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A New Technique for Measuring the Refractive Index

Asmaa J. Kadhim Al- Kinani*,Isaa.M.Kadhim*, Adnan Salih Al-Ithawi**

*Department of Physics/College of Science for Women/ University of Baghdad, Iraq

**Retired professor/Email: dradnan_salih@yahoo.com

asmaajk_phys@csw.uobaghdad.edu.iq,

issamk_phys@csw.uobaghdad.edu.iq

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Abstract: Refractive index is an essential optical parameter of materials. The operating principle of the refractometer is already known for more than hundred years. Refractometer measurement principally consists of analyzing an image which is produced by light reflection. This image analysis is aimed to find the location of the critical angle of total reflection, i.e. the borderline at which the light area turns into the dark area. There are four main types of refractometers: A new method to measure refractive index of glass and water has been documented in this paper. In this study we used a simple, easy, and accurate method to measure the refractive index of silica glass and water depending on measurement of the kinetic energy of laser light (405nm) with energy (4mj/s) in air and medium. We found the magnitude of refractive index of water and silica glass is the same as reported before.

1. Introduction

Various practical methods have been used to get the real part of the complex refractive index n_λ. The most accurate is the minimum deviation angle method, which depends on measuring the minimum deviation angle θ_{min} of a triangular prism of equal angles made of the silica glass placed in air. This method is based on Snell's law [1], it is often used to precisely measure the refractive index of transparent glass for which the absorption index *k*, i.e., the imaginary part of the complex refractive index, is very small and can be ignored. Alternatively used technique, the interferometric method is based on observing the resulted interference fringe when light is incident normally upon a silica glass plate [2,3].Other techniques such as the Abbe's or the Pulfrich's refractometers where accuracy on the index of refraction is within $2 \times 10^{-3}$and 5×10^{-5}, respectively [4]. Finally, the Kramers–Krönig relations [5], can also be used to predict either the refractive index from the absorption index, or vice versa. Refractive index has many applications. It is mainly implemented to identify a certain substance, define its purity, or depict its concentration. Usually, it is carried out to calculate the concentration of a solute in an aqueous solution. For a solution of sugar, the refractive index is a direct indicator of the sugar content (Brix degree). It is widely applied to find drug concentration in pharmaceutical industry [7]. It is defined as the ratio between the velocities of light in vacuum to the phase velocity (v_p) of light in a medium [8]. In 2002, Singh developed two options for refractive index to meet particle image velocimetry [9].A large review of literatures of the last 40 years reveals that so many techniques have been developed and improved for the measurement of refractive indices [10]. There are some limitations with the system depends on prism like components in the process flows may cause deposits to build up on the prism, the refractometer measuring the refractive index of the deposit rather than that of the sample. The current systems depends on wave length of light and the law of diffraction, this needs a lot of optical components like lenses, prism, CCD camera.

The aim of this work is to use a new technique depends on the energy of photon. As in current theory the energy of photon does not affected by refractive index, but we found in literatures, A new relation for energies in vacuum and medium which the refractive index effected on energy [11, 12] as in equation (1), In this study we want to prove that this relation is correct and to find a simple, easy, and accurate method to measure the refractive index of (silica glass and water) as an example materials.

$E_{air}= n E_{med}$ ……………………………………………..…… (1)

This relationship is used in this work to measure the refractive index of water and silica glass

2. Materials and Method

A simple system is used to measure the kinetic energy of photon in medium. This setting consists of tank of glass, block of silica glass, distilled water, laser light source, laser detector and voltmeter figures (1-3). The laser beam (450 nm) passes perpendicular to the surface of the tank with transmission efficiency equal to 97% of the incident intensity of light, from the incident light. The (energy /second) of photons was measured inside the tank with water, finally we measured the (energy/second) of photons outside of tank with water. A volt meter was used, we convert the reading of volt meter in (v) to (mw, i.e mj/s) by measuring the output of laser in inside of empty tank (4mw) as a calibrated number.

As in volt meter the results are: (0.897v) in empty tank,(0.673v) in water(24^0c), and (0.829v) out of tank with water, to convert the result of a volt meter in(volt) to(mj/s) ,we used the calibration number (4 mJ/s) as in empty tank, the results as in table (1) .

3. Calculations:

When Laser beam passes through second wall of the tank by an angle, 4% of energy will be lost by reflection from first surface and another 4% from the second surface due to refraction. Loss due to absorption is 3%.

The total loss will be 7.84 + 3 = 10.84 %..(3)

These are well-known and can be regarded as facts.

4. Results and discussion:

4.1 Measurement of refractive index of water:

Site of measurement	Inside empty tank	Inside tank with water	Outside tank with water
Volts	0.897	0.673	0.829
mj/s	4	3.0011148272	3.696767111

Table1: measurements and conversions for refractive index of water.

Comparing the measurements of inside the tank with water with that of outside the tank with water there should be an energy loss = 3.0011148272×10.84 (the total loss) which is equal to 0.32532084726mj…..…………………………….…....(4)

So that the reading is expected to be:

3.001148272 – 0.32532084726 = 2.67579397994 expected energy outside the tank with water…………………………………………………………..………..(5)

As it is seen in table1 the energy outside the tank is

3.69676711 (measured)……………………………………..………….. (6)

This means that the measured energy is higher than the expected. This is difficult to explain unless there is an increase in velocity of photons takes place immediately after photons goes to air outside the tank.

Calculating the difference, it is equal to the measured energy minus the expected and the resulted difference is equal to.

Difference = Measured - Expected

Difference = 3.6967670011 - 2.67579397994

Difference = 1.02097302117 mj/s……………………………………..… (7)

So from these calculations the energy of photons in water will be:

Energy of photons in water = Energy in air – the difference ……..…. (8)

Energy in air = 4 mj/s

Energy of photons in water = 4 – 1.02097302117= 2.97902697883 mj/s

To calculate the refractive index of water according to formula:

$$E_{air} = n\ E_{med}$$

$$n = E_{air} / E_{med}$$

n = 4/ 2.97902697883 = 1.34272.

The value of refractive index by Masahiko Daimon et al in 2007 [13] (n=1.34271 at 24^o c for 404.77nm) measuring the refractive index using an electronic refractometer. The percentage error is:

Per=((1.34272-1.34271)/ 1.34272)*100 %

Per=0.00074 %

From data base the refractive index of water at (24^0c) is 1.3427 for 405nm.

Per= ((1.34272-1.3427)/ 1.34272) *100%

Per=0.0015%

4.2 Refractive index of Silica Glass

To measured the refractive index of silica glass, we used the same system as in figures (4-7), but we immersed the block of silica glass in water because its difficult to measured the kinetic energy of photon inside the glass, As in volt meter the results are: (0.877 v) in empty tank, (0.674 v) in water (20^0c), (0.858v) out of tank with water and glass, and (0.626 v) inside with water and glass. The difference between the energy in water without glass and water with glass is:

0.674-0.626=.048v

We estimated that, the energy of photon in glass with all loss like absorption, scattering, and velocity is (0.648v)

to convert the result of a volt meter in(volt) to(mj/s) ,we used the calibration number (4 mJ/s) as in empty tank, the results as in table (2)

Site of measurement	Inside empty tank	inside tank with water and glass	outside tank with water and glass
Volts	0.877	0.648	0.858
mj/s	4 mj/s	2.955530217 mj/s	3.913340935 mj/s

Table2: Measurements and conversions for refractive index of Silica Glass Block.

The information in table (2) is used to calculate the refractive index of Silica Glass Block. The kinetic energy in silica glass is calculated and found that (E_{med}=2.721809806 mj/s) by the same above steps of calculations.

From equation (1), the refractive index of silica glass is:

n=4/2.721809806

n= 1.46961

The refractive index that measured by Kitamura in 2007 [14] by using light source (0.4μ m is 1.47017 and 0.41 μm 1.46912 at 20^0c). We used 0.405 μm we can estimated that the refractive index is (1.4696454),

The percentage error is:

Per = ((1.4696454-1. 469610)/ 1.4696454)*100 %

Per=0.0023 %

From the refractive index data base the refractive index for silica glass is (1.4696 at 20^0 c) for 405 nm

Per = ((1.46961-1.4696)/1.46961)*100%

Per = 0.00068%

5. Conclusion

In this study we used simple system to measure the refractive index on principle of measuring the energy of light rather than wave length and this the first time using this principle; the results are very accurate as seen from percentage errors. The system is very simple; there are no lenses or prism and CCD camera. We used only light source and detector. This system can be used for another materials not only water and glass which used in this study as an examples. Another important result is that, the relation (1) is valid.

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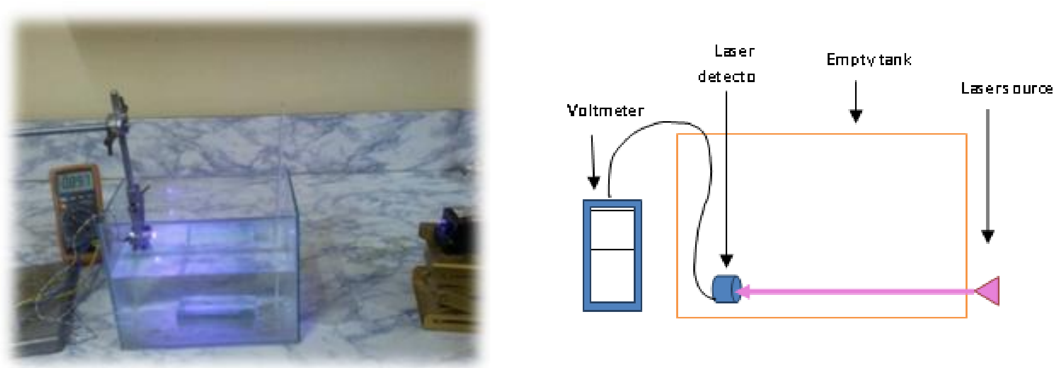


Figure (1)

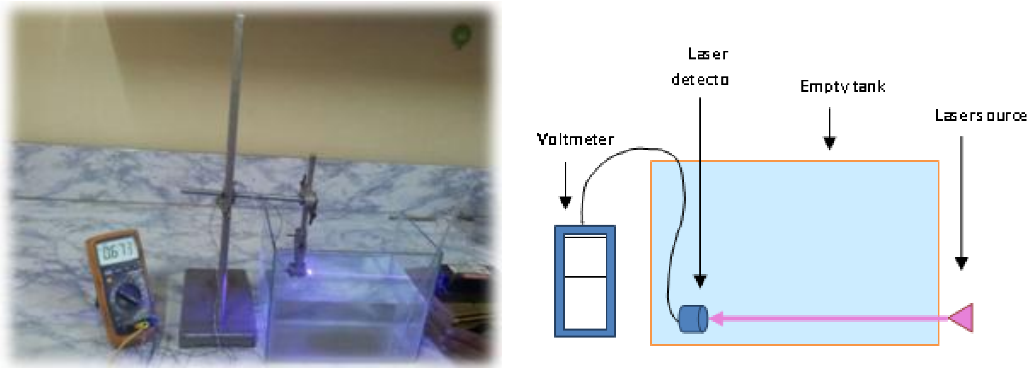
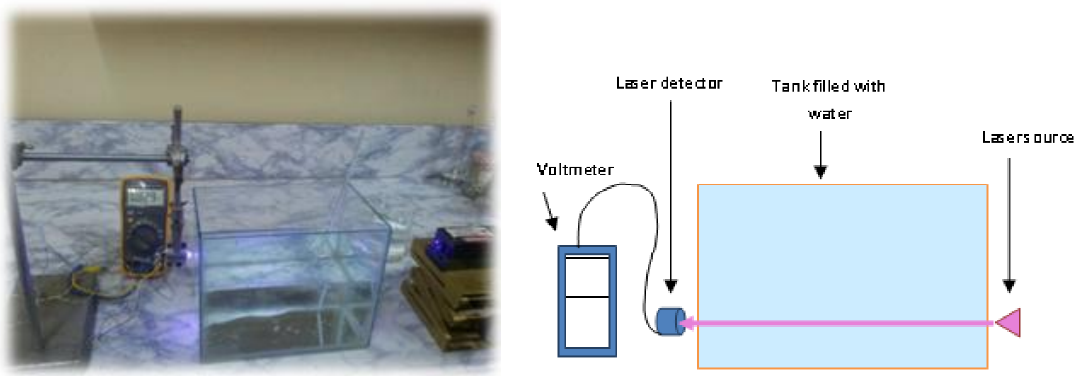


Figure (2)



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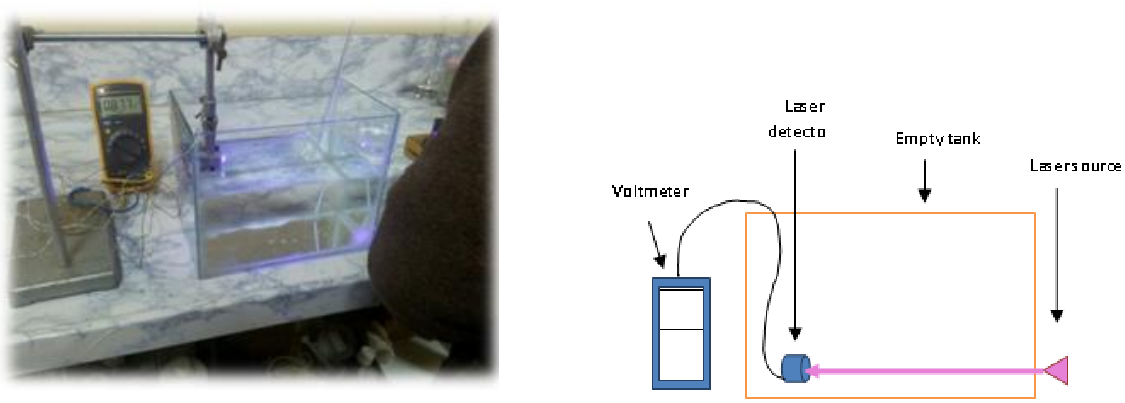

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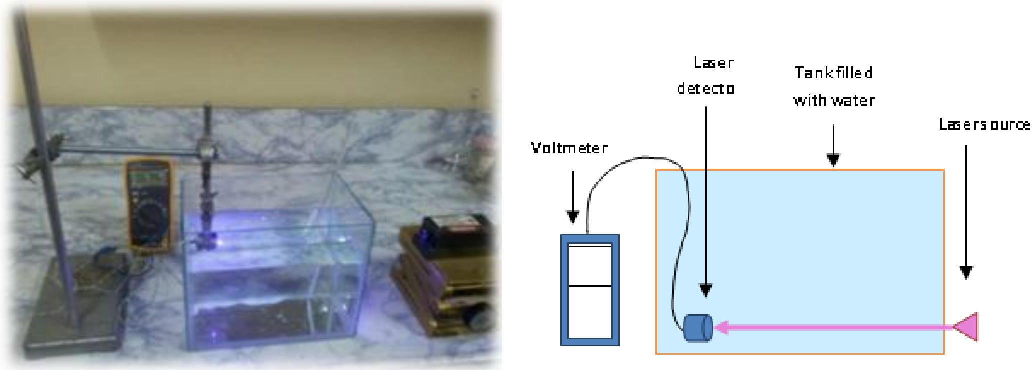

Figure (5)

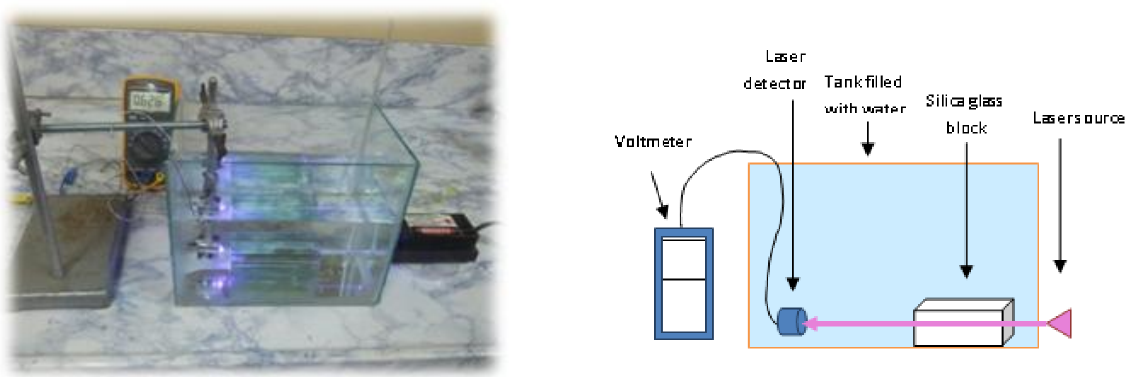

Figure (6)

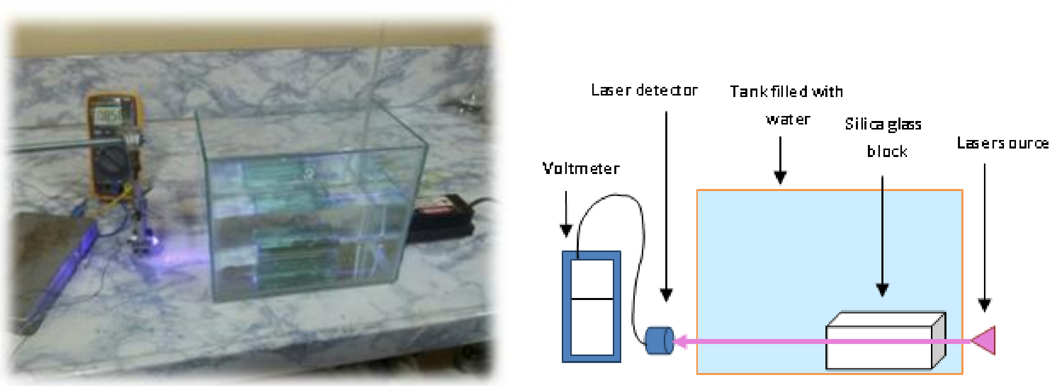

Figure (7)