras (HR camera) with 2.36m GSD and 57 Km swath and a Panchromatic/Multi-Spectral bands camera (PMS camera).

The satellite was the highest resolution satellite for civil use in China at the launch time. On the 23rd, the camera was powered on and the first image was transmitted successfully.

PMS camera is the next generation data-transferring multi-spectral bands optical payload developed for remote sensing by BISME. The older generation multi-spectral bands payload is CCD Camera which is installed in the CBERS 1/2/02B satellites (China Brazil Earth Resources Satellite). The CCD camera has one panchromatic band, 4 multi-spectral bands. The GSD of the five bands is all 20m at nadir.

Figure 1. Lunch of ZY-1 (02C) satellite and The image of PMS

II. SPECIFICAITIONS OF PMS

PMS camera is a linear push broom imager. It has one panchromatic band and three multi-spectral bands, gets 5m GSD of panchromatic band and 10m GSD of multi-spectral bands on the 780km orbit. The main performances see next [2].

- Panchromatic Band B1：0.51～0.85μm
- Mulitband B2：0.52～0.59μm
  B3：0.63～0.69μm
  B4：0.77～0.89μm
- GSD Panchromatic Band： 5m(at nadir)
  Multi-spectral bands： 10m(at nadir)
- Swath： 60km
- Sight Ability： ±32°

III. DESIGN AND VERIYFICATION OF THE PMS

The camera concept is a push broom based on a catadioptric wide field telescope imaging simultaneously all the points of a line on the monolithic CCD array located in focal plane. The image is created thanks to the satellite motion. The focal plane of the camera is constitutive of four linear detector arrays corresponding to the four respective spectral bands.

A. Overall Configruration

The overall configuration of the camera is present below.

- Image with linear push broom modal to get a higher signal to noise (S/N).

- Use the 12,000 pixels linear CCD with size of 6.5 μ m ×6.5 μ m.
- Enhanced Schmidt catadioptric optical system to get high performance at the 77lp/mm nyquist frequency
- The video circuit composed of two main assemblies, the focal plane assembly ensuring the spectral separation and transforming the incoming optical signal in electronics, and the video circuit electronics, interfacing with the focal plane assembly and the satellite.
- The focal plane is adjustable to get a better image.
- To swing the swing mirror to get the ±32° sight ability.
- The thermal control keeping the telescope within the close temperature domain. Passive and active thermal controls are required to main the average temperature within the ±2℃ while minimizing the gradient down to 0.3℃.
- The service electronics which interfaces with the satellite and controls the camera mechanisms and its active thermal control.

B. Optical system Design and Verifcation

The optical system of PMS camera has a long focal length, small big F number and wide spectral. Table I gives the specifications of the optical system. It should get high image quality at the 77lp/mm nyquist frequency. Also the method of splitting the light into multibands and the register of multibands should be considered. Optical manufacturing and alignment are two of the most important restriction factors. All these factors add the difficulties to design the optical system. Balance all the factors and choose the catadioptric Schmidt optical system. The optical elements include: swing reflective mirror, window, 45° reflective mirror, spherical reflective mirror, lens and prism. There are two imaging channels, one for panchromatic band and the other for multibands. The prism is used to split the light into three multibands. Fig. 2 gives the drawing of the optical system. Fig. 3 gives the prism sketch. Fig. 4 gives the design result of the optical system. Fig. 5 gives picture of the telescope tested in the lab.

TABLE I. OPTICAL CHARACTERISTICS

Characteristics	Requirements
Focal Length	1010 mm
Relative aperture	3.5
Field of view – FOV	±2.2º
Spectral bands	B1: 510 – 850nm; B2: 520 – 590nm; B3: 630 – 690nm; B4: 770 – 890nm;
Optical System MTF	➢ 0.45 at77lp/mm (B1 band) ➢ 0.65 at 38.5lp/mm (B2~B4 band)
Global MTF at the nyquist frequency	> 0.18 for B1 and B4 band, > 0.22 for B2 and B3 band.
Band-to-band registration	<3.9 μm

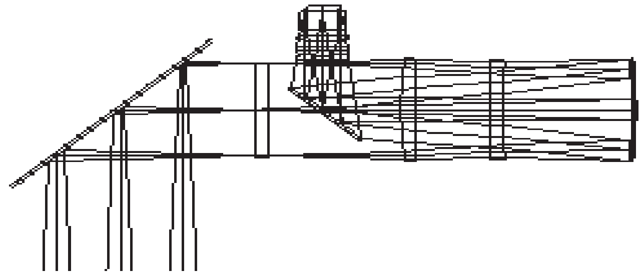


Figure 2. Optical system of PMS camera

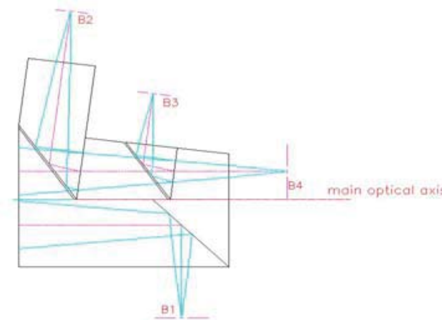
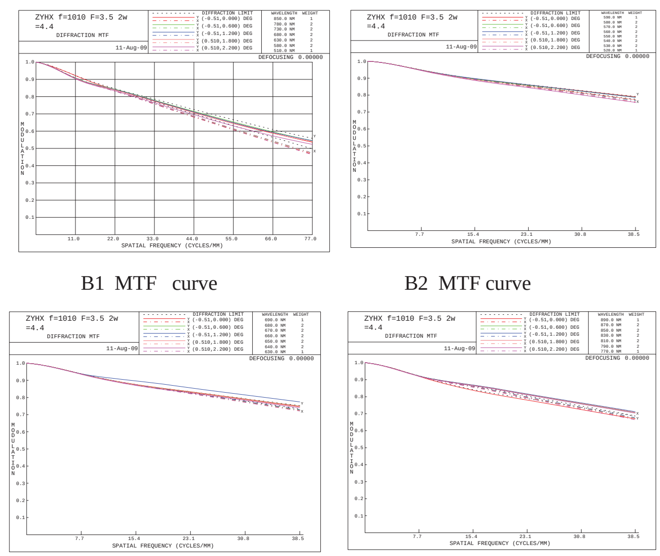


Figure 3. Light splitted in the Prism



B1 MTF curve   B2 MTF curve

B3 MTF curve   B4 MTF curve

Figure 4. Desgin Results of MTF of Four bands

From the MTF curve above, the design MTF is almost coincide with the diffractive limit.

The Optical System Performance was estimated by using a ZYGO GPI/XP interferometer that works at the 632.8nm wavelength. The measurement of the optical Performance was performed only in this wavelength and it was used as a preliminary analysis that was carried out during the alignment phase.

Fig. 5 gives the test setup of the optical MTF.

Figure 5. The Setup of the Optical MTF Test

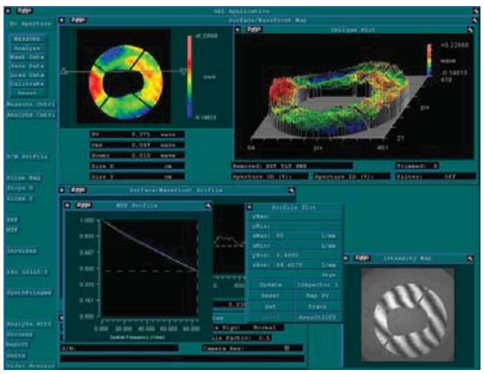


Figure 6. The Optical MTF Test Interface of B1 band

From the Fig. 6, RMS of B1 band is 0.049 λ . The optical MTF is 0.47 at 77 lp/mm. The requirement is 0.45. The other three bands also reach the requirements.

A high quality optical system is designed, aligned and tested. The test results reach the requirements.

C. *Design of the Opti-mechanical Body*

From the design result of the optical system, the body is long and thin. It is difficult to draw the sketch. In order to have the sight ability of ±32°, the swing mirror needs to swing ±16° off the track. The swing mirror is a flat and reflective mirror and it only provides the rotary direction. So the position accuracy is not very high as other optical elements. From the above analysis, we can get that the swing mirror and lens are separated mounted in the satellite. There is no fix connection between the two parts. Fig.7 gives the two separate assemblies. Fig.8 gives the whole opti-mechanical body.

The main function of the swing mirror is to swing ±16°. The main function of lens is to collect the light that reflected by the swing mirror and transmit the light into electrical signal. The separation mount also saves about 60kg mass. The mass of opti-mechanical Body is 218kg.

The Swing Mirror Assembly The Lens Assembly

Figure 7. The Two Seperation Assemblies

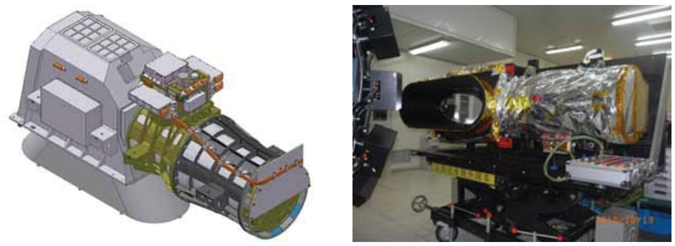


Figure 8. The Opti-Mechanical Body

D. *Design and Verification of Thermal Control*

The thermal control of the camera consists of passive thermal control and active thermal control. Passive thermal control is composed multi-layer heat insulation materials, thermal control coat and reasonable heat emission plane. Active thermal control means the heating loops on the steer mirror, lens and focal plane. The function of active thermal control is to ensure the suitable work environment temperature of the optical mechanism main body with the thermal controller.

The requirements of the camera are above:

- The temperature range of the steer mirror 15℃～21℃;
- The temperature range of the lens: 16℃～20℃, the gradient except the window down to 0.3℃;
- The temperature range of the prism: 16℃～20℃, the gradient down to 0.7℃;
- The temperature of CCD: no more than 28℃.

In order to get a better image, there is a refocus mechanism with the prism, CCD and driving circuit boards. The prism and CCD will move some distance relative to the main body. But in order to keep the temperature of the CCD and prism, the heat generated by CCD should be dissipated. Conventional ways to dissipate the heat such as heat pipe or copper can not be used because they are fixed. Conductive rope is manufactured to solve this problem. The conductive is made of copper and has a high conductive efficiency. It is also like a rope and has freedom to move.

Fig.9 gives the scheme of the dissipation chain of the CCD. Table II gives the results tested in the lab.

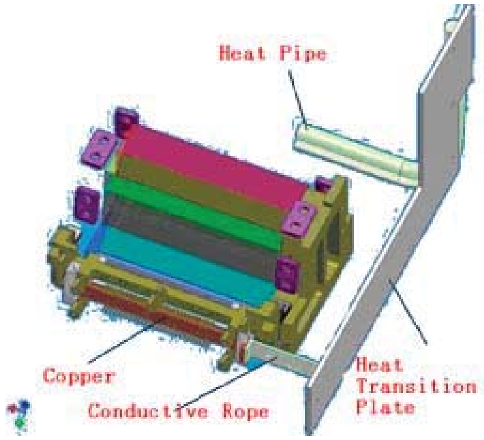


Figure 9. The dissipation chain of the CCD

TABLE II. TEST RESULTS OF THERMAL CONTROL

Assembly	Temperature Range		Temperature Gradient	
	Requirements	*Test results*	*Requirements*	*Test results*
Steer Mirror	18±3℃	16.2-19.2℃		
Lens	18±2℃	17.4-19℃	≤0. 3℃	0. 24℃
Prism	18±2℃	17.6-19.3℃	≤0. 7℃	0. 3℃
CCD	≤28℃	10.4-19.4℃		

IV. PMS SYSTEM TEST IN LABORATORY

Once the camera is built up, a series of tests will be conducted to verify the performance the camera.

A. System MTF Test

The MTF is of high importance on the evaluation of the spatial frequencies transferred from object to the image of an imaging optical system.

The MTF is equivalent to a combination of the MTF of optical system (MTF_{lens}), CCD (MTF_{CCD}), amplification and signal processing electronic ($MTF_{electronics}$)

$$MTF_{System} = MTF_{lens} \times MTF_{CCD} \times MTF_{electronics} \quad (1)$$

The system MTF test is a very important phase. The system MTF was obtained by using an on-axis collimator (EFL =7000 mm) and a square target. This target is positioned in the focal plane of the collimator and then is moved in steps of 500μm, which allows for determining the CTF of the target image around a specific pixel in discrete steps of 4.2 μm. MTF is calculated by the equation 2.

$$MTF \approx (\pi/4) \times CTF \qquad (2)$$

Table III gives the test results of globe MTF of PMS. Use equation 1 to get the prediction value.

TABLE III. OPTICAL CHARACTERISTICS

	Requirements	Prediction	Test Value
B1	B1≥0. 18	0. 18	0. 18
B2	B2≥0. 22	0. 33	0. 31
B3	B3≥0. 22	0. 28	0. 26
B4	B4≥0. 18	0. 19	0. 19

B. Calibration Test

Calibration test is to verify the radiometric quality of the camera. We can get the absolute calibration coefficients, relative calibration coefficients, linearity and S/N of the camera by the calibration test. A high steady and precision integral sphere is used to conduct the test. Fig.10 gives the test setup.

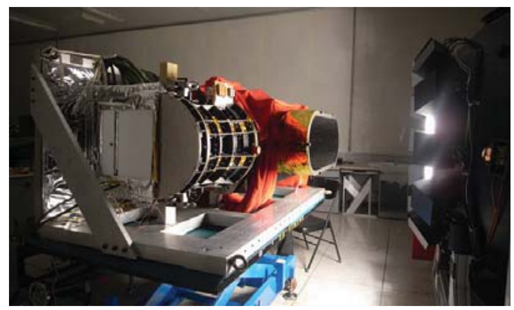


Figure 10. Integral Sphere Test

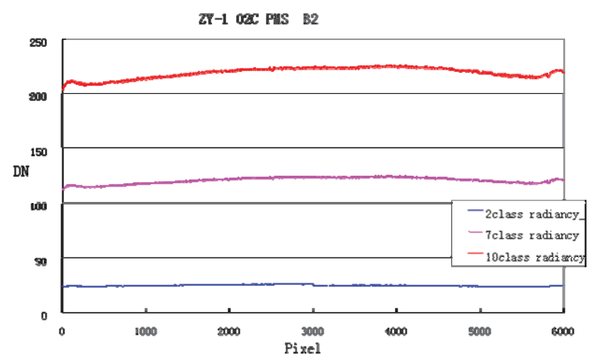


Figure 11. Response curve of B2 band at different radiance

TABLE IV. ABSOLUTE CALIBRATION COEFFICIENT

Band	Test result of absolute calibration coefficient at default gain DN/(W·m-2·sr-1·μm-1)
B1	1.4283
B2	1.6945
B3	1.5198
B4	1.7993

Fig.11 gives the response curve of B2. Table IV gives the test result of absolute calibration coefficient at default gain.

V. Conclusions

The PMS camera of the ZY-1 (02C) satellite is a new developed generation payload. The payload has used the improved Schmidt catadioptric optical system. The design result of optical system reaches the diffractive limit. According the characteristics of the optical system, the opti-mechanical body is separated into two separate parts. The camera has experienced the test and experiment. The test result has reached the requirements. From the image transmitted by the satellite in the orbit, the image quality has reached the requirements.

References

[1] G. D. Boreman, Modulation Transfer Function in optical and electro-optical systems. Bellingham: SPIE PRESS, 2001.

[2] CAST. ZY-1 (02C) PMS Subsystem Specification. (unpublished).

[3] Shiping Chen, Design and Experiment of the Space Camera. Aerospace Publishing Company, 2003 (in Chinese).