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Three Gratings System for the Measurement of Refractive Index of Liquids

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***Abstract* – This paper describes a very exciting method of finding the refractive index of liquids using a three transmission diffraction gratings. An especially design glass cell is used whose width can be changed using a railing. Light from a low power helium-neon laser is diffracted by a transmission diffraction grating and is collimated by a lens L of short focal length. The parallel beams of light are received by the second grating mounted on the first wall of the glass cell and its first order diffraction is formed on the second wall of the glass cell. The interference is received on a screen at a distance *x* from the third grating mounted on the second wall of the glass cell. The gratings on the glass walls are very similar having the same grating pitch.**

***Keywords* – Refractive Index, Liquid, Grating, Glass Cell, Lens.**

I. Introduction

The refractive index of liquids has been measured by using various techniques [1-10]. These techniques require big laboratory space[1] and lot of preparations[2-3]. Recently some work[13-14] has been reported on developing new techniques for the measurement of refractive index of liquids. However, there is always a need to develop new simple and inexpensive techniques for measuring the refractive index of liquids and to detect any impurity in the liquid. In the present paper, we perform a very simple and inexpensive method by modifying the procedure [11,12] for measuring the refractive index of liquids using a low power He-Ne laser. These methods[11,12] have various drawbacks, one of the them is using thick liquid layers and second ignoring the effect of the lens glass. The present method under discussion is based on the diffraction and interference method and hence can detect any impurity in a liquid easily. The only distance required in the formula (Eqn. 3) can be measured by using a position detector. The results obtained from the current methods have been compared with standard values and with the results obtained by[11,12].

II. Principle and Method

The experiment was set up on an optical bench as shown in Fig 1. The first grating G_1 receives light from a He-Ne laser and diffracts on to a lens L. The lens is placed at the focal point to collimate the diffracted light by G_1. The second grating G_2 is mounted on the first wall of the glass cell. The diffracted light from G_2 is received on the second wall of the glass cell where the third grating G_3 is mounted. Three bright spots are observed on the screen at a distance *x* from the third grating due to the interference of diffracted light from the third grating. The central point is brighter than the other two points but the other two points are at equidistant from the central point as can be seen in Fig 1. This situation confirms the perfect alignment and setup of the experiment. The distance between the walls of the glass cell *d* is predetermined based on the experimental liquid and this is the only drawback of this experiment. However, this drawback is not so crucial as the distance *d* can easily be adjusted by a railing for a particular liquid.

The distance between the walls of the glass cell depends on the angle of refraction α of the diffracted light by the second grating G_2. The angle α is the angle of incidence for the second wall of the glass cell. Finally, the refracted light is received on the screen. Three bright points as a result of interference are received on the screen at a distance *x* from the second wall of the glass cell which determines the refractive index of the experimental liquid. From Fig 1, it can be shown that for small angle of incidence,

$\tan\beta = \sin\beta = y/x$ and $\tan\alpha = \sin\alpha = y/d$ (1)

The Snell's' law $n \sin\alpha = \sin\beta$ gives (2)

$n = d/x$ (3)

where *d* is the width of the glass cell and *x* is the distance from the second wall of the glass cell to the screen. This shows that the refractive index can be measured just by knowing one parameter *x* as *d* is constant for a particular liquid. In deriving Eqn.3, the angle of refraction α which serves as the angle of incidence and the angle of refraction β have been assumed small so that $\tan\beta = \sin\beta = y/x$ and $\tan\alpha = \sin\alpha = y/d$.

III. Measurements and Results

The experiment was set up on an optical bench. The light from the laser is diffracted by a grating G_1 and the diffracted light is collimated by a lens L. The second grating G_2 is now mounted on the first wall of the glass cell. The light is diffracted by G_2 and five light spots with two central bright spots are observed on the second wall of the glass cell. Now the experimental liquid is filled in the glass. The refraction takes place at the first wall of the glass cell. The second wall is moved by the railing so that two bright spots are again seen on the middle of the second wall of the glass cell. A third grating G_3 is now mounted on the second wall of the glass cell and three bright points are observed on the screen at a distance *x* as shown in Fig 1. The refractive index is then easily calculated from Eqn. 3. The values of the refractive index of different liquids are given in Table 1. If the refractive index of liquid is found different from the standard value, it will confirm some impurity in the liquid.

Table 1. Refractive index of liquids at room temperature 25^0C $\pm$ 0.5 ^{0}C

Liquid medium in hollow lens	Refractive index using the current methods	Refractive index using references(11-12)	Standard value of refractive index
Water	1.3312	1.3311	1.3311
Xylol	1.4923	1.4927	1.4927
Banzol	1.4996	1.4991	1.4991

IV. Conclusion

A three gratings system for the measurements of refractive index of liquids has been presented. The refractive index of the liquid depends on one parameter only as can be seen from Eqn. 3 as d is constant for a particular liquid. The interference distance x from the third grating to the screen determines the refractive index of the experimental liquid.

A linear scale can be drawn between d and x to obtain an instant value of the refractive index of liquid. The variation in x will help in checking the impurity in a liquid instantly. The width of the glass cell is adjusted for the second liquid so that the diffraction from the second grating is received on the second wall of the glass cell. Hence with this system, the refractive index of different liquids can be obtained and if there is any impurity in it, it can be checked instantly.

V. Acknowledgment

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References

[1] S. Nemoto, 'Measurement of the refractive index of liquid using laser beam displacement', *Applied Optics*, **31**, 6690 (1992).

[2] M. H. McCay, Semak V. V., Hopkins J. A., and B. Blaha, ' Refractive index of NH_4Cl-H_2O as a function of wavelength: the effect of temperature and concentration', *Applied Optics*, **35**, 3715 (1996).

[3] M. A. Khashan and A. Y. Nassif, 'Accurate measurement of the refractive indices of solids and liquids by the double layer interferometer', *Applied Optics*, **39**, 5991 (2000).

[4] S. Singh, 'Refractive index measurement and its applications', *Physica Scripta*, **65**, 167 (2002).

[5] S. Singh, 'Measuring the refractive index of liquids using a laser', *Physics Education*, 152 (2002).

[6] S. Singh, 'Measurement of refractive index of liquids using a He-Ne laser and a thin glass cell', *Research Journal of Chemistry and Environment*, **7**, 62 (2003).

[7] S. Singh, 'Diffraction method measures refractive indices of liquids', *Physics Education*, **39**, 235, (2004).

[8] S. Singh, 'Two-beam method to determine the refractive index of liquids and translucent solids', *South Africa Journal of Science*, **100**, 18, (2004).

[9] S. Singh, 'Deviation method for the measurement of refractive index of liquids using a helium-neon laser and two identical prisms', *Research Journal of Chemistry and Environment*, **9**, 18-19 (2005).

[10] S. Singh, 'Experimental verification of two-beam method to determine the refractive index of liquids and translucent solids', *Journal of Optics*, **34**, 193 (2005).

[11] R. S. Kasana and A. K. Deshmukh, 'Refractometery of liquids by using liquid immersion and three beam interferometric techniques', *International Journal of Pure Applied Physics*, **6**, 263-268 (2010).

[12] A. K. Deshmukh and R. S. Kasana, 'Refrectometry of lens material by using interferometric techniques', *International Journal of Physics and Application*, **2**, 51-55 (2010).

[13] S. Singh, 'Self-checking impurity method in liquids, ISTJN, **1**, 7 (2013).

[14] N Shafudah and Shyam Singh, An inexpensive new multipurpose refractometer, *ISTJN*, **4**, 36 (2014).

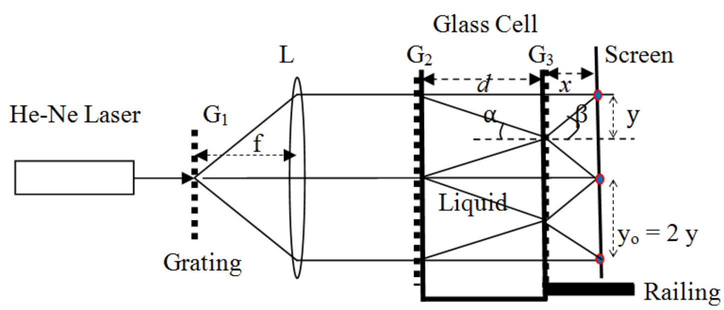

Fig. 1. Three gratings system for refractive index