

An inexpensive new multipurpose refractometer

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Abstract

A new yet very inexpensive refractometer for the determination of refractive index and impurity in liquids at instant has been proposed. This refractometer requires a high resolution grating, a low power laser and a position detector. The position detector analyses and determines the impurity in a liquid directly based on its refractive index. The use of a plane mirror enhances the accuracy of the refractive indices as the measurements of required parameters are greatly increased.

Keywords: refractometer, diffraction, liquid, impurity

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1 Introduction

Various techniques (Nemoto, 1992; Khashan and Nassif, 2000) for the measurements of refractive indices of liquids have been reported. All these techniques are too complicated and too expensive. One of the most important optical constants, the refractive index has been used to detect adulteration in liquid products. Various techniques for the measurements of refractive indices of liquids have been reported (Singh, 2002; Singh, 2004) using a low power laser. The proposed refractometer is based on the diffraction from a grating and then refraction through the testing liquid (Kasana and Deshmukh, 2010; Singh, 2013). A plane mirror is added in the experiment to measure the angle of refraction quickly and accurately.

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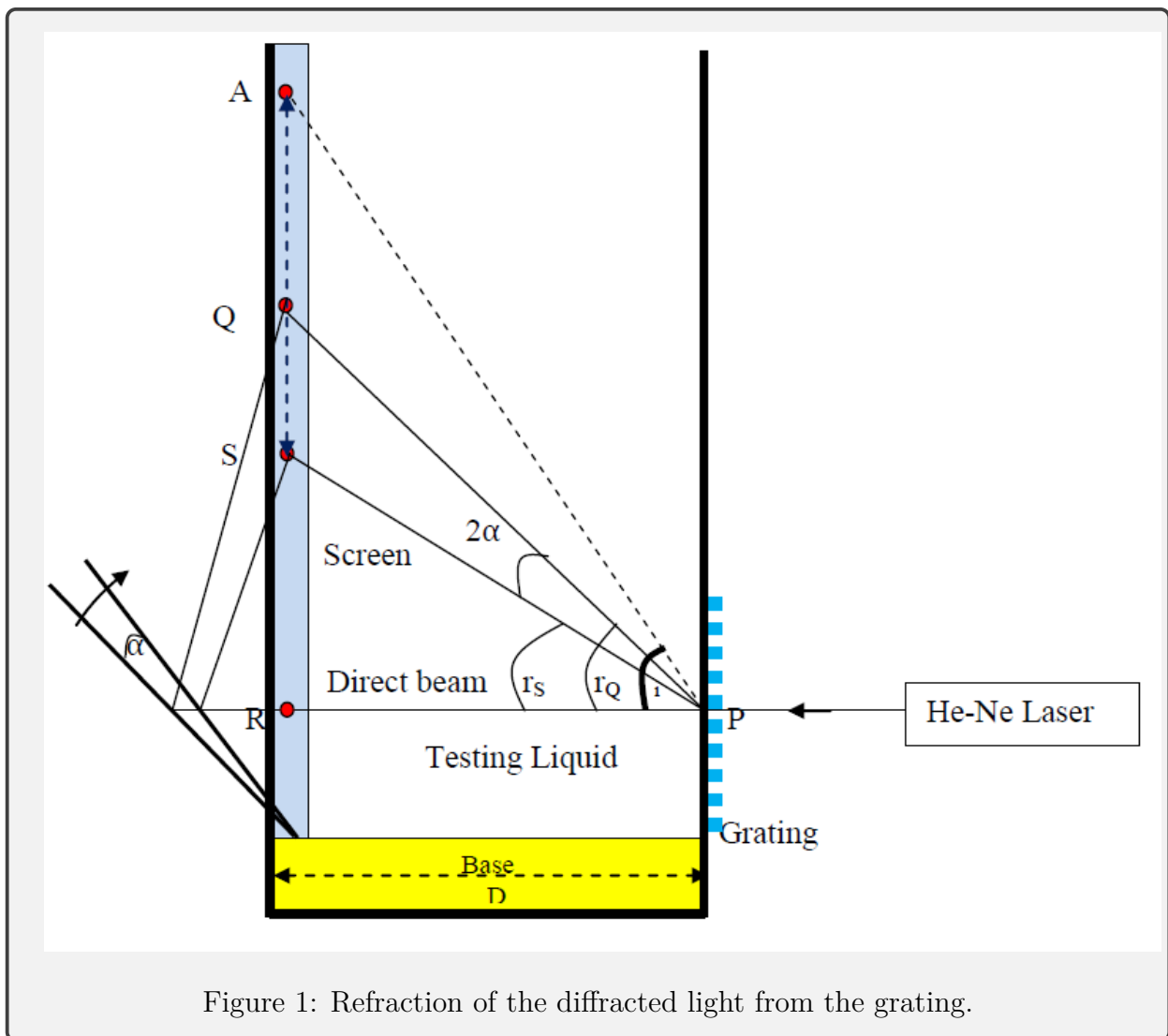


Figure 1: Refraction of the diffracted light from the grating.

2 Description of the Apparatus and Method

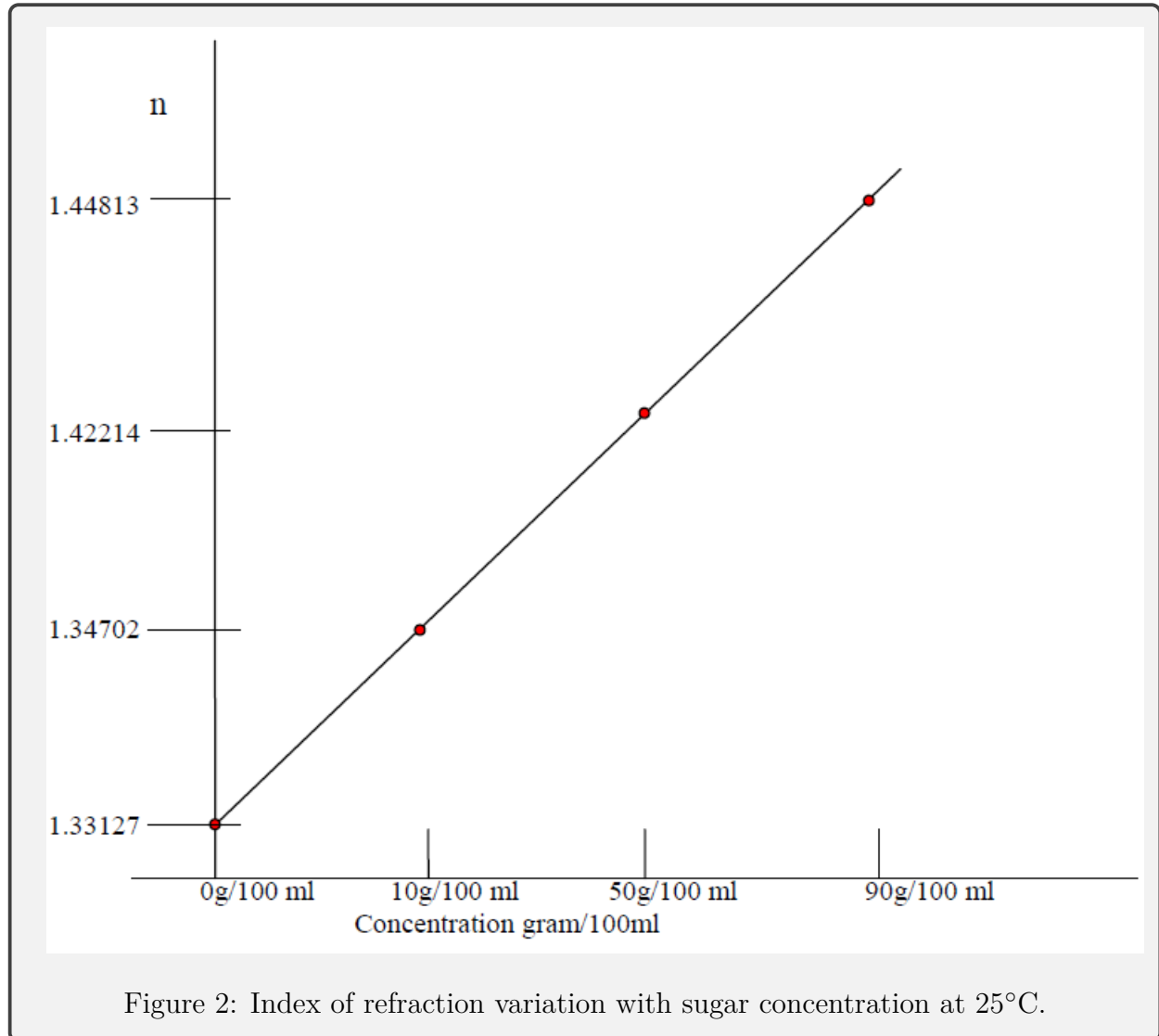
The experimental setup consists of a rectangular glass cell of about 2 cm wide \times 10 cm long. On one side, a grating is mounted and on the other side a calibrated scaled is attached. At the bottom of this side, a plane mirror is attached which can be rotated with the help of a screw. The glass cell is first calibrated for different quality liquids. To do this, a high quality grating is mounted on one wall of the cell and its first order diffraction is marked on the other side of the wall for different quality liquids as shown in Figure 1. For example, if pure quality liquid is filled in the glass cell, after refraction, the first order diffracted light from the grating is marked at point Q . The direct beam hit the attached mirror. The mirror is rotated so that the maximum intensity is recorded by the position detector. The point Q is the reference point for quality liquid and the position of the mirror is also noted. If now the quality liquid is replaced by the sample liquid which contains some impurity, the light from the grating will not shine at point Q but below it at point S . The gap between the current spot of light at point S and the original point Q will determine the impurity in the sample liquid as compared to quality liquid. The mirror is rotated through a small angle $\hat{I}S$ so that the maximum intensity is recorded at point S . The angle SPQ will be 2α . Bigger is the gap between points S and Q , greater will be the impurity in sample liquid.

When there is no liquid in the glass cell, the first order diffraction from the grating is observed on the screen (wall of the glass cell) at an angle i at point A following the direction given by $\sin i = \frac{\lambda}{d}$, since the order of the diffraction, $m = 1$, λ is the wavelength of light, and d is the grating constant. The angle i will be treated as angle of incidence in this case. Now the quality liquid (pure liquid) is poured into glass cell. The refraction takes place with the angle r_Q and the refracted light is observed at point Q following $n_Q = \frac{\sin i}{\sin r_Q}$, where n_Q is the refractive index of the quality liquid. Now the quality liquid is replaced with the sample liquid of refractive index n_S , which is under investigation. The light is refracted at an angle r_S and shines the screen at point S following $n_S = \frac{\sin i}{\sin r_S}$, where n_S is the refractive index of the sample liquid. The difference between the angles r_Q and r_S will directly give the impurity in the liquid, which is equal to the gap between the points Q and S refracted through the quality and sample liquids respectively. If the thickness of the glass cell is D , we can have the following equations,

$$\sin i = \frac{\lambda}{d} = n_Q \sin r_Q = n_S \sin r_S \quad (1)$$

$$n_Q = \frac{\lambda}{d \sin r_Q} \quad (2)$$

$$n_S = \frac{\lambda}{d \sin r_S} \quad (3)$$



3 Results and Discussion

As an experimental verification, the quality liquid was considered distilled water and the sample liquid was the concentration of sugar solutions in water. The sugar concentration is considered as impurity in liquid. The angle of incidence i was calculated directly from equation 1 as both λ and d are known. The refractive index n_Q of the quality liquid can be obtained from the index table and hence the corresponding angle of refraction r_Q can be calculated from equation 2. Now the quality liquid is replaced by the sample liquid. The diffracted light is observed at point S . The attached mirror is tilted so that the maximum

intensity is observed at point Q . The angle SPQ is the twice of the angle of mirror rotation, α . Thus the angle $r_S = (r_Q - 2\alpha)$ easily computed which can be used to obtain the refractive index of the sample liquid (Eqn 3). The concentration of sugar solutions or the impurity is directly proportion to the change in refractive index between the quality and sample liquids. As a test, the refractive index of water and different sugar solutions were measured using this refractometer. The refractive index of quality water at 25°C for wavelength 632.8 nm was calculated to be 1.33127 . The graph shown in Figure 2 is for different sugar concentrations. The use of a high quality grating can further enhance the performance of the refractometer.

4 Conclusion

A simple and inexpensive new refractometer has been developed for detecting the impurity in a liquid based on the refractive index. The method is based on the rotation of a mirror attached to the bottom of the glass cell. This refractometer can give instantly an accurate value of the refractive index of any liquid. It can also be used to compare the refractive indices of two liquids. The most important advantage of this refractometer is to check the adulteration in any liquid-product instantly.

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