Top Lateral Refraction and Reflection of Polarized Light in Lenses. Coplanar Lens System. Applications.

Miranda Díaz Lázaro J.
Electronic Design Center of Technological Applications and Nuclear Development (CEADEN),
Ciudad Habana, Cuba. *Email: miranda@ceaden.edu.cu*

ABSTRACT

When linearly *polarize*d light impinging on a lens, it will reflect and refract along the lines curves resulting from the interception of a plane (plane of polarisation) with a sphere (lens surface) maintaining the orientation of refraction and reflection within the plane of polarisation. This effect is significant only looking at the lens laterally. Therefore, a lens acts as a lateral analyser when the polarisation plane of *polarize*d light incident on the lens is rotated. Following this principle that in the spherical surface of a lens fit **n** circles of radius **r**, where **n** is inversely proportional to **r**, and each circle is a lens itself. Then if a beam of light is shined in one of these areas, the phenomenon is expressed lateral side and diametrically opposite to the incident linearly *polarize*d light place, the lens acting as a waveguide for the light beam *polarize*d.

Keywords: *Polarisation, Optic, Lens*

I. INTRODUCTION

The intersection between a plane and a spherical surface take place, when a linearly polarized light beam incident on a lens. A polarized light beam is composed of electromagnetic waves to oscillate in planes parallel to each other and in the same direction. Taking one of these planes to affect orthogonally on the spherical surface of a convex lens, the light is reflected and refracted without leaving the plane that which belongs, as shown in Figure 1 where only the central portion of the lens is showing for a better understanding. Now if we rotate the polarisation plane of polarized light beam, not the lens, then also changes the direction of the rays reflected and refracted as they remain within the plane of polarisation of light.

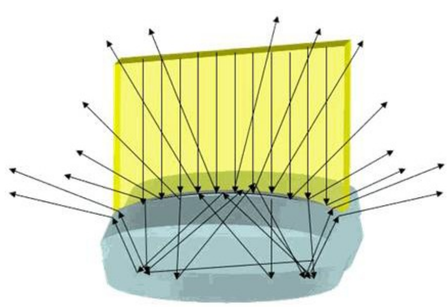


Figure 1. Representation of refraction and reflection to affect polarized light in a convex lens

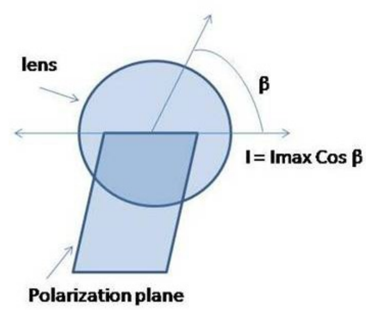


Figure 1.a. Representation of intensity light variation

When a non-polarized light and or a light circularly polarized incidents on a lens, the light will be reflect and refract inside the lens body in all directions. But a linearly polarized light beam incident on a lens, the light will be reflect and refract inside the lens body only in the same direction that polarize plane (Figure 1.a), the light can not through out from the polarize plane that it belong. Them, polarize plane acts like a filter that only permit the maxim light intensities in only one direction, that is polarize plane orientation. In other directions the intensity will be equal to the maxim light

12th Education and Training in Optics and Photonics Conference, edited by
Manuel F. P. C. Martins Costa, Mourad Zghal, Proc. of SPIE Vol. 9289, 92890E
 · doi: 10.1117/12.2070746

intensity by the Cosβ, where β is the angel between a deferent position that polarize plane position and the position of polarize plane.
When a linearly polarized beam incident on a lens, will be reflect and refract inside the lens body following the interception between a plane (plane of polarisation) and a sphere (lens surface), maintaining the orientation of the beams refracted and reflected within the polarisation plane. On both sides of the lens are forming two pairs of fans on opposite edges to the lens diameter. The higher intensity of the resulting beams will take place at opposite ends to the diameter of the lens, so that this phenomenon is noticeable only by observing the lens laterally, i.e., and placing parallel to the optical axis.

II. EXPERIMENT

Take two observers situated one on the right and one on the left of Figure 1. The observer on the left sees the right side of the image of the light source, because the rays that reach it are refracted and reflected within of the lens from the side opposite the light source. While the right observer sees the left side of the image of the light source.

Turning to the position as seen in Figure 1, both are observed to reduce the light intensity of the image completely when the plane of polarisation is orthogonal to the plane of the paper, or it is parallel to the two observers.

Therefore, a lens can be used like an analyser of polarized light, which gives information about the orientation of the plane of polarisation, shows this effect, as shown in Figure 2.

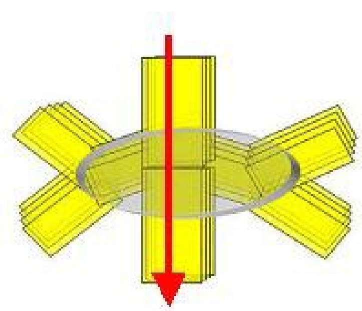


Figure 2. The reflection and refraction at a convex lens representation

Figure 2 represents the entire lens and the beam of polarized light. With this figure can be seen together as discussed earlier and conclude the greatest refraction and reflection takes place where the geometric central plane of the beam impinges on the diametric line of the circumference defined by the beam on the surface of the lens.

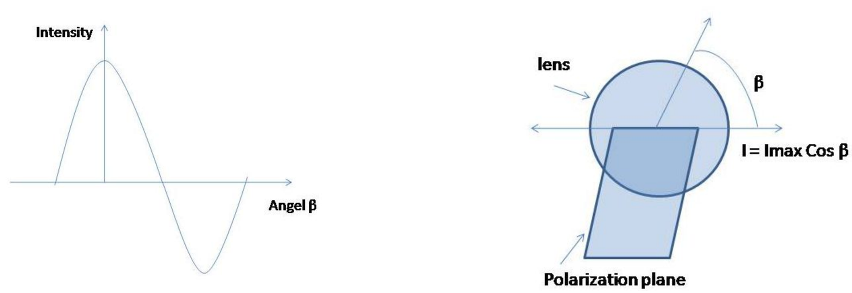


Figure 2.a. Intensity vs Angel β

The intensity light distribution around the lens has sinusoidal shape according of polarize plane orientation and the angel β between a select position and the polarize plane. If we know β for a point, we can know the light intensity for that point. Then, if I=0, polarize plane position is 90^0 from that point. In this way we can use this principle to a polarymetric detection method (Figure 2.a).

Figure 3 is a sequence of rotation of plane polarized light beam. In the centre of the lens side, a light spot is observed that its light intensity varies depending on the spatial position of the plane of polarisation relative to the position of the observer. Hence, an observer who turns laterally around the lens with the same speed to the plane of polarisation will always see the same intensity.

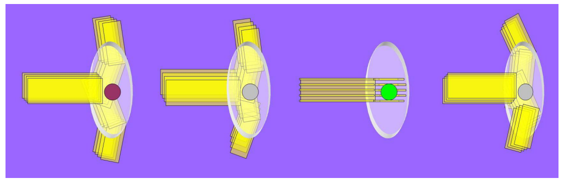


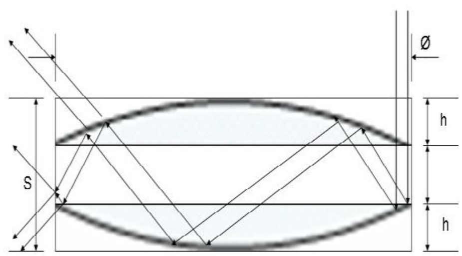
Figure 3. Polarize plane rotation sequence

The lens being a spherical surface, over it can be placed perfectly **n** circles of radius **r**; the number **n** is inversely proportional to the radius **r**. Each circle can be seen as a lens.

Taking this into account, if the linearly polarized light incident is on the lens edge, it will pass all explained above, but in the region of incidence, the light will exit the edge of the lens diametrically opposed to the incident beam and it just shows the image at that point and not in any other region of the lens.

Figure 4 shows what has been explained here, including an equation to determine the number of reflections that occur within the geometry of the lens and selecting the appropriate lens.

This permit us select the geometrical dimensions of the lens that we most use in our optical design, the reflections must be lest than or equal 3, with more than that, we lost many intensity of light in that reflections and this is to bad to design results for.



$$\mathrm{Re}\,flections = \frac{\phi(1/S + 1/2h_{arc})}{2}$$

Figure 4. Reflections on the lens to make an impact on its edge beam perimeter

If the beam of polarized light is shinning in the lens edge, rotate the plane of polarisation of light along the diametrical opposite of the lens coinciding with the orientation of the polarisation plane, it will have a very bright image of the light source. To rotate the plane, the intensity will decrease

Figure 5 shows a sequence in that can be seen how to change the outgoing light when the polarising plane is rotated

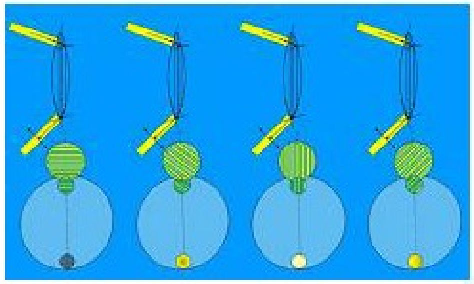


Fig.5 Sequences that shows how changes the out coming light lens in a lens side view

In other words, when beams of polarize light pass through of a biconvex lens, occurred refraction and reflection inner the body lenses with out of the beam light polarization plane that it belong. Then there are two beams go out of the lenses in the same direction that polarize plane and opposite to the diameter (Figure 5.1).

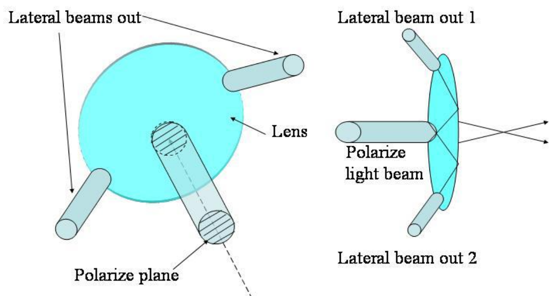


Figure 5.1. Representation of refraction and reflection to affect polarized light in a convex lens

The lateral beam out 1 is the lower part of the object's image. The lateral beam out 2 is the upper part of the of the object's image.

If the polarize plane of polarize light beam is rotated, both lateral beams out (1 and 2) will be rotated too around the external lens's circle, following polarize plane position.

This is the reason for what is very difficult use this phenomena in order to build measurements instruments.

III. COPLANAR LENS SYSTEMS

Taking two identical lenses and placing them in the same plane. The intercept between the lines extending perpendicular where the edges of the lens join, with a line tangent to the upper edges of the two lenses, will be the centre of the light beam. The two points diametrically opposite light emerging in each of the lenses will be 90^o to each other. Figure 6 is the geometric representation of this phenomenon.

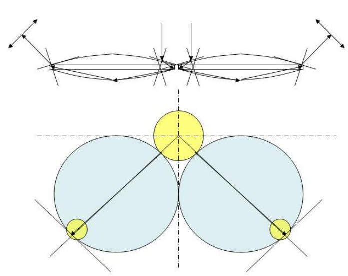


Figure 6. Parallel lens system

By rotating the light beam linearly polarized, when the diametrical path of the lens coincides with the orientation of the polarisation plane, a bright image of light source is obtained in the side diametric position, while the position diametrically opposite in the other lens there is not light. If we rotate the plane of polarisation in the direction of the lens with a lower intensity of light, this will grow in intensity and the other will decrease. There is 90^o of difference between the points.

Using this principle is possible to get very good results with two lenses in coplanar position. In this case the input beam of polarize light must be projecting between the two lenses and not to lenses center (Figure 6.1).

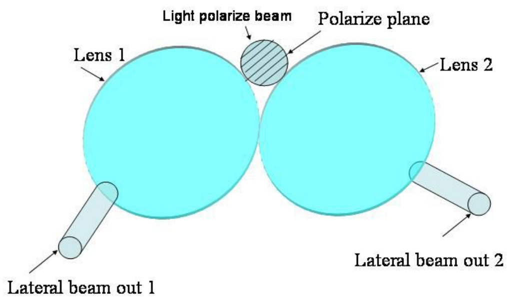


Figure 6.1. Parallel lens system

For both lenses polarize light beam touch the external circle of each lens and polarize light beam is reflecting and refracting along the lens diameter and get out for the opposite side.

If the polarize plane have the same position of lens diameter, the lateral beam out will be very strong, but if it is orthogonal to the lens diameter, the lateral beam will be very weak.

When the polarization plane of the polarize beam is rotated, the lateral beam 1 and 2 don’t change its positions, but change its intensity in opposite form. This is due to that is the same light beam for the two lenses, but the polarize plane position not is the same for both lenses, and this deference produce that the lateral beam out 1 and the lateral beam out 2 shining in deferent forms.

When the light beam polarize plane is orthogonal to both lenses, the shining of both lateral beam out will be the same; this occur too when polarize plane is parallel to the both lenses. In this two positions is possible considering there is not polarize plane rotation, then, this will be the zero of the polarizing measurement instrument.

At this point, if an active optically substance is putt on in the light polarization beam trajectory, one of the lateral beams out will increase its shining and the other decreases its shining. The differences of shining between both lateral beams out will be polarize plane rotation value.

In order to make this most easy; the source of the light polarization beam is pulse modulated. In this form is possible compare the rise time of both lateral beams out pulses signals

If the rise time of the both lateral beams out occurs at the same time there is not polarizing plane rotation. If the one rise time occurs before the other, then there is polarizing plane rotation (Figure 6.2).

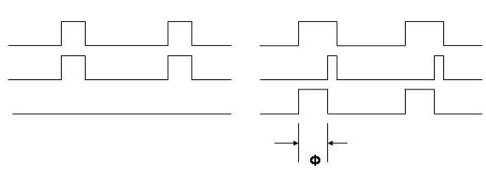


Figure 6.2. Electronic circuit letters time

It is possible to know if the rotation was a clockwise or not, depending which rise time was occur first. For the first rise time, its lateral beam out shining more than that rise time produced by the other lateral beam out. For that the first optic-electronic sensor respond before that the second because it receive more than light that the second optic-electronic sensor which receive less than light (Figure 6.3)

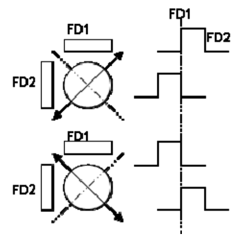


Figure 6.3. Operational amplifier output following the rise time of the pulse signal in each output amplifier, according to the Malus`s Low.

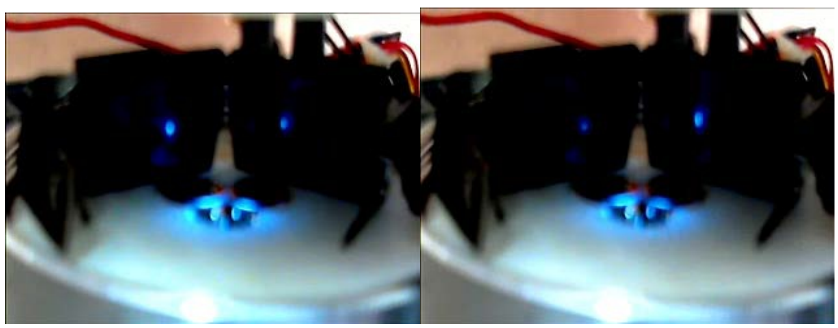
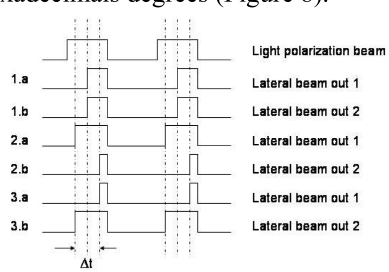


Figure 7. Vista fixed to an experiment made media

Figure 7 is the capture of two still pictures taken from a media conducted in the laboratory. At the bottom is a hole through which passes the polarized light beam, downwards for the back and sides of the orifice are positioned two lenses, and the bottom two black screens on which projects the light emerging from the lens which are the white-bluish halos. On the left of the spot of light of greater intensity on the screen is dark in the left and the right is in the right display as a consequence of the rotation of the polarisation plane.

Using an optimal modulation frequency of the light polarization beam, according to the optic-electronic sensors uses, is possible obtain polarize plane rotation in hexadecimals degrees (Figure 8).



$$\phi = \Delta t \frac{360^O}{2} f$$

$$\Delta t = Wild_a - Wild_b$$

Figure 8. Graphic method to obtain polarizes plane rotation value in hexadecimal degree.

After this point is very easy make a microprocessor program, which does the both pulses wild measurement and after that do the rest in order to get Δt and multiplication by $\frac{360^O}{2} f$. The result is showing in a digital display (LCD).

IV. APPLICATIONS

The optical system and the phenomenon can be used in various applications.

1) It can be used in data transmission. Using polarized light in which the variation of the polarisation plane position can represent ones and zeros. This is very advantageous because it would avoid the loss of information, because it does not matter the levels of light intensity does not remain constant, only interested the angles of the plane of polarisation, who would take the information corresponding to ones and zeros.

2) Use in sea and air signalling.

3) In weighing systems in which rotation of the polarisation plane would be proportional to body weight.

4) Polarimetry instruments.

5) In determining if a beam of light is polarized or not (astronomic).

V. CONCLUSION

The optical system and the phenomenon can be used as a new polarimetric detection method, in which the accuracy of alignment of the optical system is essential for accuracy of detection. It's a new polarimetric detection method, based, first, in the new principle of refraction and reflection of light polarized in lenses and the first time use of coplanar optical lens systems that significantly improve the use of the phenomenon analysed.

Principle of refraction and reflection of linearly light polarized in lenses:
When a linearly polarized light beam incident on a lens, the light will be reflect and refract inside the lens body only in the same direction that the polarize plane, the light can not through out from the polarize plane that it belong.

The system allows determine the beam of light polarization plane orientation. It also allows to determine the magnitude that has been rotated when introducing an active optic substance and to also know if the same one is levorotary or not.

By first time have been used a parallel lens systems and this is a new optical method for polarimetric measurement, with this, extremely simple, sure and precise polarimeters can be built.

REFERENCE LINKING

Book: [1] G.S. Landsberg, Optic, First Book, MIR, (1976), Light Polarization 395-414

[2] E. Hecht, Optics, Fourth Edition, 5Geometrical Optics, 5.1Lens, 150-170, 8Polarization, 325- 378

Proceedings paper: [3] Va[1] Miranda Díaz L.J., Invention Author Certificate, CU 23333 A1, EQUIPO DE POLARIMETRÍA Y MEDICIÓN DE ABSORCIÓN, 2008.12.24

Note References have been mentioned rather to indicate the field that the subject matter belonging hereof, as the phenomenon is not reflected in the literature.