PMS, AN ENHANCED MULTI-SPECTRAL CAMERA OF ZY-1 02C SATELLITE

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Abstract: ZY-1 02C satellite was launched successfully on 22nd November, 2011. PMS supplies the GSD 5m panchromatic band and GSD 10m multi-spectral data. The swath of PMS is 60Km. It also has the ±32°side-looking ability. PMS is a linear pushbroom camera. There are many improvements in the PMS.

The optical system of the camera is a high performance catadioptric Schmidt optical system. It can give good image quality at 77lp/mm nyquist frequency. Also a new high performance CCD is used and a low noise video circuit is designed. Stray light is suppressed greatly. The design is verified in the laboratory and on orbit.

This paper gives the main improvements of the camera and related test result.

1. INTRODUCTION

ZY-1(02C) satellite is built by Chinese Academy of Space Technology (CAST), which is customized by Ministry of Land and Resources of China to satisfy the urgent 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 22nd December in 2011, ZY-1 (02C) satellite was launched successfully. The mass of the satellite is 2056 kg. The power of the satellite is 2400W. After launch, the satellite is adjusted to run on the 778Km 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 camera (PMS camera).

The satellite is 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.

2. PERFORMANCE OF PMS

PMS is a new generation payload, which is developed for the land resource satellite by Beijing Institute of Space Mechanics and Electricity. PMS camera is a linear pushbroom imager. It has one panchromatic band and three multi-spectral bands, gets 5m GSD of pan band and 10m GSD multi-spectral bands on the 778km orbit. The main performances see table 1.

Table 1 Main parameters of PMS

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

3. DESIGEN AND VERIFY OF THE QUALITY OF PMS

According to the specifications, a plan design is conducted.

1) Image with linear pushbroom modal to get a higher signal to noise (S/N).

There are three main imaging models in the field of satellite remote sensing, pushbroom, wiskbroom and staring array. The pushbroom is the most popular modals.

3) Use the prism to split the light into three multi-spectral bands.

4) The focal plane is adjustable to get a better image on orbit.

5) To swing the swing mirror to get the $\pm 32^\circ$ sight ability.

6) Use the pixel size of 6.5 μm×6.5 μm linear CCD.

3.1 Design and verify of Optical system

The optical system of PMS camera has a long focal length, small big F number and wide spectral. It should get high image quality at the 77lp/mm nyquist frequency. Also the method of splitting the light into multi-spectral bands and the register of multi-spectral bands should be considered. 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. Figure 1 gives the drawing of the optical system. Figure 1 gives the design result of the optical system.

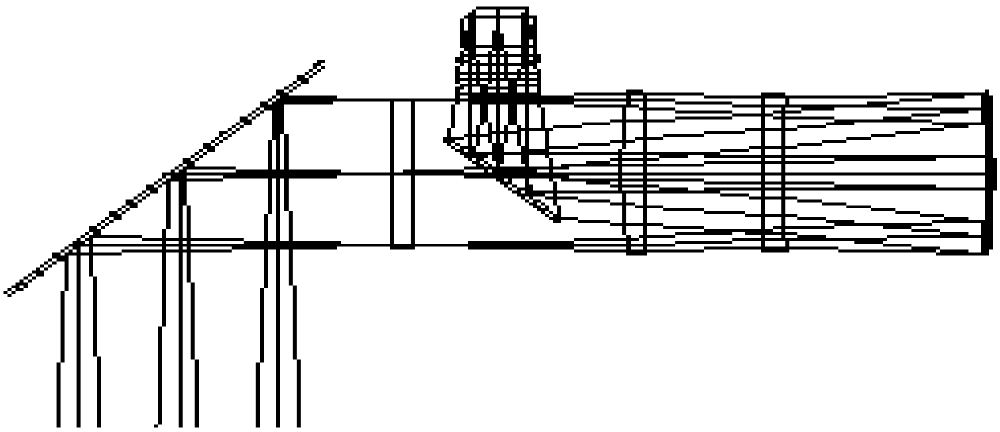
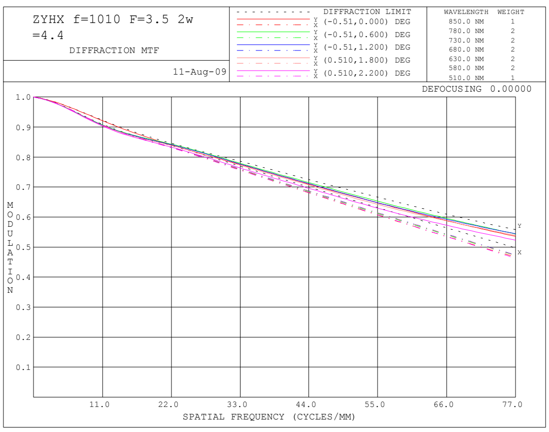
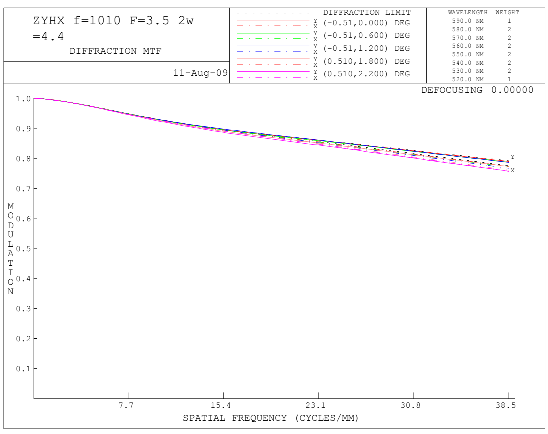


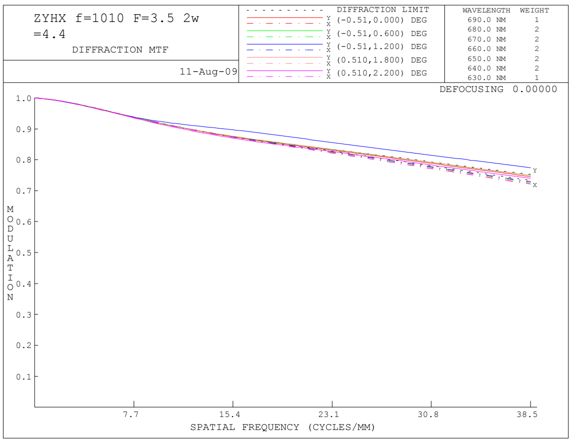
Figure1 Optical system of PMS camera

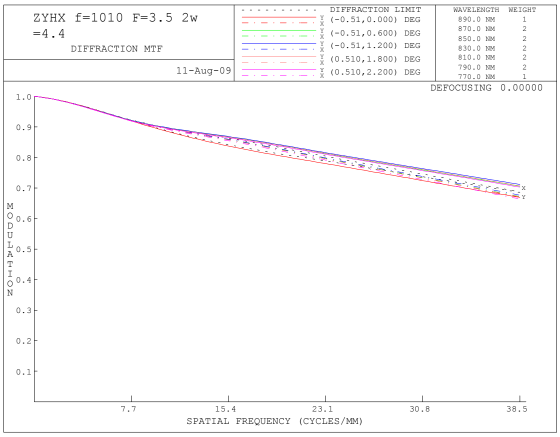


B1 MTF



B2 MTF



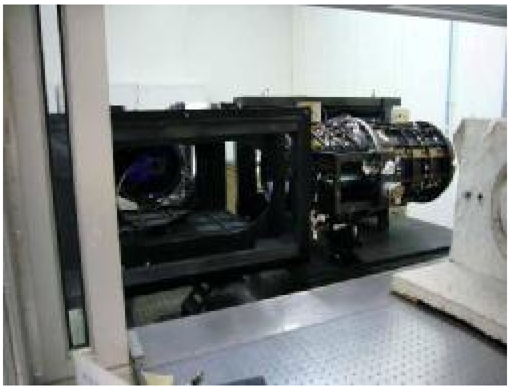


B3 MTF **B4 MTF**

Figure2 MTF of Four bands

From the figure2, the MTF almost reaches the diffractive limit. Design result is high quality.

When the lens is aligned, 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. The wavefront emitted by the interferometer crosses the optical system, reflects on the reference flat and returns through the optical system back to the interferometer, where it interferes with the reference beam to obtain the interferometric pattern. From this pattern the software can calculate the system performance for the reference wavelength. The peak-to-valley wavefront error (P-V) and rms value can be analyzed for the evaluation of the system.



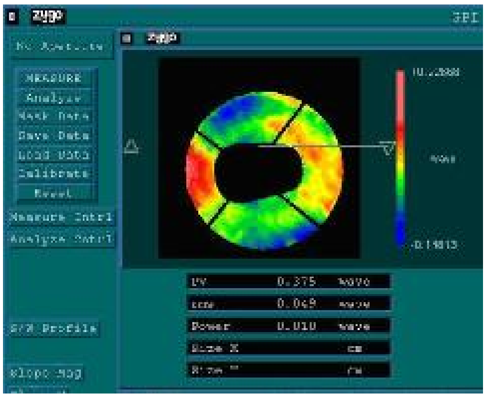


Figure 3 The test result of the optical system of the PMS camera

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.

$$MTF \approx (\pi/4) \times CTF \qquad (1)$$

Table2 gives the test results of globe MTF of PMS. Use equation 1 to get the prediction value.

Table2 MTF test

	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

3.2 Design and verify of SNR

Signal to Noise ratio (SNR) is one of the most important parameters that affect the image quality. To improve the SNR, several ways are adapted. First, pushbroom image model is adapted to extend the dwell time and then to collect more energy and improve the signal level. Second, a high performance CCD is used. Third, Correlated Double Sample (CDS) circuit is used to reduce the noise. 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 calibration test. Table 3 gives the test result of SNR at default gain.

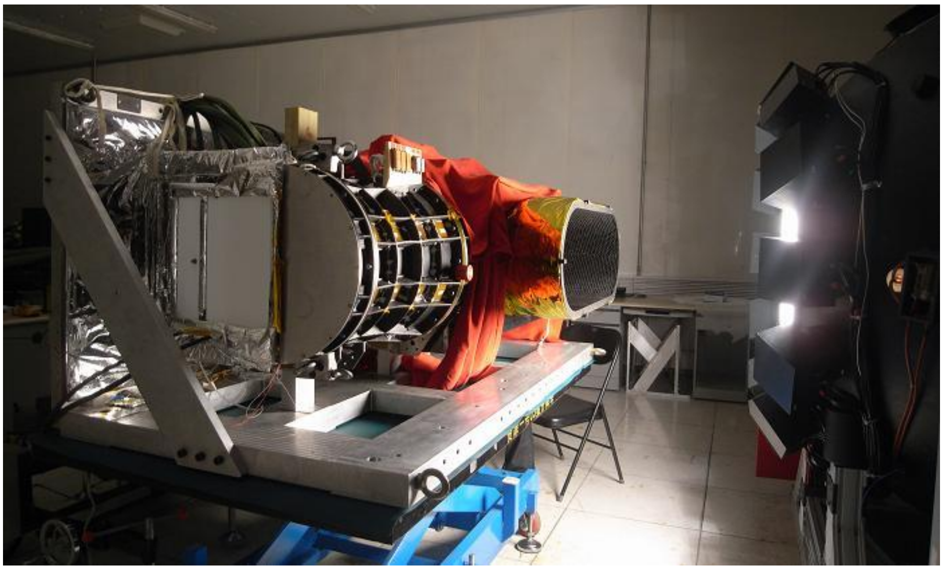


Figure4 Integral Sphere Test

Table2 Test results of SNR

BAND	Test Value of SNR（dB）	
	Min. Input	Max. Input
B1	32.4	51.6
B2	39.6	51.8
B3	31.2	51.4
B4	37.7	50.8

3.3 Stray Light Suppress

At the primary design, the coefficient of the stray light is very high. It is almost 24.4%. It greatly degrades the quality o f the image. By analysis, there is a beam of light directly into the surface of CCD, see figure5.

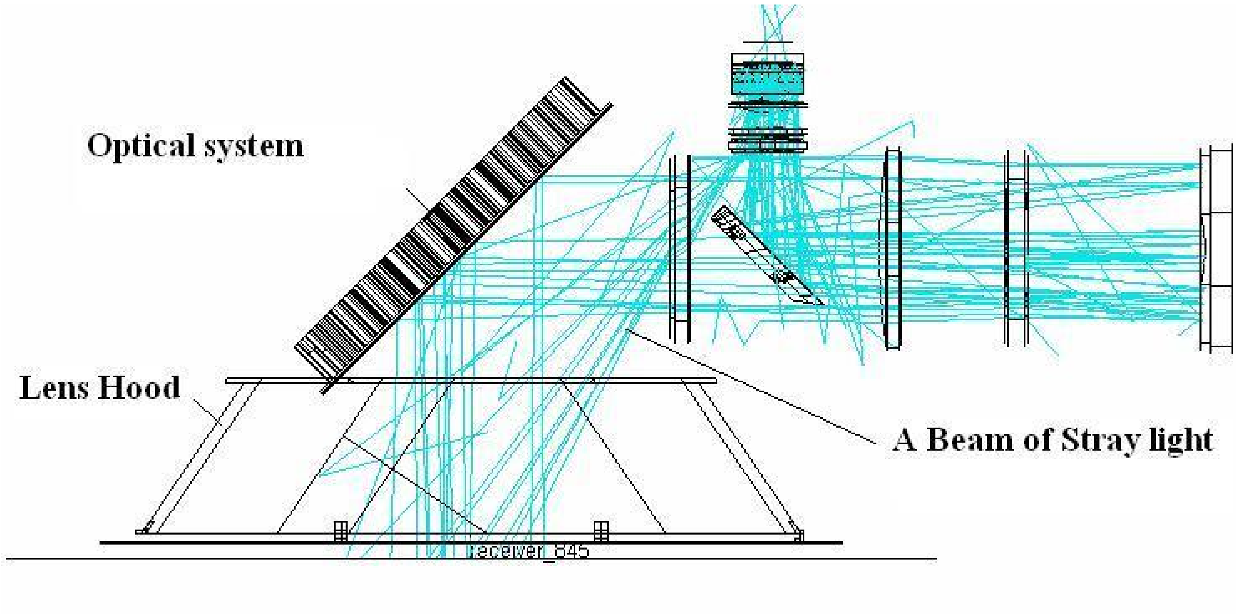


Figure5 the stray light traces

The stray light structure is used to suppress this beam of light. By analysis, we can get the stray light coefficient, see table3

Table3 Test results of SNR

Band	B1	B2	B3	B4
stray light coefficient	0.80%	1.64%	0.72%	0.93%

The verification test is conducted, see figure6.

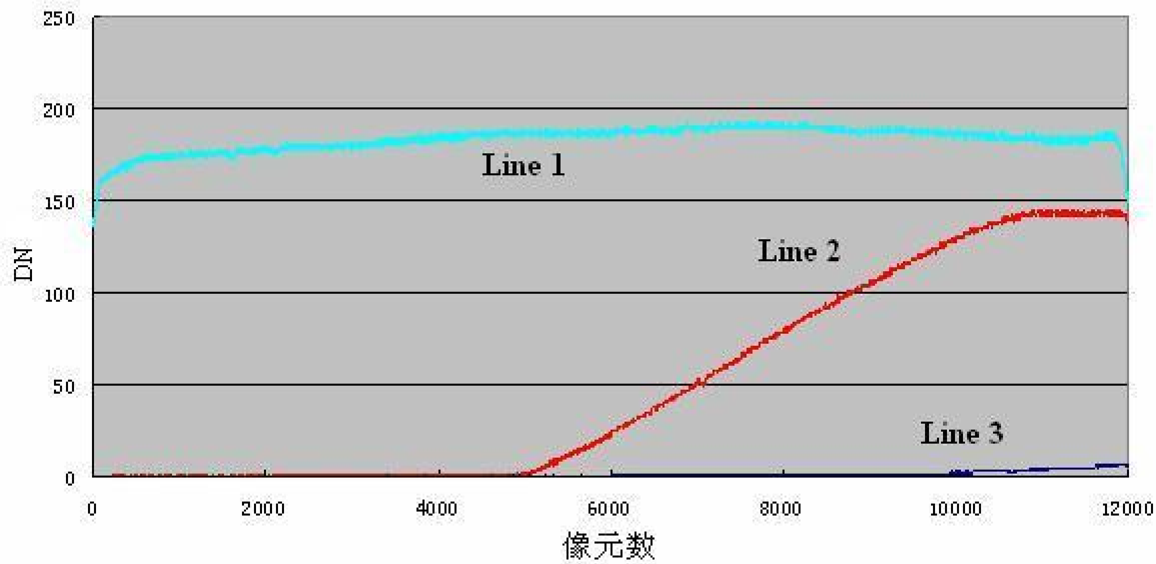
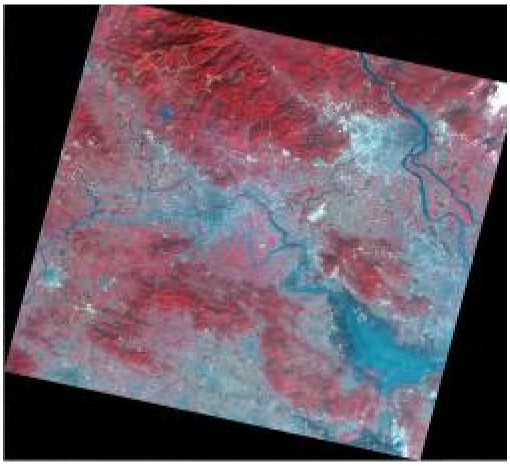


Figure6 Test curves of stray light suppress

From the figure6, line 1 is the normal response curve without stray light. Line 2 is the stray light response. Line 3 is stray light with suppress structure. We can get that the stray light is greatly reduced to guarantee a good image.

4. VERIFICATION ON ORBIT

After launch, a series tests are conducted to verify the image quality,. The test results reach the specifications and gives good image see the figure7.



Meizhou District in Guangdong Province **Indian Coral Sea**

Figure7 Test curves of stray light suppress

4. CONCLUSION

The PMS camera of the ZY-1 (02C) satellite is a new developed generation payload. The payload has adapted several ways to improve the quality of the image. A catadioptric Schmidt optical system is designed and verified. By the stray light analysis, a beam of stray light is greatly reduced. The high SNR is designed and tested.. From the image transmitted by the satellite on the orbit, the image quality has reached the requirements.

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