**Experiment 4: Lens Aberrations**

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**Abstract**

~~Spherical Aberrations are studied using apertures and colored film. By defining the radial height which light passes through a large diameter lens, focal lengths were found to decrease with increasing heights. The effect of chromatic aberration was observed to be that the focal power of a lens is effectively increased when the wavelength of that light is shorter.~~

**Introduction**

Light can be thought of as a wave, an electromagnetic wave with electric and magnetic field components which are always perpendicular to each other and to the waves direction of travel. These fields are such that the cross product of the two always points in the direction of motion. When a ray of light is described this simply, its polarity is described as the orientation of a line which lies on the plane of the electric field and which is perpendicular to the direction of travel. Most waves are not polarized but are instead comprised of components oriented in all directions.

Polarizers are light filters that discriminate based on the orientation of its electric field components, where only the components aligned with that of the polarizer’s pass through. This filtering can be described very simply as reducing the total field amplitude of the light by a cosine of the angle between the orientations of that light and the polarizer. In practice, most polarizers do not filter out all non-aligned wave components, nor do they truly transmit 100% of what is aligned. Also, polarizing effects are generally wavelength dependent.

Intensity of a light wave is the square of the total electric field at a given location and time. As a polarizer only allows of the wave through, the intensity will go down by a square of that factor; i.e. . For un-polarized light, the effect of a linear polarizer is a convenient factor of ½ of the initial intensity. This is due to the average of cosine over all angles being equal to .

Brewster’s angle is the angle of incidence where incoming light of a certain polarization is completely transmitted through the second media, and none is reflected. However, when the incoming light is un-polarized there is a portion of it that gets reflected and that reflected light will be perfectly polarized. Brewster’s can be described as the arctangent of the ratio of the two medias indices of refraction.

**Analysis & Discussion**

We first set out to determine whether light can be polarized when reflecting off a glass plate. This was done by letting un-polarized light from a lamp reflect off the glass plate, and up through a polarizing film to our naked eye. By rotating the film, the observed intensity of the reflection could be very nearly completely removed. It was noted that the degree to which this effect was possible depended on the light’s angle of incidence with the plate. This observation of angular dependence on polarized reflection supports the idea that what’s being seen is the effect of Brewsters’ angle, as noted in the introduction. The polarization of reflected light is perpendicular to the plane spanned by the incoming, refracted, and reflected rays. It’s oriented in this direction because of the many dipole moments at the surface—which allow the radiation of transmitted light—also uniquely do not transmit light oriented along the direction of their moments. A situation somewhat analogous to how moving electrons along wires in a wire grid polarizer reflect light in that orientation but allow orientations 90 degrees from it pass through. If we had instead observed light reflecting off of a heated road, the orientation of the reflected light would be the same but due to the fact that the indices of refraction are so much closer to each other their ratio would be closer to one and Brewsters angle would be much larger. Meaning that if one were to manufacture sunglasses, they’d want the polarizing media to be oriented in the vertical direction (if it were a grid, the wires oriented horizontally).

**Conclusion**

~~The parabolical longitudinal shift in focal lengths was seen to be negative when light passed through increasing radial displacements of the lens. The fit of the data was very good with R-Squared values of 0.9941 when the planar side of the lens faced the object, and 0.9983 for when the lenses’ orientation was reversed. However, the fitting parameters seemed to be a factor of 1000 off from the calculated value of S, where the second order factor of the fit was -0.0015 and S was about -1.6. It’s curious that the value for S was found to change between each change in height h.~~

~~A linear shift of the same sign was seen when decreasing the wavelength of light that passed through the lens. The fit of this data was poor relative to the other fits in this lab with an R-Squared value of 0.8492. One factor likely plays a large roll in this error: the aperture used was very small and at the center of the lens, this means that the angle at which the focused light met with the optical axis is very small and meaning the change in clarity for the image with longitudinal shifts of the screen was also very small. However, the inverse slope of the fit (0.164) would match very nicely with the radii of curvature calculated from measurements made with the spherometer (16.3cm).~~