A Short Note On

“Fresnel Zone Plate”

(For 2nd Semester Physics-Hons. Students)

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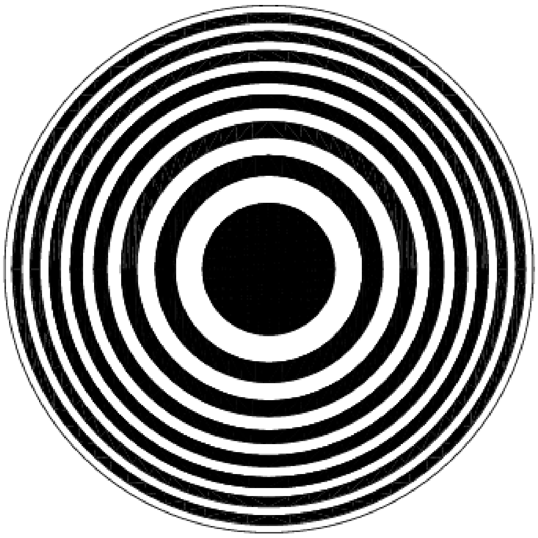
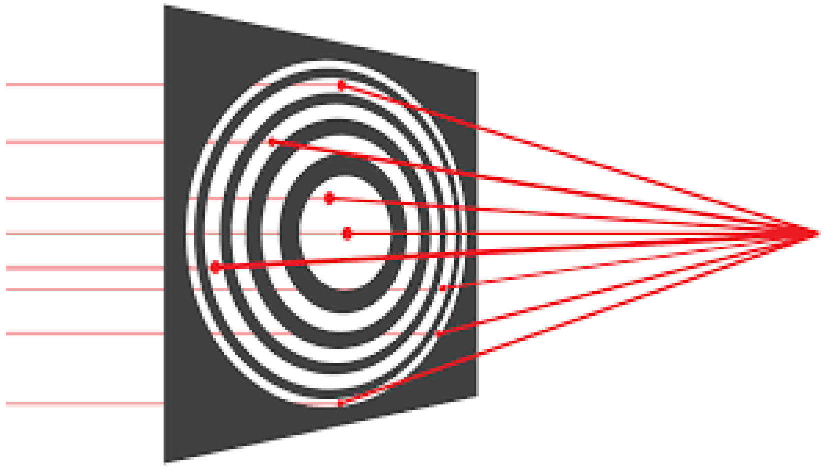
Zone Plate



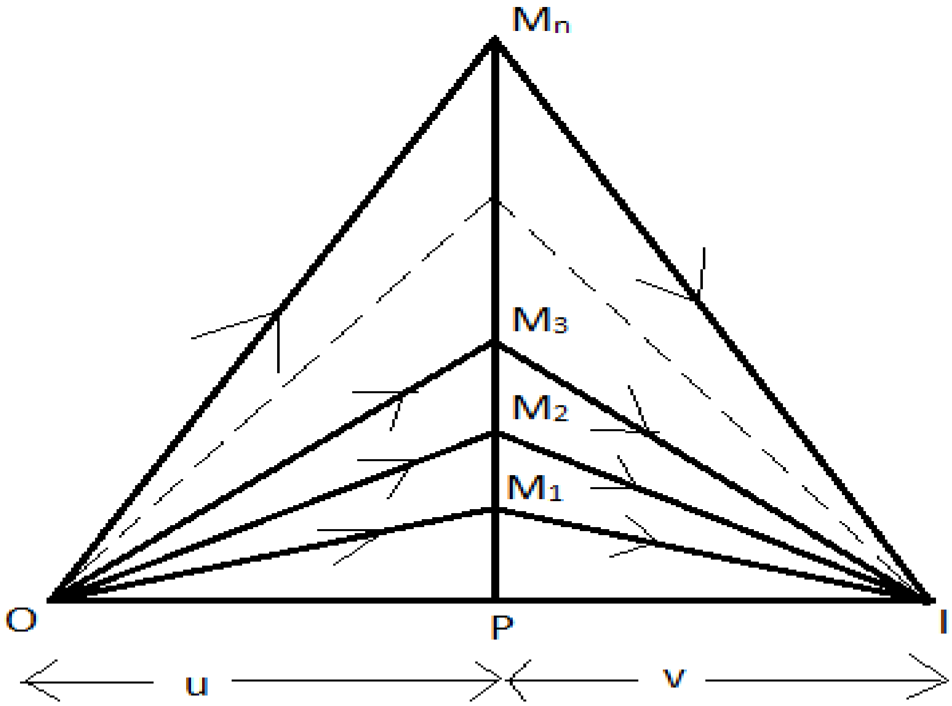


Definition:

A zone-plate is an optical device – a special diffracting screen – deigned to put a stop to the light from alternate half period zones. It is usually constructed by drawing a series of concentric circles on a white paper sheet, the radii of the circles being proportional to $1^{1/2}$: $2^{1/2}$: $3^{1/2}$,…..etc. The different zones thus formed are alternatively painted black. A highly reduced photograph of this drawing is taken on a glass plate. The negative thus obtain is the zone plate.

If odd zones are transparent and even zones are opaque, it is called positive zone plate. If however even zones are transparent and odd zones are opaque, then it is called negative zone plate.

<u>Theory of a Zone Plate:</u>



Let O be a point source of monochromatic light giving out spherical waves of wavelength λ whose effect at a point I, on the screen is required. Consider an imaginary plane through P, of a transparent medium, perpendicular to the plane of paper and the line y, the plane is divided into zones bounded by circles with centre at P and radii $PM_1=r_1$, $PM_2=r_2$, ………., $PM_n=r_n$, such that,

$$OM_1+IM_1 = OP+IP+\lambda/2$$
$$OM_2+IM_2 = OP+IP+2.\lambda/2$$
$$OM_3+IM_3 = OP+IP+3.\lambda/2$$

$$OM_n+IM_n = OP+IP+n.\lambda/2$$
…………………………. (1)

The annular rings thus formed are therefore half period zones for I, since the path difference between corresponding points of two consecutive zones is λ/2.

Let, OP=u, and IP=v

So, $OM_n = (u^2+r_n^2)^{1/2} = u(1+r_n^2/u^2)^{1/2}$

$= (u+r_n^2/2u)$ since $u>>r_n$

Similarly, $IM_n = (v+r_n^2/2v)$

Now from eq-1,

$$u + r_n^2/2u + v + r_n^2/2v = u+v+n.\lambda/2$$
$$\text{Or, } r_n^2(1/u+1/v) = n.\lambda$$
$$\text{Or, } 1/u+1/v = n.\lambda/r_n^2$$

Applying sign condition,

$1/v - 1/u = n\lambda/ r_n^2 = 1/f_n$ ………………(2) where, $f_n= r_n^2/n\lambda$

Equation-2 looks similar to convex lens formula $1/v - 1/u = 1/f$.

Thus the zone plate may behave like a convergent lens of focal length, $f_n= r_n^2/n\lambda$; provided it has the focusing action.

Focusing action of a zone plate:

In a zone plate the alternate zones, say even zones are blocked. So the waves from transparent zones (1st, 3rd, 5th etc.) reach the point I in the same phase. Therefore the resultant amplitude at I is given by $A = A_1+A_3+A_5+A_7+$ -------------------------. Thus the resultant amplitude is many time greater than that the $A_1/2$, the resultant amplitude due to all zones. So, I is extremely bright and may set to the image of O. This explains the focusing action of the zone plate.

Similarities and Dissimilarities between zone-plate and convex lens:

Similarities:

a) Both Zone plate and convex lens has a focusing action.
b) Both are having chromatic aberration while focusing.
c) The relation between conjugate distances are similar.

Dissimilarities:

a) The zone plate works by diffraction and the lens works by refraction.
b) The image produced by a lens is very intense where as the image produced by the zone plate is not intense.
c) The zone plate has an array of focal lengths (n numbers) where as a convex lens has a single focal point.
d) The focal length of a convex lens directly proportional to the wavelength where as the focal length of the zone plate inversely proportional to wavelength.
e) There is no time delay when light is passing through one point to another in the convex lens but there is a time delay as light passes from one period to other in zone plate.