Synopsis of
"Design of reflective projection lens with Zernike polynomials surfaces"

Zhenrong Zheng, Xutao Sun, Xu liu, Peifu Gu

Published in Science Direct, Display 29 (2008) 412-417

University of Arizona

College of Optical Sciences

Haosheng Hu

OPTI-521

10/29/2016

Abstract:

This synopsis is mainly about the design of wide view reflective projection with Zernike polynomials surfaces. From the original paper, the wave-front aberration of Zernike polynomials surface is analyzed and two types of reflective projection are designed with Zernike polynomials mirrors. In this synopsis, I followed the same ordering as the original paper.

1. Introduction:

Normal projector projectors are using refractive lens now. Due to the defects of using refractive projectors, the original paper introduced two types of designs of reflective projection lens with Zernike polynomials surfaces. The first one is using three aspherical mirrors and a Zernike polynomial mirror, and the second one is using three Zernike polynomial mirrors, both designs with wide view angle and off-axis.

2. Zernike polynomials surface and aberrations:

The original paper analyzed the wave-front aberration of Zernike polynomials surface in this section.
At first, the original paper described the expression of Zernike polynomials, one in xy-coordinates and other one in polar coordinates. These two expressions are shown below.

$$Z(x,y) = \frac{cr^2}{1+\sqrt{1-(1+k)c^2r^2}} + \sum_{i=1}^{M} a_i r^{2i} + \sum_{i=1}^{N} A_i E_i(x,y) \quad (1)$$

$$Z(\rho,\theta) = \frac{cr^2}{1+\sqrt{1-(1+k)c^2r^2}} + \sum_{i=1}^{N} B_i F_i\,(\rho,\theta) \quad (2)$$

In this two equations, both Z(x,y) and Z(ρ,θ) are Sags, k in those equations means conic constant and c is the radius of curvature of the reflective surface. In both equations, the r means the ray height at the surface above the optical axis, but in equation (1) we have r = $x^2 + y^2$, and in equation (2) we have r = $\rho^2 + \theta^2$.
Also, a_i is the even aspheric coefficient and A_i is the Zernike polynomials coefficient in equation (1), same meaning of B_i in equation (2) as A_i in equation (1). Due to the Zernike polynomials expression contains more information and parameters than the even aspheric surface polynomials, the original paper used the Zernike polynomials to analyze the wave-front aberrations.
In the original paper, the analyze processing of wave-front aberration based on the construction as shown in Fig. 1. This figure determined reflection of an incoming ray at the Zernike polynomials surface.

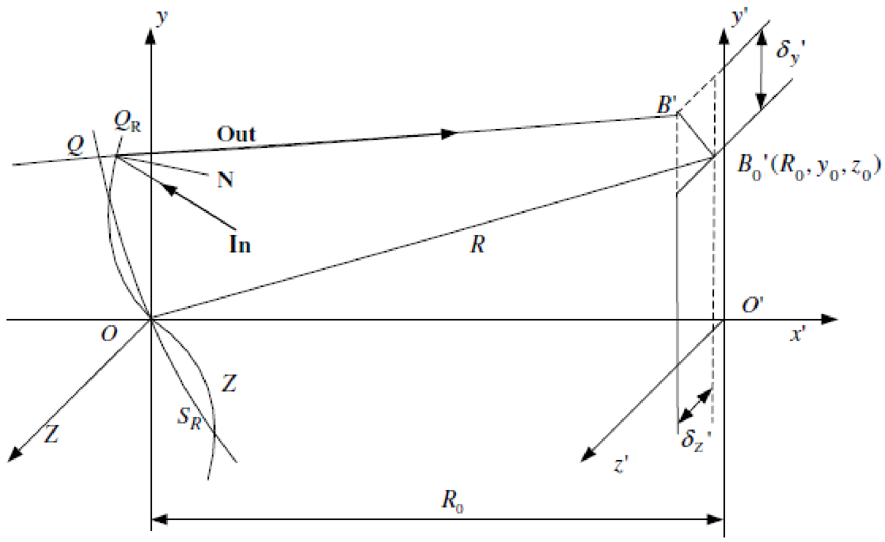

Fig. 1.A ray reflected by Zernike polynomials surface

Based on this figure, after analyze, the wave-front aberration is:

$$W = \int_{\sum R} d|R_0\vec{\imath} + (y_0 + \delta_{y'})\vec{\jmath} + (z_0 + \delta_{z'})\vec{k} - |Q_R B'|Out - OQ| \qquad (3)$$

The original paper described the normal unit vector N must satisfy $N \cdot curl(N) = 0$. According to the original paper, the method of solving the differential equation to determine the initial shape of the Zernike polynomials surface is numerical method. The ideal diagram of the method as shown in Fig. 2. The original paper described that Ray_n can be calculated by Ray_{n-1}, and derived the initial merit for optical surface by numerical method. The final method used in design should be optimize, the result in details are cited in the original paper.

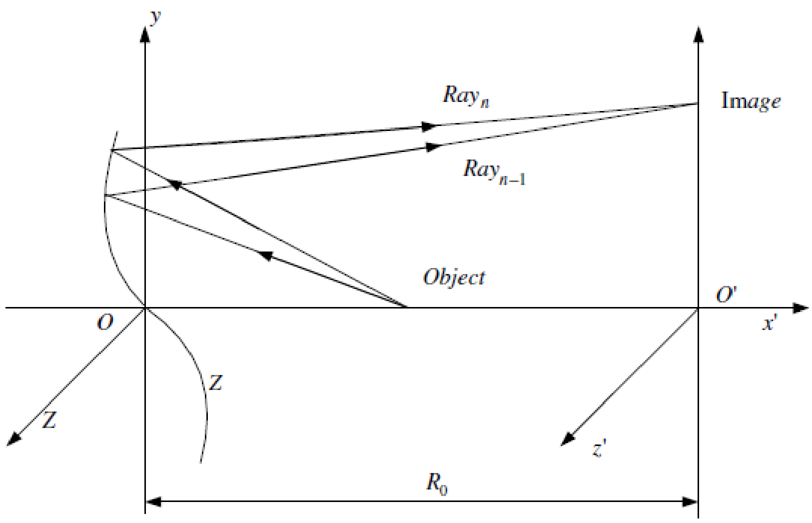

Fig. 2. Scheme of reflective ray

3. Design of reflective projection lens with Zernike polynomials surface:

(1) Design with three even aspheric mirrors and one Zernike polynomials mirror:
The mainly design concept of this section in the original paper is based on the design of four even aspheric mirrors. The new design in the original paper change the mirror M4 into Zernike polynomials mirror, the configurations are shown in Fig. 3.

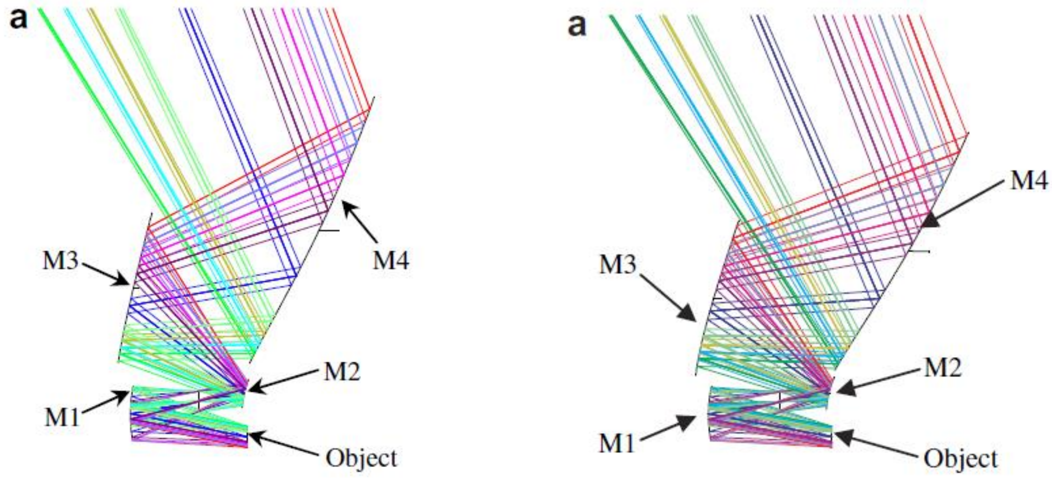

Fig. 3.Layout of projection lens with four even aspheric mirrors and three even aspheric mirror + one Zernike polynomials mirror

The original paper analyzed and compared the MTF performances of these two different system, the new design of the paper improved the MTF in full-field from 50% to 57% at 60 lp/mm, but has the same performance at 0 and 0.7 fields, which means the performance of the new design method is better than the old one. The MTF of these two system are shown in Fig. 4.

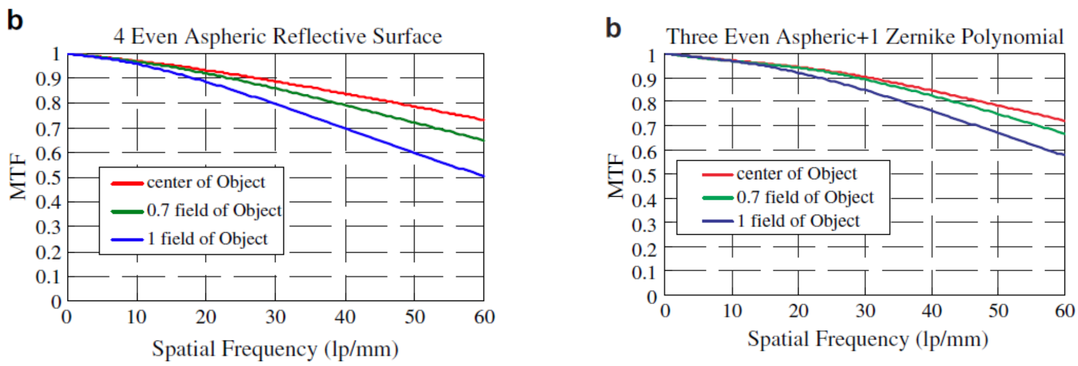

Fig. 4.The MTF performances of four even aspheric mirrors and three even aspheric mirror + one Zernike polynomials mirror

(2) Design with three Zernike polynomials mirrors:
From the original paper, the configuration of three Zernike polynomials mirrors system is designed and indicated the chief ray condition of is telecentric in object space.

This system design has many advantages described by the original paper. First of all, the aperture stop is located between the first and second mirrors to achieve high contrast ratio. Second, second and third mirrors make the projection distance of the system short and correct most aberrations. Third, the third mirror make the system has large image and distortion is corrected by the third mirror. After data analyze, the configuration and MTF performance of three Zernike polynomials mirrors system are shown in Fig. 5.

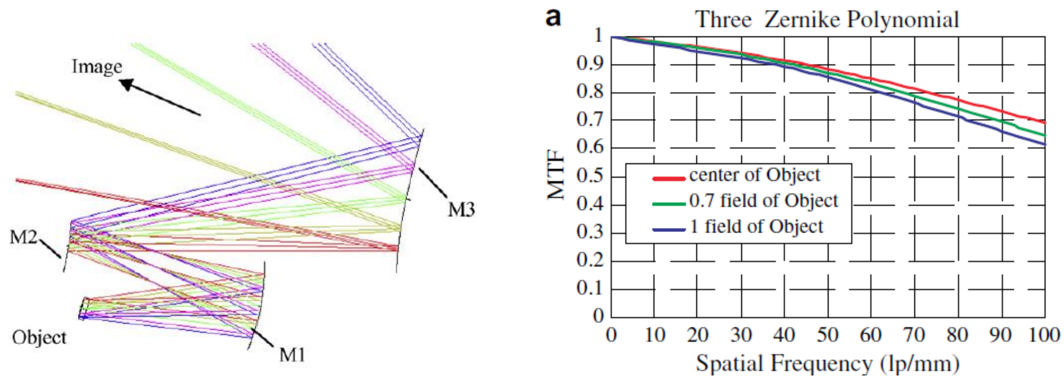

Fig. 5.Configuration and MTF performance of three Zernike polynomials mirrors system

The original paper described that F-number is 2.5 and FOV is 130 degrees of this system, the MTF is 60% at 100lp/mm and distortion smaller than 2%, which means the performance of the system with high quality.

Additionally, the original paper compared the transverse and sagittal aberration of these three kinds of design, the result is shown in Fig. 6, which means the Zernike polynomials surface can really improve the performance of a system.

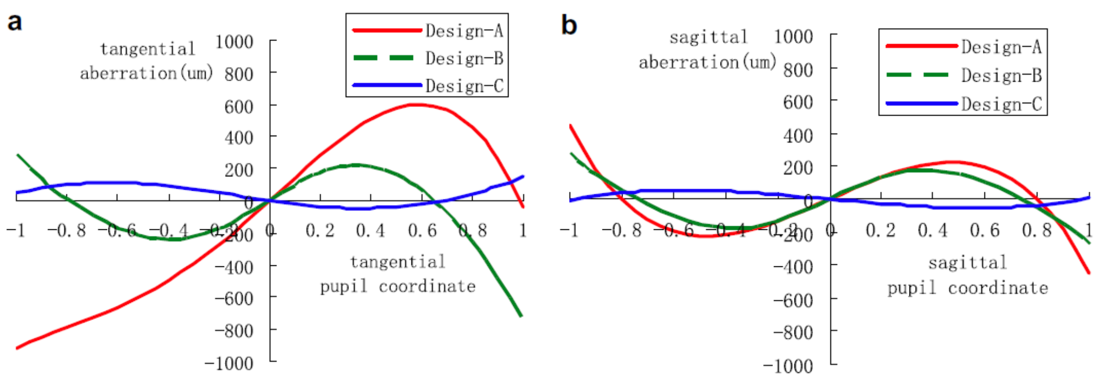

Fig. 6. The aberration comparison of these three kinds of design concepts

4. Compare to other paper's results:

There is another paper designed a system of reflective projection lens with three even aspheric mirrors and one Fresnel surface. The system layout and the analyzed data are shown in Fig. 7.

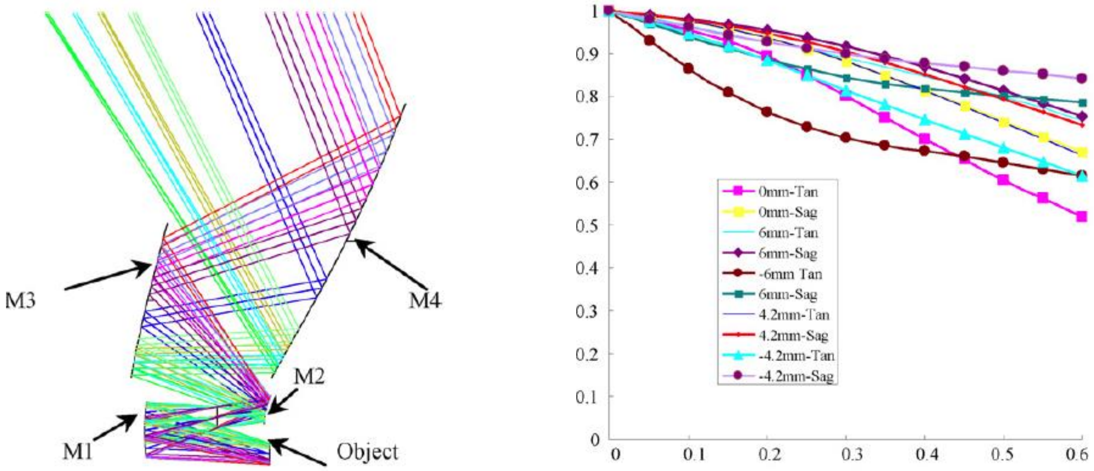

Fig. 7. The layout and MTF performace of the three even aspheric mirrors + one Fresnel surface

According to the description of the Fresnel surface design paper, the conditions are magnification is 100X, F-number is 2.5, projection distance is 250mm, FOV is 120 degrees and MTF is 40% at 60 lp/mm. Which means the MTF perfomance of the design with Fresnel surface is worse than the designs of the original paper I choose (40% at 60 lp/mm compare to 57% at 60 lp/mm and 60% at 100 lp/mm).

5. Conclusions:

This synopsis is from a paper about design of wide view reflective projection with Zernike polynomials surfaces, and with the original paper, I summarized the analyze of Zernike polynomials surface's aberration and two types design of projection lens with Zernike polynomials surface. Additionally, I compared the performances of two designs from the original paper and the design from another paper with Fresnel surface, the performances of the designs in original paper are better than the Fresnel one's.

References:

[1] Zhenrong Zheng, Xutao Sun, Xu liu, Peifu Gu, Design of reflective projection lens with Zernike polynomials surfaces, in Sciences Direct, Display vol. 29(2008), 412-417
[2] Zhenrong Zheng, Design of off-axis reflective projection lens using spherical Fresnel surface, in Optik, vol. 122(2011), 145-149