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

Miranda Díaz Lázaro J.

Electronic Design, Center of Technological Applications and Nuclear Development (CEADEN), Ciudad Habana, Cuba.

Email: miranda{AT}ceaden.edu.cu

Abstract

When linearly polarized light impinging on a lens, it will reflect and refract along the lines curves resulting from the interception of a plane (plane of polarization) with a sphere (lens surface) maintaining the orientation of refraction and reflection within the plane of polarization. This effect is significant only looking at the lens laterally. Therefore, a lens acts as a lateral analyzer when the polarization plane of polarized 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 where the incident linearly polarized light, the lens acting as a waveguide for the light beam polarized.

Keywords: Polarization, Optic, Lens, Measurement

1. Introduction

When a linearly polarized light beam incident on a lens are made to manifest the algebraic properties of geometric shapes, such as the intersection between a plane and a spherical surface, 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 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 polarization 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 polarization of light.

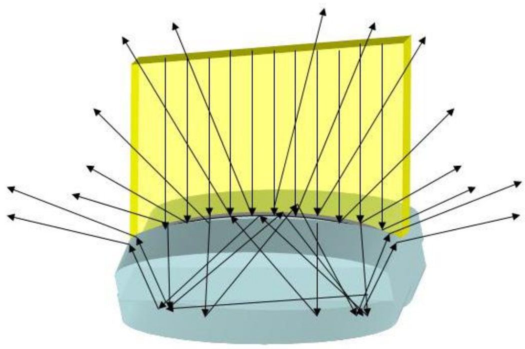


Fig.1 Representation of refraction and reflection to affect polarized light in a convex lens

A linearly polarized beam incident on a lens will reflect and refract following the interception between a plane (plane of polarization) and a sphere (lens surface), maintaining the orientation of the beams refracted and reflected within the plane of polarization that originated them, forming two pairs of fans on opposite edges to the diameter on both sides of the lens. 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., placing parallel to the optical axis.

2. Experiment

If two observers, are situated one on the right and one on the left as seen in Figure 1, the observer 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 left observer sees the right 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 polarization is orthogonal to the plane of the paper, or it is parallel to the two observers.

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

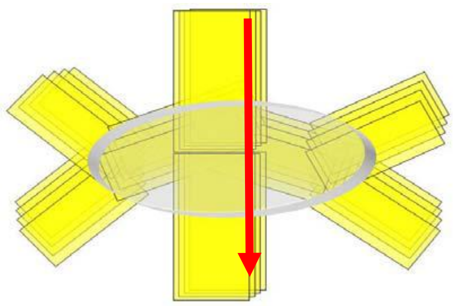


Fig. 2 The reflection and refraction at a convex lens representation

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 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 polarization relative to the position of the observer. Hence, an observer who turns laterally around the lens with the same speed to the plane of polarization will always see the same intensity.

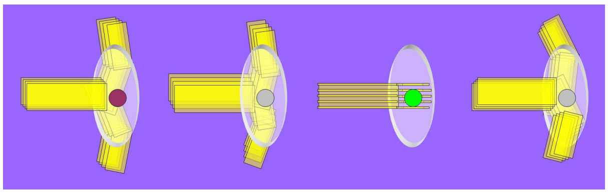
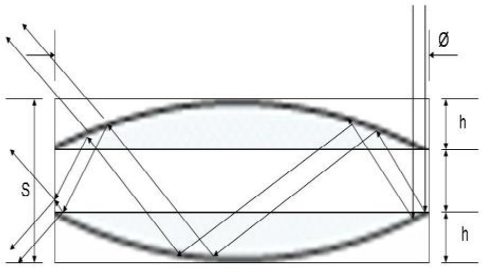


Fig. 3 Polarize plane rotation sequence

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.



$$Reflections = \frac{\phi(1/S + 1/2h_{arc})}{2}$$

Fig. 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 polarization of light along the diametrical opposite of the lens coinciding with the orientation of the polarization 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 which can be seen how to change the outgoing light when the polarizing plane is rotated

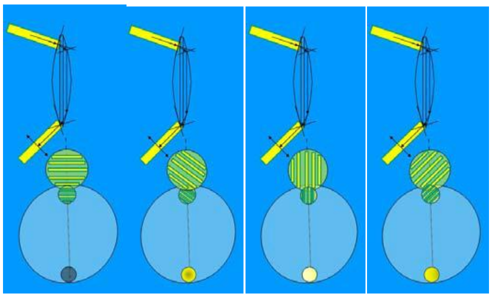


Fig.5 Sequences that shows how changes the out coming light lens in a lens side view

3. Coplanar lens systems

Taking two identical lenses and placing them in the same plane so the intercept between the line extending perpendicular where they join the edges of the lens, with another line tangent to the upper edges of the two lenses and orthogonal to the first, 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.

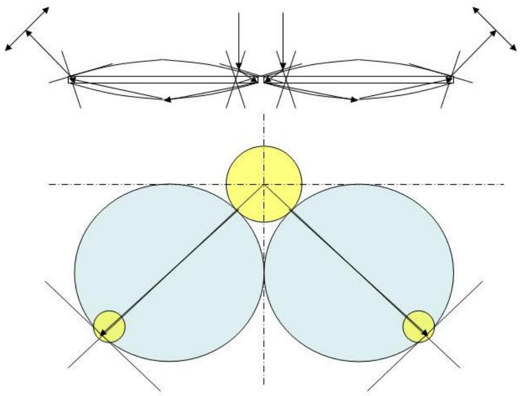


Fig. 6 Parallel lens system

By rotating the light beam linearly polarized, when the diametrical path of the lens coincides with the orientation of the polarization plane, a bright image of light source is obtained in the side diametric position, while the position diametrically opposite in the other lens there be not light. If we rotate the plane of polarization 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.

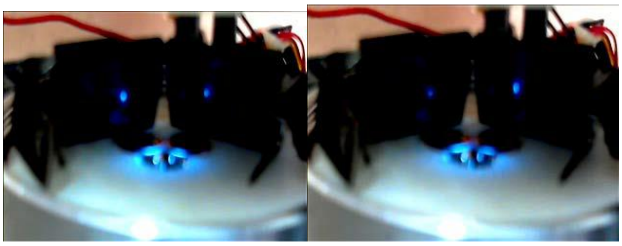


Fig. 7 Vista fixed to an experiment made media

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 polarization plane.

4. 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 polarization plane position can represent ones and zeros by the use of polarizer electric effect, which would be very advantageous because it would avoid the loss of information because it does not matter the levels of light intensity does not remain constant because we are only interested in the angles of the plane of polarization, 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 polarization plane would be proportional to body weight.

4) In polarimetry instruments.

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

4.1 One application

Abstract:

When passing a pulsing beam of polarize light of a light emitter diode (LED) or a semiconductor laser thru an optical system and two photodiodes spatially arranged at 90^0 to each other and both with their detection surfaces parallel to the transmission shaft of light, and polarization axis oriented at 45^0 of the vertices of the edges where the photodiodes join, in the outputs of two operational amplifiers, we have two signals with the same shape in time, i.e. a pulse train with the same phase, but when you turn the polarization plane, change the radiance of the light projected onto the photodiodes, being out of phase signals to the outputs of the amplifiers, where the difference between the fronts of the pulses is proportional to the angle of rotation of the plane of polarization of polarization light.

In a digital circuit phase discriminator, a pulse is obtained equal to the time difference between two sides of the rise time in the output of two amplifiers.

The width of this is directly proportional to the value of rotation the plane of polarization of light, that is, the greater the rotation, the greater the width of this.

4.1.1. Introduction

Using a very simple optic system, with a luminous source to light emitting diode (LED) and as sensor two Optic-Electronic Amplifiers associated to front wave differentiating digital circuits, it is possible determined the polarized light plane rotation in very comfortable and precise form, without the necessity to use analyzers, rotational modulators, neither magnetic coil that are those more commonly employees for the polarized light plane measure. Give there that the outlined method has the advantage the mobile mechanical parts total lack and not having to use big currents densities in induction coils, its precision depending of the pulses modulation electric sign stability and the optic system alignment precision, including the photodiodes spaced to 90^0 degrees among them incidence faces.

When you affect linearly polarized light in a lens, it will reflect and refract along the curves lines arising from the interception of a plane with a sphere on the surface of the lens while maintaining the orientation of the plane of polarization. This effect is significant only looking at the lens side. Therefore the lens is like a side analyzer if we rotate the polarization plane of polarized light that falls on it.

Following this principle and that over the spherical surface lens few can put n circle of radius r, where n is inversely proportional to r, and each circle is in turn a lens, so if we shine a beam of light in one of these areas The phenomenon of polarization is expressed lateral side and diametrically opposite to where the incident linearly polarized light.

4.1.2 System with only one lens

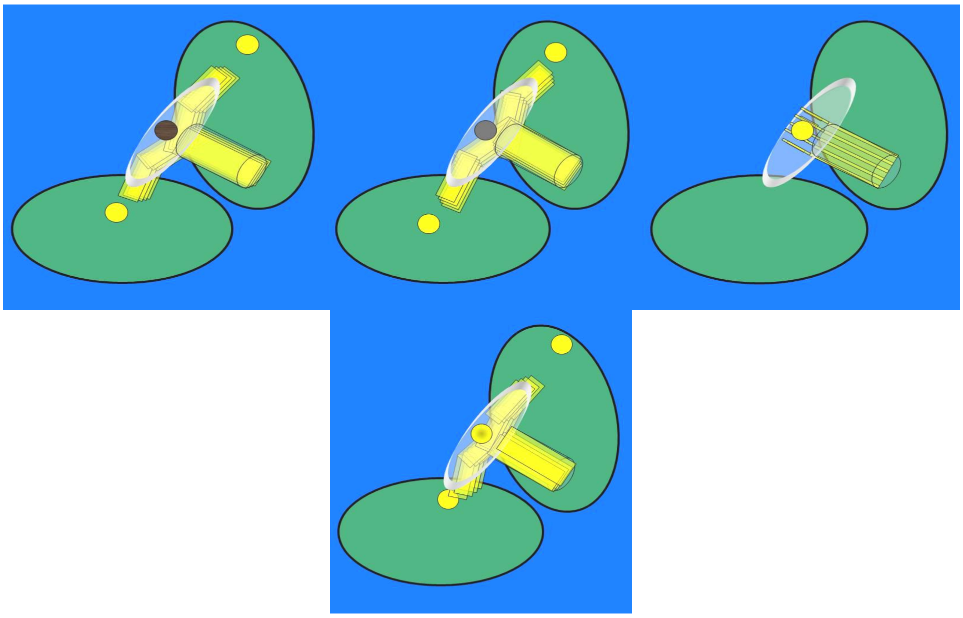


Fig. 8 Sequence showing how two photodiodes spatially to 90 degree are illuminated when the polarize plane change.

To use this phenomenon in the construction of an instrument to determine the value of the rotation of the plane of polarization of light, would have two light sensors placed parallel to the optical axis 90^0 spaced from each other and on the sides of the lens. In Figure 8, the green color circles are the photodiodes and when the plane of polarization of light rotated, the light over photodiodes detection surface change. But this has two disadvantages, one is the light intensity is low and the other is the absorption effect of distorting information because there is a lighted space between the sensors would not touch the surface of both.

4.1.3. System with only two lens

Using a geometric study of the lenses we find out the solution to this problem. As is the spherical surface lens on it can be matched perfectly circles of radius **r**, the amount will be inversely proportional to that radius. Each circle may be regarded as a lens. Given this consideration, if linearly polarized light we shine on the edge of the lens, everything will happen explained above, but in the region of incidence, so the light will go over the edge of the lens is diametrically opposed to incident beam and which can only be observed the image at that point and do not in any other region of the lens. In this way we will not have a cone-shaped beam on the side of the lens, but a point where we will get the whole picture and therefore with greater intensity.

In this case the sequence is showing in Figure 5, where the out coming light intensity is a function of the polarize plane incident position over the border lens surface.

But we still have a problem and we have to use two sensors to polarized light to come on as a light source. The solution to this problem is to use a system of two identical lenses placed in the same plane and positioned so that they cross a line where you play two of its edges with another drawn from the edges that touch the two lenses and orthogonal to the first, is the center of the beam. This ensures that the two points of light coming out diametrically opposed in each of the lenses are at 90^0 from each other. Figure 6 is the geometric representation

By rotating the linearly polarized light beam, the lens diameter path coincides with the orientation of the polarization plane will have a very bright image of the light source, while the diametrically opposite position of the other lens will not light. If we continue to rotate the plane of polarization in the direction of the lens with less intensity than light, it will grow in intensity and decreasing the other, when both intensities are equal will be in the place where the instrument has its zero. There will be a gap of 90^0 between the points.

Now the light sensors are always under the light field (see Figure 9), recording exactly light variations that are proportional to the rotation of the polarization plane of light. So that by modulating the polarized light with a train of pulses of light and use as sensors photodiodes, electric current is generated in them will be directly proportional to the amount of light reaching them, there is a gap between rising fronts amplified signal pulses obtained in photodiodes if they do not receive the same amount of light and that is the value of rotation of the polarization plane.

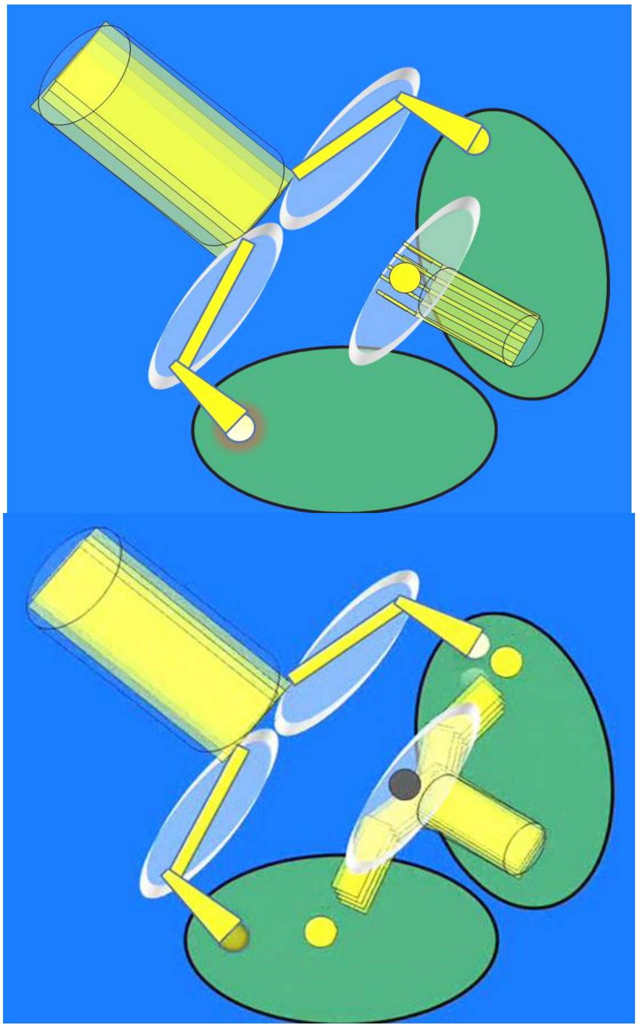


Fig. 9 With two lenses the light sensors are always under the light field

5. MALUS`S LOW BEHAVIOR.

If between a pulsating light source and a radiometer we place two polarizing sheets, with their polarization axes at 90^0, the radiometer will measure zero or minimal candle power, then as broken the polarizing sheet, will go increasing the light intensity reading in the measuring instrument, until a maximum that will correspond when we have rotated it 90^0 (Malus`s low).

If now the polarizing sheet utilized as analyzer is retired and used instead of the radiometer and our amplifier is placed, its exit, view in an oscilloscope, a pulse will appear which width will go increasing until a maximum valor when going rotating the polarizing sheet in the same sense, and starting from there it will begin to diminish until a minimum and a phase shift will take place, increasing the width until a maximum, but now in opposed sense (Figure 10).

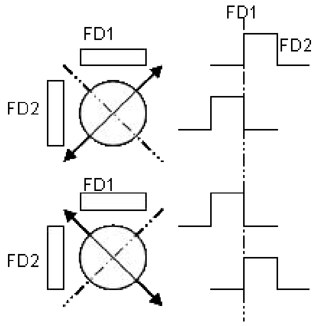


Fig. 10 Operational amplifier output following the rise time of the pulse signal in each output amplifier, according to the Malus`s Low.

Comparing both methods has obtained more information with our amplifier than with the radiometer. When in the oscilloscope appear a minimum, the polarized light plane will be exactly at 45^0 or – 45^0 regarding the horizontal one give the paper plane and like the line with double arrow represent, that is to say that already know in the fact that the sense the polarization plane is oriented of and to identify this in the polarizing sheet.

Now then, if we place an active optic substance in that trajectory, being the plane of polarization placed at 45^0, superior image gives the drawing in Figure 10, we will have a pulse that will increase its width toward the right if the substance is levorotary, and counter-clockwise if it is not levorotary, being its magnitude in agreement with the angular quantity that the substance has rotated the plane of polarization.

If initially the plane of polarization is to – 45^0, inferior image gives the drawing in Figure 8, a pulse will increase its width counter-clockwise if the substance is levorotary, and toward the right if it is not levorotary. FD1 and FD2 in the Figure 10 represent the photodiodes space disposition utilized.

6. Wave form at the output electronic amplifier.

In the Figure 11 the signs time letters, where we only use the rise time between the pulse signals in each output of both operational amplifiers. That difference is equivalent to the rotation of the polarize axis, this value is equal to signal pulse in the last one line.

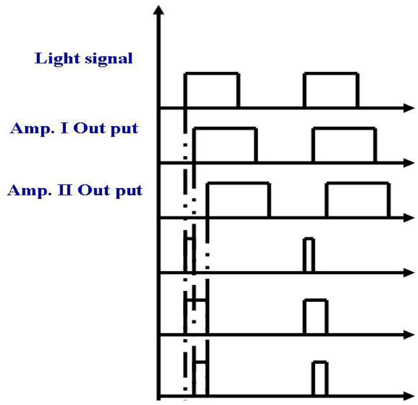


Fig. 11 Electronic circuit letters time

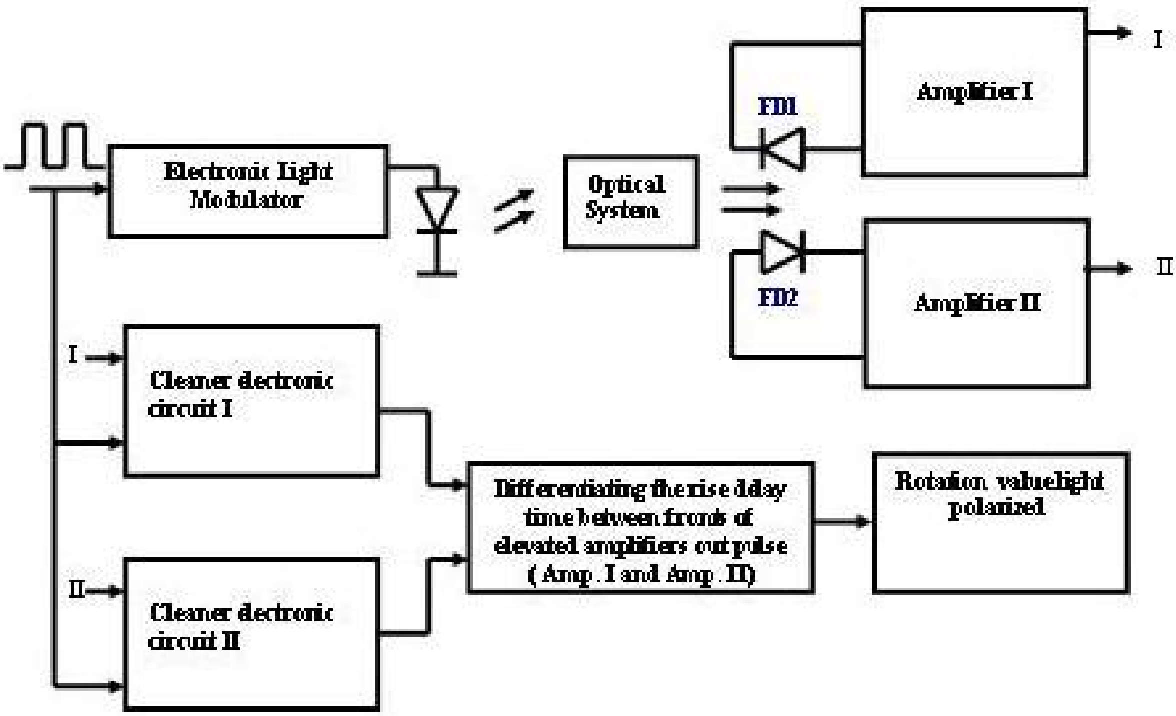
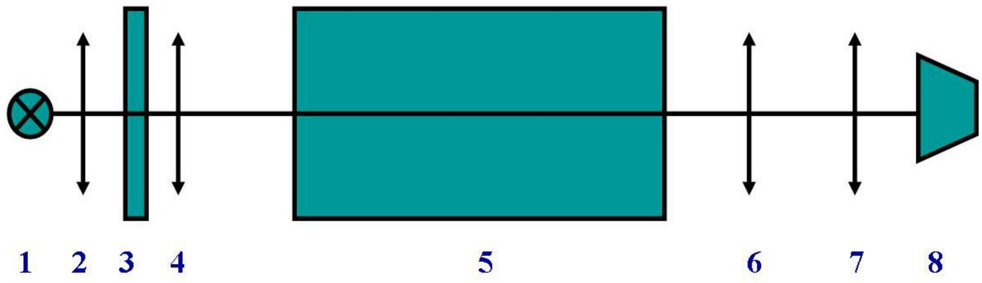


Fig. 12 Equipment block diagram

The Figure 13 is the optic system utilized



1) Light source
2) Objective lens
3) Polarized lens
4) Converging lens
5) Optically active substance
6) Converging lens
7) Converging lens
8) Electro – Optical Amplifier

Fig. 13 Optic system

7. Conclusions

The optical system and the phenomenon which occurs therein can be used as a new polarymetric 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, 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 analyzed.

The Constant Height and Variable Phase Electro-Optic Amplifier allow 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 polarymetric measurement, with this, extremely simple, sure and precise polarimeters can be built.

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