Paper Synopsis

Opti521
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Paper: Lens centering using the Point Source Microscope by Robert E. Parks, Proc. of SPIE Vol. 6676 667603

Abstract: this paper synopsis summarized a technique to achieve precision centering by viewing simultaneously through the upper lens surface of the centers of curvature of each element as it is assembled in a lens barrel and the barrel is rotated about its axis. Other papers that cover similar topics are briefly discussed.

1. Introduction

The paper first states the importance of lens centering in the manufacture of rotationally symmetric optical system. Then it discusses the definition of centering and uses an example to show how to locate both centers of curvature of one lens from the same side of the element. And the point source microscope (PSM) is used to demonstrate the centering procedure. Finally it discusses how sensitive the PSM is.

Other papers that cover similar topics are briefly discussed and the comparison of the PSM with other optical alignment tooling is shown.

2. Locating the centers of curvature of the lens surface

Definition of centering

The optical axis of a lens is the line between the centers of curvature (CC.) of the two surfaces. It is completely independent of the mechanical features of the lens such as the periphery or seat, and the definition is incomplete without considering both lens surfaces because a single sphere has no intrinsic axis.

A lens system example

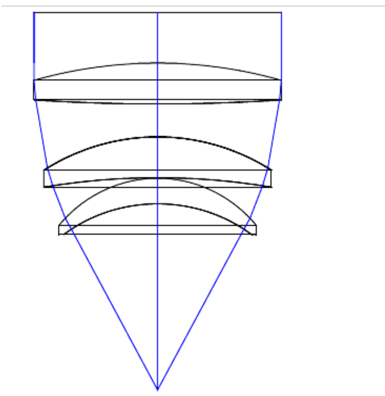

Fig. 1 Example f/1 infinite conjugate lens system

GENERAL LENS DATA:

```
Surfaces                 :                8
Stop                     :                3
System Aperture          : Entrance Pupil Diameter = 50
Effective Focal Length   :         50.00003 (in image space)
Image Space F/#          :         1.000001
Maximum Radial Field     :                0
Primary Wavelength       :             0.55 µm
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SURFACE DATA SUMMARY:

Surf	Type	Comment	Radius	Thickness	Glass	Diameter	Conic
OBJ	STANDARD		Infinity	Infinity		0	0
1	STANDARD		Infinity	10		50	0
2	STANDARD	Element 3	94.28602	8	BK7	50	0
STO	STANDARD		-392.8918	6.456843		49.28267	0
4	STANDARD	Element 2	43.81682	8	BK7	46	0
5	STANDARD		143.1817	0.1169485		46	0
6	STANDARD	Element 1	26.17266	5	BK7	40	0
7	STANDARD		33.70628	36.45994		38	0.2594
IMA	STANDARD			Infinity		0.00199	0

Table 1 Example lens parameters

It is clear from Fig. 2 that all optical sensing of the CC. of the elements no need to be done from the bottom of the lens system.

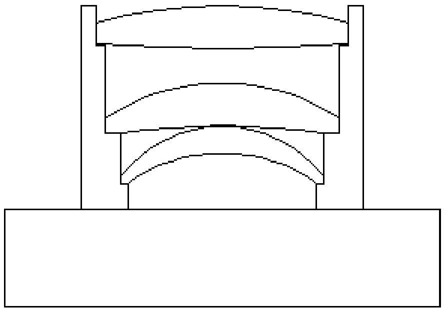

Fig. 2 Example lens in its cell sitting atop an air bearing rotary table

The CC. of the upper sides of the lenses lay a distance equal to the radius of the upper surface below the lens element. The apparent location of the CC. of the rear surface of each lens element is the distance looking through the upper surface.

How to locate the centers of curvature

Take the bottom lens for example: the radius of the upper surface (**26.17266 mm**) is used directly to locate the CC. of the upper sides of the lens.

Then use lens design program such as Zemax to find the apparent location of the CC. of the rear surface. Since light will focus at the CC. if it is strike that surface at normal incidence, the focus of light need to be fixed at the CC. of the rear surface first. Then add a paraxial surface of 100mm efl, and set its distance from the front surface to variable. Use the design optimizer to find out that distance to be 48.627mm. Therefore, the apparent location of the CC. of the rear surface is the distance that the paraxial lens focal length minus 48.627mm, that is 51.373 mm from the front surface and **46.737mm** from the rear surface.

Same method can be use to find the location of both CC. of other lenses.

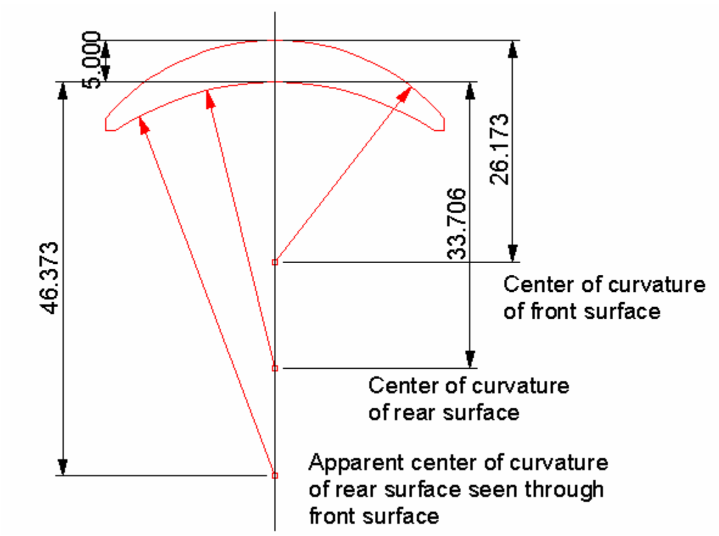

Fig. 3 Location of the CC. for the front and rear surfaces of the bottom lens
and the locations of the apparent CC. after refraction in the front surface

3. Viewing both center of curvature simultaneously using PSM

<u>Introduction of PSM</u>

A point source of light makes the PSM into an autostigmatic microscope, and it is this feature that is used to view the centers of curvature of lens elements during centering.

The PSM has a point source of illumination produced by the end of a single mode fiber pigtailed to a laser diode that is conjugate to the microscope object plane. The PSM is also a video metallographic, or reflected light, microscope using Köhler illumination to provide uniform intensity over the field of view.

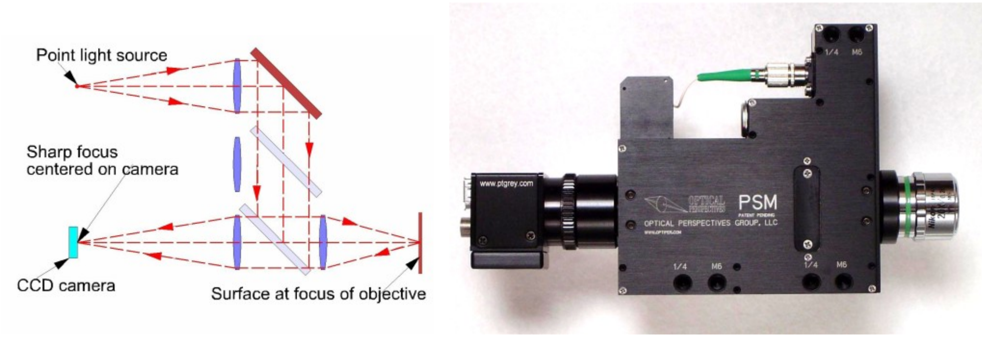

Fig. 4 Layout of the PSM in the point source mode, and the photo of PSM

The PSM produces a retro-reflected spot when focused on a surface. When the PSM objective focus is at the center of curvature of a concave sphere, light will be reflected from the sphere at normal incidence and produce a focused spot at the PSM objective focus. The same is true for a convex sphere whose radius of curvature is limited by the working distance of the objective. The PSM then relays this spot back to the CCD detector as shown in Fig. 5. The difference between this point image and the retro-reflected spot is that the spot image from the center of curvature is sensitive to the lateral alignment of the PSM to the center of curvature as well as to focus.

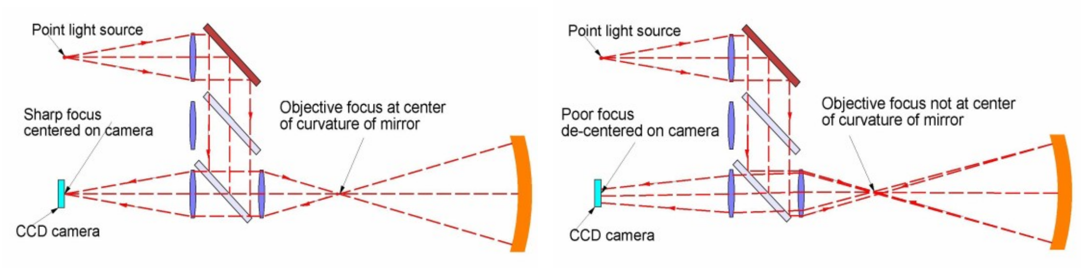

Fig. 5 A well centered and focused spot on the detector (left) and poorly focused and centered (right)

<u>Scheme for simultaneous viewing</u>

For practical condition, instead of using a 100 mm efl lens at infinite conjugates a 50 mm efl lens at 1:1 finite conjugates is used to relay the front surface CC. to the right side of the 50 mm lens. In addition, this same lens can be used to relay the rear surface apparent CC. with an object conjugate of 125.20 mm to the right side with an image conjugate of 83.254 mm accomplishing to image both centers of curvature simultaneously.

Similar setups work for the other two lens elements even though the rear surface CC. appears above the front surface. However, it is no restrict to find a conjugate, which can be flexible for different elements.

Modification for viewing with two PSMs

Separate the centers of curvature so they can each be viewed without having to move a PSM. Then two PSMs send out cones of light, and the relay lens with a beam splitter change it into converging beams of light to both the CC. of the front surface and to the CC. of the rear surface after the light has been refracted in the front surface. The light reflects off the front and rear surfaces of the lens and retraces itself back into the two microscope objectives. Both reflected light beams enter both objectives. But the beams from the incorrect conjugates are so far out of focus that very little light reaches the detector and is inconsequential. Only light from the correct conjugate is well focused and bright on the detector of that PSM.

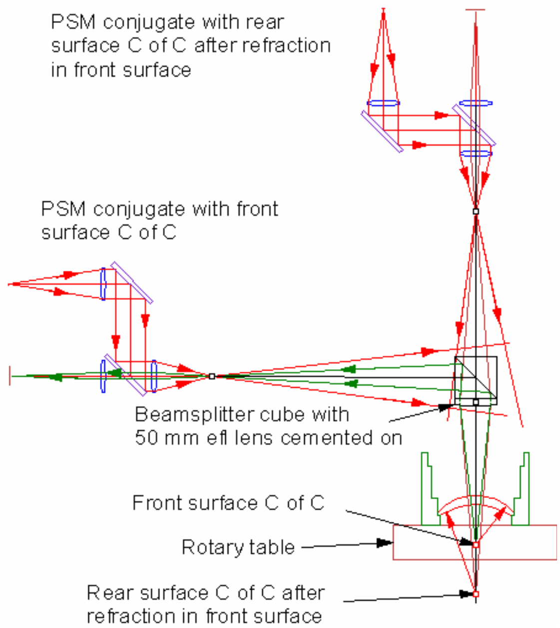

Fig. 8 the entire setup for centering lens using two PSMs

4. Sensitivity of centering

Decenter

When the lens is rotated 180º with the rotary table the lens is decentered in the opposite direction so the total spot motion is 4 μm for a 1 μm decenter from the rotary table axis of rotation. The detector has 4.65 μm pixels and can centroid to 0.1 pixels. Working backwards gives us a theoretical sensitivity to front surface decenter of about 47 nm.

Tilt

Working backwards from the above example we find the sensitivity to tilt about 10 seconds of arc per mm of radius. Thus if a concave surface had a radius of 10 mm the PSM would be sensitive to a 1 second tilt of the surface and to a 0.1 second tilt if the radius of the surface were 100 mm.

5. Conclusion

Conculsion of the paper

The paper showed how to implement such a method to assure the centering as lenses are assembled using a precise rotary table and a modern version of the classical autostigmatic microscope. The method can sense the CC. of both surfaces of an element so that any errors in tilt and decenter can be corrected during assembly to the sub-micron and sub-second level.

Compare PSM with other optical alignment tooling (from other papers)

The PSM is a flexible compliment to, rather than replacement for, traditional autocollimators and alignment telescopes. A combination of the PSM's accuracy and its use aligning the optically significant features of an opto-mechanical system make it possible to achieve higher alignment accuracy than attempting alignment via strictly mechanical features. This leads to systems with better optical performance than can presently be achieved at a reasonable cost.

	Visibility of light and ease of initial setup	Precision in decenter and tilt	Cost of equipment	Ease of use performing alignment
Laser beam	Good for both visibility of beam and initial alignment of laser	About 25 µm for decenter About 25 µradians for tilt but depends on power and distance	Cost is quite modest, laser, 4 DoF mount and beamsplitter cost maybe $3K	Easy to use but limited in axial spacing. Somewhat limited alignment capabilities
Alignment telescope	Beam difficult to see. Need to darken room Most difficult part of use	About 20 µm for centering. Generally less than 5 µradians for reflections off surfaces	For new equipment including suitable mounts and a ‘pip’ generator about $20K	Relatively easy to use but often requires two persons, one tied to eyepiece. Darkened room to find initial reflections
Autostigmatic microscope or PSM	Beam easy to see. Psm is small and lightweight so easy to align initially	Depending on mode of use 20 to <1 µm centering and 25 to 1 µradian for angle	About $24K including sturdy mounts	Easy to use Video image at place of alignment. Good had/eye feedback Images like at video microscope Good for micro-

In another paper, a binary phase grating is used as a beam splitter. Laser beam after passing through the grating only ±1 orders are kept unstop, reflected back by lens surface, recombined by the same grating, and very good contrast interference fringes can be attained. If the lens rotates around an axis of asymmetry, the fringes will move. And the centering accuracy from experiment is about 0.6μm

Reference

Robert E. Parks, **Lens centering using the Point Source Microscope**

Thenwu Lu, Zhicheng Weng, **Lens centering by using binary phase grating**

Robert E. Parks，**Line of sight methods of alignment**

William P. Kuhn，**A simple tool for alignment and wavefront testing**

Robert E. Parks，William P. Kuhn，**Optical alignment using the Point Source Microscope**