Quantifying Spherical Aberration of Plane Convex Lens

Sonal Tripathi, Aman Cheema

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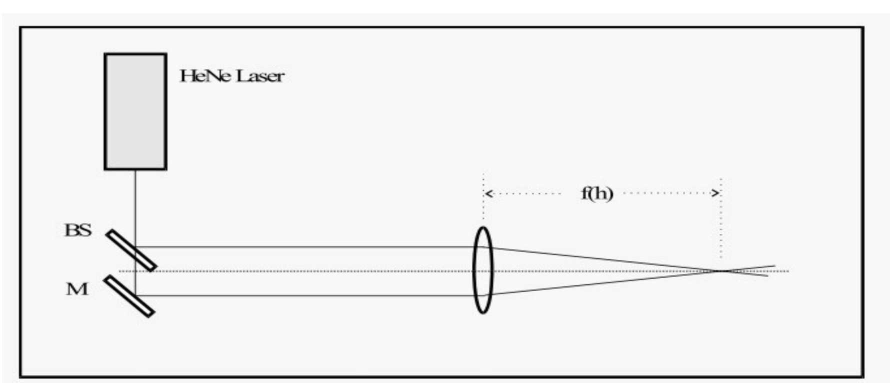
Aim:

In this experiment we try to:

- To find the characteristic measure of the spherical aberration of a plane convex lens by measuring the change in the focal length for marginal and paraxial rays.

Method:

- Align the laser and set up the table as shown in the schematic diagram (Figure 1).
- Mount the beam splitter and the mirror on a translation stage.
- Align the beam splitter at an angle of 45◦ to the incoming laser beam and then mount the mirror parallel to it such that the maximum distance between them is equal to the diameter of the lens. (Significant time should be devoted to make sure that the reflected beams are parallel)
- Place the screen at a distance of about a meter from the mirror.
- Place the lens in between the screen and the mirror and record the position for the brightest spot on the screen (where the two rays converge).
- Measure the lens position for different separation between the mirror and the beam splitter.



(Figure 1: This is the schematic representation of the basic setup.)

Theory:

The lens formula relates image distance from lens (v) and object distance from the lens (u) to the focal length f.

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

The difference Δ between the focal length for paraxial rays, f(0) , and rays being incident on the lens a distance h from the optical axis, f (h), is approximately given by,

$$\Delta = [\mathrm{f}(0) - \mathrm{f}(\mathrm{h})] \approx \frac{1}{2} K h^2$$

The parameter, K is a characteristic measure of the spherical aberration of the focusing element which we aim to measure in this experiment.

One of the beams should propagate along the optical axis defined by the lens. By changing the positions of M(mirror) , one can vary h. The focal length f (h) is measured by translating the lens until the two beams intersect at the observation screen. Various values of f (h) can be measured by changing the distance h .

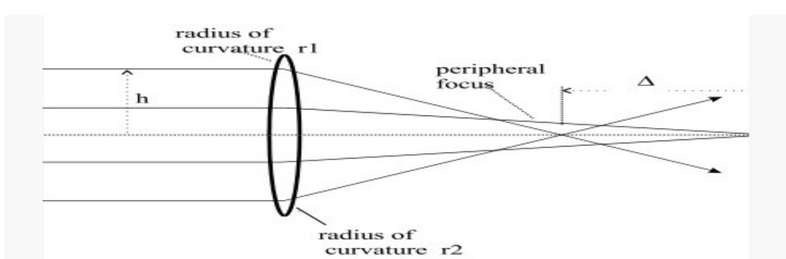
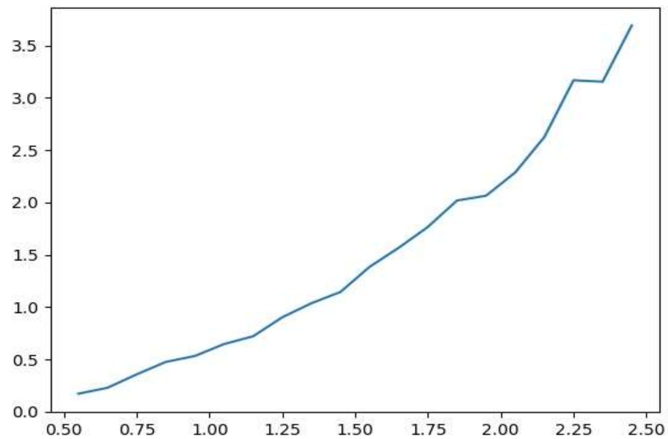


Figure 2: This diagram depicts **h** (distance of incident ray from the optical axis) and **Δ** (distance between the focal length of marginal and paraxial rays).

<u>Observation and Calculations:</u>

The following graph was plotted between Δ measured and h (distance of incident ray from optical axis) which is equal to D/2 where D is the distance between beam splitter and the mirror.



<u>X-axis</u>: h (distance of incident ray from optical axis) in cm.

<u>Y-axis:</u> Δ (difference between focal length of paraxial and marginal rays) in cm.

<u>Observation table:</u>

K is calculated from the readings obtained.

D	Δ	K
1.1	0.173	1.143
1.3	0.23	1.089
1.5	0.358	1.273
1.7	0.477	1.320
1.9	0.534	1.183
2.1	0.648	1.176
2.3	0.722	1.092
2.5	0.904	1.157
2.7	1.038	1.139
2.9	1.146	1.090
3.1	1.386	1.139
3.3	1.568	1.152
3.5	1.767	1.154
3.7	2.02	1.180
3.9	2.066	1.087
4.1	2.288	1.089

4.3	2.627	1.137
4.5	3.169	1.252
4.7	3.155	1.143
4.9	3.692	1.230

$$\text{Mean K} = 1.161\ cm^{-1}$$

$$\text{Standard Deviation}(\sigma) = 0.0349 cm^{-1}$$

Result:

- The value of characteristic parameter of spherical aberration, K is $\mathbf{1.161 \pm 0.0349\ cm^{-1}}$

Analysis:

- There is a quadratic relation between Δ (distance between focal length of paraxial and marginal rays) and h (distance between the incident ray and optical axis) which is experimentally verified by the graph which is in the shape of parabola.