**Experiment 4: Lens Aberrations**

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**Abstract**

Briefly state the major goals and results of the experiment. For example: “A Michelson interferometer has been used to determine the difference in wavelength of the sodium D lines. A value of 5.9+- 0.2 A was found, which agrees with the accepted value.”

**Introduction**

This summarized the main ideas of the experiment and the conclusions of appropriate theory. A clear sketch of the experiment should be included.

One can determine the focal length of a lens by using its radii of curvature and index of refraction in the Lensmakers Equation (1). If the radii are unknown, they can be calculated with the Spherometer Equation (2)—essentially Pythagoreans—using values obtained using a device with the same name.

Spherical aberration is one of several types of lens aberrations, and is where the focal length is dependent on the radial distance incoming rays enter a lens. This variation of focal lengths is because the effective focal power of the lens changes as you go farther from the optical axis (go through different meridians). Light passing close enough to the optical center of the lens will get focused at a distance approximately equal to the focus of the paraxial position—the position that can be calculated using the simple Lens Equation (3). Circular apertures can then be used to define the median at which light will pass through the lens: doing so will allow probing of focal powers at defined radial distances (meridians). As an extra note, when the varying focal lengths lie on the shorter side of the paraxial position the aberration is called undercorrected, or negative. Traditionally the relationship between the longitudinal shift of focus from the paraxial position is graphed against the radial height of the circular aperture.

Axial chromatic aberration is where the focal length varies with a light’s wavelength. Indices of refraction are greater for short wavelengths than they are for long, meaning that light with shorter wavelengths will be more strongly focused and have closer focal lengths compared to light with longer wavelengths through a convergent lens. For instance, an image made with blue light will be closer than one made with red. Indices of refraction assumed to pertain to the lens used in this lab are tabulated below for the different wavelengths of visible light used.

|  |  |  |
| --- | --- | --- |
| *Color* |  | *n* |
| Violet | 420 | 1.5318 |
| Blue | 460 | 1.5265 |
| Cyan | 485 | 1.5240 |
| Green | 540 | 1.5196 |
| Yellow | 580 | 1.5172 |
| Red | 640 | 1.5145 |

The arrangements set up in this lab relied on the use of a long metal rail secured to large tables in the room. Each optical element, the lens, aperture, lamp head, and image screen could be screwed into a metal clamp which clamped onto the rail. These clamps could be loosened and slid longitudinally along the rail, making it relatively easy to make the adjustments needed for successive measurements while maintaining the transverse alignment of the elements with the optical axis.

**Analysis & Discussion**

Present your results. Quantitatively compare your data with expectations. Error estimates must always be given. Do not recopy all the raw data for your report. Give examples and/or the range of the numerical values where appropriate. Present data by graphs as much as possible. Do the measurements within the error estimation agree with theory/ If not, can you suggest possible sources of the discrepancy/

A large diameter lens was used and its properties calculated using a Spherometer and equations (1) & (2). As our lens was planar on one side, the second radii of curvature is infinite and the additional term from equation (1) goes to zero. Note that the focal length calculated the day of the lab was erroneously calculated to be 15.20cm due to mistaking the lens’ index of refraction to be 1.56 rather than the correct value of 1.52.

Using a lamp as an object, the lens was secured on the rail in line between the object and screen, and the screen was moved to the location of a focused image. This object distance was measured at , and the image distance . Inserting these distances into the Lens Equation (3) results in a focal length of 15.97cm. Though it wasn’t acknowledged at the time, this value turned out to be closer to the expected focal length of the lens than 15.20cm.

The lens was placed a distance 1.25f away from the object, which based on our calculation at the time meant that the object distance was set to 19cm. Though the lens was rotated later, it was always immediately re-positioned to maintain this distance of 19cm.

A aperture, the smallest on hand, was placed immediately before the lens so that a more accurate paraxial position of the focal length could be determined, and serve as our initial data point. After logging measurements for the image distance, the aperture was replaced with one circular aperture after another, each one defining a median of larger radii than the one before it. The measurements for image distance and aperture radii are seen in a table below. Note that the radial value h(cm) is found by taking half of the average of inner and outer diameters.

It was quickly noted that the difficulty in determining the exact location of the focused image was substantial. Throughout the lab there were relatively large ranges where the sharpness of an image was arguably equally optimal, so a decision was made to log the limits of this optimal range in every measurement and to assume the midpoint of the range reasonably accurate for input into later calculations. Though this is less than ideal, the error induced on each measurement should be fairly consent and a comparison of deltas between them was expected to be far more accurate than if we’d used single points with large and random error.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Stops | ID*(cm)* | OD*(cm)* | h*(cm)* | ∆x*(cm)* | *(cm)* | Si*(cm)* | Error |  |
| open |  | 0.5 | 0-.25 | 40 | 75.5 | 95.5 | 20 | 0.010471 |
| #1 | 1.5 | 2 | 0.875 | 11.5 | 88.8 | 94.6 | 5.8 | 0.010571 |
| #2 | 2.5 | 3 | 1.375 | 5 | 85.6 | 88.1 | 2.5 | 0.011351 |
| #3 | 3.7 | 4.4 | 2.025 | 6 | 77.1 | 80.1 | 3 | 0.012484 |
| #4 | 4.7 | 5.2 | 2.475 | 8.5 | 69.7 | 73.95 | 4.25 | 0.013523 |
| #5 | 5.7 | 6.2 | 2.975 | 4 | 60.6 | 62.6 | 2 | 0.015974 |
| #6 | 6.7 | 7.2 | 3.475 | 3.2 | 51.3 | 52.9 | 1.6 | 0.018904 |

**Conclusion**

A brief statement summarizing your results is required. Did you find what you expected? What improvements would you make if you were to repeat the measurements?