EXPERIMENT 7

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PHY 115L

INTRODUCTION

In this experiment I sought to learn about the optical properties of light through various lens arrangements. I wanted to determine focal length of a positive lens and observe the real images it forms and their magnifications to verify the thin lens predictions. I then set out to observe virtual images in positive and negative lenses. I then measured the radius of curvature of the positive lens and used that information to compute the focal length of the lens to compare to the initially observed focal length. Finally, I sought to observe lens aberrations, specifically spherical, coma, and chromatic aberrations.

RESULTS

Observed Focal Length of Plano-Convex Lens:

In this section, I shined laser light through a plano-convex lens at various source-lens distances with the convex side facing the source to find the focal length. I determined that the focal length of the lens was using this method. I also observed that for small tilts of the lens about a vertical axis or a flip of the lens such that the flat side faced the source, neither the focus position or the focal length changed.

Image Formation by Lens:

I now shined a spot lamp through an arrow-shaped aperture and ultimately through the lens to observe the real image that is created. Initially, with object right in front of source, the image was inverted, and the magnification was -1. This is because the “object” was at the light source and at a position beyond the focal length of the lens. To make the magnitude of the magnification greater than 1, I was able to move the object closer to the lens while still staying further than the focal length. I could not make the magnitude of the magnification smaller than 1. As I increased the object-lens distance, I observed the image-lens distance decrease.

I then measured the object size (y), image size (y’), lens-object distance (s), lens-image distance (s’), and magnification (M = y’/y) at a few set-ups of varying s to try to verify the thin lens predictions. My results are as follows.

Table 1

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Magnification** | **δ** | **Object-lens distance (m)** | **δ** | **Lens-image distance (m)** | **δ** | **s'/s** | **δ** |
| 2.4 | 0.3 | 0.43 | 0.02 | 0.94 | 0.02 | 2.2 | 0.1 |
| 3.5 | 0.4 | 0.39 | 0.02 | 1.26 | 0.02 | 3.3 | 0.2 |
| 1.9 | 0.2 | 0.47 | 0.02 | 0.81 | 0.02 | 1.7 | 0.1 |
| 1.2 | 0.2 | 0.56 | 0.02 | 0.60 | 0.02 | 1.1 | 0.1 |

As seen in table 1, the observed magnifications and s’/s ratios agree, at least within experimental uncertainty. Furthermore, I calculated the focal length of the lens using the thin-lens equation and compared it to the initially observed focal length. I computed from this method, which agrees with the initially observed value. This validated the thin-lens model for this scenario.

Virtual Images:

I first confirmed that I was indeed able to observe a virtual image through a positive lens by holding an object within its focal length. This virtual image from the positive lens was larger than the object, i.e. . I then observed that doing a similar set-up with the negative lens, the virtual image formed was smaller than the object, i.e. . There was no object-lens distance s at which I was unable to observe a virtual image through the negative lens. This is because the negative lens has a negative focal length, so the virtual image exists for all possible object-lens distances. The relative sizes of the image to the object in each lens is a consequence of the ray-optic geometries of each lens, with the positive lens converging rays while the negative lens diverges rays.

The Lens Maker’s Equation:

In this section, I sought to verify the lens maker’s equation by measuring the radius of curvature of the convex lens and using that to compute the predicted focal length. If this computed value agreed with the observed length from the previous section, the equation would essentially be validated. I measured the radius of curvature to be . Using the observed focal length, the lens maker’s equation predicts the radius to be , which is within experimental uncertainty of the measured value. Furthermore, the focal length calculated from the measured radius of curvature and the lens maker’s equation was while that observed initially was . The close agreement of these focal lengths, one computed and the other observed, serves to confirm the validity of the lens maker’s equation.

Lens Aberrations:

I now turned my attention to the breakdown of the thin lens model in studying the aberrations present on the same plano-convex lens. The first type of aberration I looked for was the chromatic aberration. I observed this around the edges of the image, it being most pronounced when the aperture was removed from the lens which permitted rays to enter far from the center of the lens.

Next, I tried to observe the spherical aberrations of the lens by measuring the diameter of the circle of least confusion at various set-ups of the apparatus. My measurements are as follows.

Table 2

|  |  |  |
| --- | --- | --- |
| **Set-up** | **Diameter (cm)** | **δ** |
| No aperture, convex side towards lamp | 0.7 | 0.1 |
| No aperture, flat side towards lamp | 0.5 | 0.1 |
| 70mm aperture, convex side towards lamp | 0.4 | 0.1 |
| 50mm aperture, convex side towards lamp | 0.3 | 0.1 |

I noticed that with the flat side facing the lamp, a smaller circle of least confusion was measured since light hits the convex side slightly later and has less time to diverge. I also experimented with the various sized apertures, and notices that the circle of least confusion shrinks with more restrictive apertures since they limit the light entering far from the center of the lens which diverges and creates the aberration.

Finally, I tried to observe coma by tilting the lens with respect to the source lamp. I noticed that coma was evident and appreciably distorting the image even for small tilts of only 1 or 2 degrees to either side.

SUMMARY

I successfully measured the focal length of a positive lens while studying the properties of light through lenses in this experiment. I also succeeded in investigating the real images created by a positive lens and the virtual images created by both positive and negative lenses, confirming the geometry and physical theory of optics. I then was able to verify both the lens maker’s equation and the thin-lens model based on what I observed and measured. Additionally, I was able to observe three types of the aberrations associated with the spherical lens, namely chromatic, coma, and spherical aberrations. In doing so, I was able to fulfill each of the objectives outlined in the introduction. A question for a future experiment could be how non-spherical lenses, such as parabolic or hyperbolic ones, behave compared to their spherical counterparts.