Determination of the width of a paper employing wedge interference phenomenon

Aim: evaluating the width of a sheet of paper via wedge interference phenomenon.

Apparatus: microscope glass slide, thick glass plate (opaque one is preferable), traveling microscope, convex lens.

Theory

When a piece of paper of width t is introduced between the edges of two transparent glass plates, a thin wedge – shape air film will be formed as illustrated in figure 1. The monochromatic light incident normally on the air wedge will be divided into two parts by the wave amplitude – division method. One part is reflected at the upper glass surface OP and the other part passes to the lower glass surface OP′ where it undergoes a further reflection upon striking that surface. Since this reflection is from an optically denser (higher refractive index) medium (glass) to a lower optical density medium (air), the reflected light waves will be phase shifted by 180° (this is equivalent to an additional optical path difference of $\lambda/2$ between the two upper and lower reflected beams). Due to the overlapping (interference) of the two reflected light beams, bright and dark straight fringes are observed in the traveling microscope's field of view.

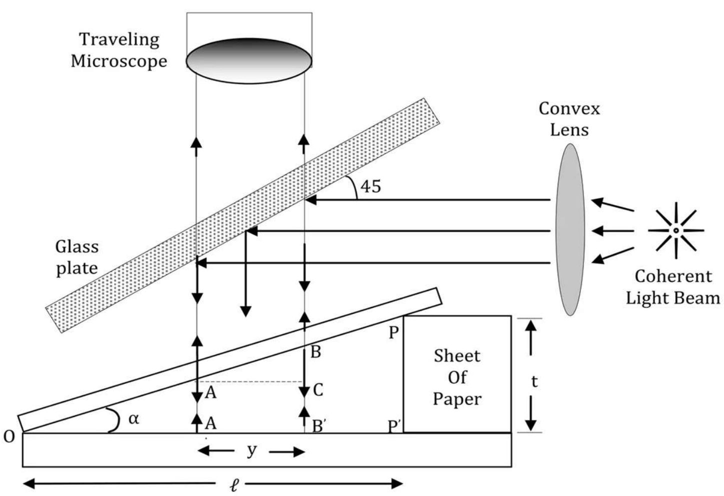

Figure 1: experimental set – up of air – wedge interference phenomenon

Baghdad University – College of Science – Department of Physics – Optics Laboratory Administration Tele: +009647702981421

The fringe at point A is formed by interfering light ray, reflected off the upper glass surface OP, with the one reflected from the lower glass plate which suffered a 180° - phase shift in addition to traversing double the distance AA′ when it propagates back and forth. If the total phase shift equals odd multiples of half the light wavelength, then a dark interference fringe will be formed. On the other hand, the interference fringe will be bright whenever the total phase shift equals even multiples of the light wavelength used. The next interference fringe formed at point B is due to the increase of air – wedge width by an amount of half the light wavelength (the distance BC in the figure 1).
If α is the wedge angle in degrees, then from the triangle ABC it is apparently that:

$$\tan\alpha = \frac{BC}{AC} = \frac{BC}{A'B'} = \frac{\lambda/2}{y} = \frac{\lambda}{2y}$$

Where: y represents the distance between two successive (dark or bright) fringes. In the triangle OPP′:

$$\tan\alpha = \frac{PP'}{OP'} = \frac{t}{\ell}$$

Where t=PP′ represents the width of the paper in mm unit and $OP = \ell$ is the separation between the inner edge of the paper and line of contact of the two glass plates.

$$\frac{t}{\lambda} = \frac{\ell}{2y} \Rightarrow t = \frac{\lambda\ell}{2y} \quad ----(1)$$

Procedure:

1. A convex lens is used to get a parallel light beam emerging from the monochromatic light source (typically the monochromatic sodium light $\lambda_{average} = 589.3\ nm$ or any other coherent light source, for example He-Ne laser light $\lambda = 632.8\ nm$). This parallel light beam is to be making 45° - angle of incidence with a horizontally oriented, 45°- angle, half – silvered glass plate. The light rays reflected off this plate will perpendicularly incident on the lower thick glass plate of the air – wedge.
2. The traveling microscope is then focused until getting the lower thick glass plate of the air – wedge at the focal plane of the traveling microscope's eyepiece. Doing so, a distinct interference pattern should become viewable.
3. The distance between a suitable number of dark (or bright) fringes is measured using the traveling microscope vernier and the width of the dark of bright fringe is deduced by dividing the measured distance on the number of fringes. The measurement is then recorded in a suitable table.