Viser Technology Pte. Ltd.
Mechanical Engineering Science
DOI: 10.33142/mes.v8i1.20092

Research Article Open Access

Design of a Vehicle Mounted Pan Tilt Testing Tamera

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Abstract

The camera, designed for testing the vehicle-mounted gimbal, boasts compact size, lightweight, and superior imaging quality, enabling more precise debugging of precision gimbals. By optimizing the optical system using ZEMAX optical simulation software and incorporating aspherical elements to improve imaging quality whilereducing the weight of the test camera, the design is manufactured. Finally, the machined aspherical surface is inspected, and imaging quality is verified through image capture.

Key words: *test camera; vehicle mounted pan tilt*

1 Introduction

The vehicle-mounted gimbal is primarily used for outdoor shooting while driving. Since it requires camera imaging, the motion stability of the gimbal is subject to extremely high demands, necessitating the installation of a test camera during factory debugging to evaluate its performance parameters[1]. This test camera must feature excellent imaging quality[2], lightweight design, and minimal impact on the gimbal's movement. Aspherical mirrors can enhance imaging quality[3].

2Optical System Design

2.1 Calculation of initial optical values

Firstly, calculate the entrance pupil diameter D of the camera, as shown in equation (1):

$$D=\frac{f'}{F} \tag{1}$$

In equation (1): D is the diameter of the entrance pupil; f' is the focal length of the lens, taken as 80 mm; F is the F-number of the lens, F=8, and the entrance pupil diameter D is obtained as 10 mm.

According to the field of view, the effective area of the detector can be obtained.

$$\tan\omega=\frac{y'}{f'}\rightarrow 2y'=2f'\tan\omega \tag{2}$$

In equation (2): ω is the half field angle; If $2y'$ is the diagonal size of the CCD (charge coupled device) sensor, then the diagonal size of the receiving surface of the CCD sensor of the camera lens can be calculated as $2y'$=39.892mm.

The designed camera is used for vehicle mounted gimbal testing, and the expected parameters of the camera imaging system are shown in Table 1.

Table 1 Camera Design Indicators

parameter	numerical value
MTF (91 lp/mm)	>0.3
CCD receiving surface size（mm）	>39.892
focal length (mm)	80
F#	8
field of view (°)	greater than 28
Object distance（mm）	500 or more to infinity
distortion	<1%
Optical band	visible light band

2.2 Selection of initial structure and correction of aberrations

2.2.1 Selection of initial structure

The selection of the initial optical structure is a prerequisite for the overall design of the optical system. Firstly, it is necessary to meet the basic requirements of lens design in the basic structure

Received on March 24, 2026; Accepted on April 30, 2026

Under the condition of satisfying the requirements, correcting the primary aberration and selecting a suitable initial structure can greatly shorten the design cycle. Select an approximate optical system from existing optical systems by comparing focal length, aperture, and field of view. Choose a double Gaussian optical structure as the initial structure, as shown in Figure 1. The optical system has a total of 25 design parameters, including 12 surface curvatures, 6 lens thicknesses, 5 air gaps, and back focal length.

2.2.2 Correction of aberration

Select the appropriate optical system data from ZEMAX lens design software, and the initial lens design data is shown in Table 2.

Table 2 Initial data of mirror group

	Surface type	curvature radius	thickness	material
object surface		-	infinity	
1	spherical surface	27.057	4.37	HZBAF50_CDGM
2	spherical surface	78.260	0.25	
3	spherical surface	17.975	7.8	HF13_CDGM
4	spherical surface	6.86	1.34	
5	spherical surface	16.93	1.89	HZK6_CDGM
6	spherical surface	11.135	7.13	
7 aperture	spherical surface	-	4.61	
8	spherical surface	-12.84	1.85	HZK20_CDGM
9	spherical surface	-10.84	1.09	
10	spherical surface	-6.91	5.4	F2_CDGM
11	spherical surface	-18.49	0.27	
12	spherical surface	98.2	3.43	HZBAF50_CDGM
13	spherical surface	-10.4	75.6141635	
Imaging surface	spherical surface	-	0	

Using ZEMAX software to simulate an optical system, it was found that there are aberrations in the system that seriously affect imaging quality. Therefore, the parameters of the optical system should be optimized. Optimize the optical system through the default evaluation function in ZEMAX. Additional auxiliary operands are used to balance specific aberrations. The importance of the default optimization function lies in calculating aberrations when the object's light is given from a specific image plane. The default selection is RMS+Spot Radius+Centroid, and then add a small number of custom optimization objectives. Table 3 shows the optimization functions used in the optimization process.

Table 3 Optimization Numbers

Operand	Meaning	Target
EFFL	Effective focal length	8
SPHA	Spherical aberration	0
DIST	Distortion contribution	0
DIMX	Distortion	1%

The following is an analysis of the optimized optical system. The results indicate that there are still aberrations that do not match the initial target. From Figure 1, it can be seen that the value of MTF (modulation transfer function) is much smaller than 0 3@91 lp /mm。 This means that the optical system cannot meet the imaging requirements. Therefore, the system should be optimized more deeply.

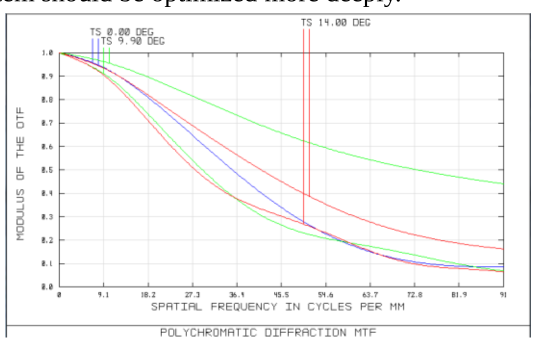

Figure 1 Initial optimized MTF diagram

2.3 Utilizing non spherical surfaces to improve image quality

Non spherical surfaces can be used to correct aberrations and reduce the weight of the lens. Figure 2 shows the effects of correcting spherical aberration using spherical and non spherical surfaces, respectively. In Figure 2, the spherical surface has fewer optimizable factors compared to the non spherical surface, and the non spherical surface has more advantages in correcting spherical aberration.

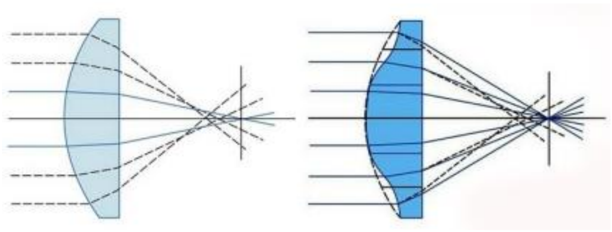

Figure 2 Comparison between spherical and non spherical surfaces

In order to achieve the expected imaging performance, it is necessary to use non spherical surfaces reasonably to correct its primary and higher-order aberrations. Therefore, a surface with a larger ASP is chosen as the non spherical surface. After calculation, select the third surface of the optical system as the non spherical surface. The high-order coefficient data obtained from non spherical optimization are shown in Table 4.

Table 4 High order Non spherical Coefficients

K	a_6	a_8
-1.697116	8.3467e-09	-4.645519e-11

In the simulation of ZEMAX software, a non spherical optical system was established, The radius, thickness, and diameter of each surface are shown in Table 5. Then optimize the optical system by using the previous operands.

MTF curve and as shown in Figure 3. Figure 3 shows that the MTF of all domains is greater than 0.3 @ 91 lp/mm. Compared to the previous MTF curve, the MTF has increased by over 42%.

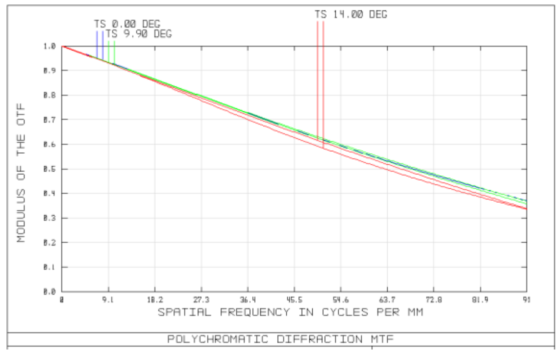

Figure 3 Non spherical optimized MTF diagram

Table 5 Mirror group data

	Surface type	curvature radius	thickness	material
object surface		-	Infinity	
1	spherical surface	18.046	6.4	HZBAF50_CDGM
2	spherical surface	50.12	0.1	
3	Non-spherical surface	34.574	2.4	HF13_CDGM
4	spherical surface	13	5	
5	spherical surface	24.77	2	HZK6_CDGM
6	spherical surface	28.444	2.6	
7 aperture	spherical surface	1e+018	5	
8	spherical surface	-64.993	2.4	HZK20_CDGM
9	spherical surface	-27.427	0.97	
10	spherical surface	-16.218	2.4	F2_CDGM
11	spherical surface	192.31	1.32	
12	spherical surface	402.5	6.2	HZBAF50_CDGM
13	spherical surface	-20.7	62.1258262	
Imaging surface	spherical surface	-	0	

3 Non Spherical Lens Detection Imaging Experimental Testing

3.1 Non spherical lens testing

The actual lens produced after processing is shown in Figure 4. The PV (peak value), Ra (average roughness), and RMS (root mean square) values of the processed non spherical mirror were measured using a ZYGO interferometer, and the final results are shown in Figure 10. The final measured PV is 14 422, Ra is 2 641, RMS is 3.102, both within a reasonable range.

3.2 Imaging experiment detection

Evaluating image quality through resolution is a widely accepted system performance measure. By adjusting the speed control box to adjust the standard resolution drum, the assembled mirror group can obtain the target image. Take a photo of ISO12233 as shown in the figure. Black lines can still be distinguished in the smallest image of the resolution map, meeting the imaging quality requirements of the camera.

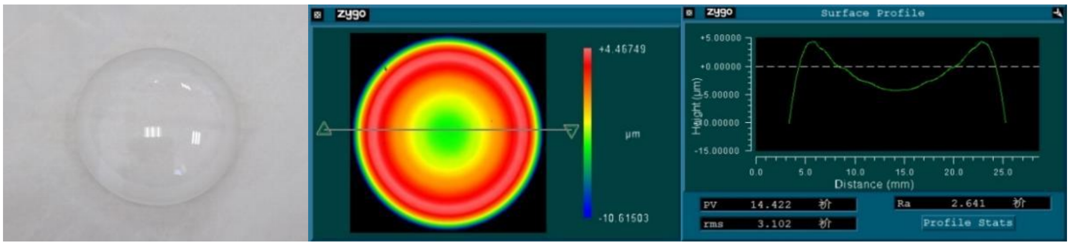

Figure 4 zygo imaging image

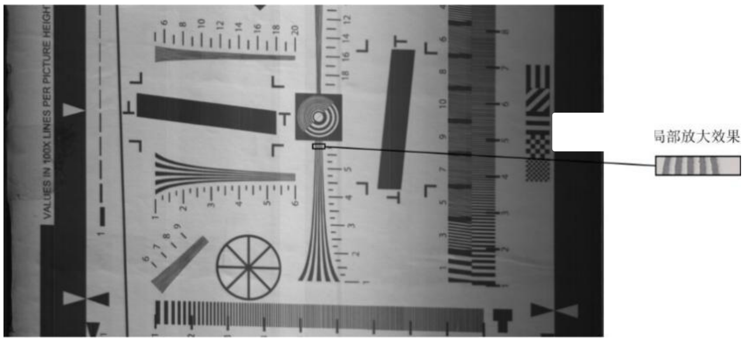

Figure 5 Imaging image of assembled lens

4 Conclusion

Designed and tested a non spherical detection camera. The results indicate that the performance of optical systems based on non spherical surfaces is superior to those based on spherical surfaces. The test proves that the designed vehicle mounted gimbal test camera can meet the design requirements. After optimizing the optical system, the MTF of the optical system is better than 0.3 @ 91 lp/mm. Use ZYGO interferometer to detect the qualification of non spherical mirrors. The test image shows that the camera imaging effect can meet the requirements.

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