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Study of the Optical and Physical Roles of a Dielectric Laser Dye Solvent Which Affects on the Dye Laser Operation

Riyad A.M. Ghazy
Laser Laboratory, Department of Physics,
Faculty of Sciences, Tanta University, Tanta, Egypt

Abstract: It is well known that when the pump laser beam incidence on the laser dye liquid it will be absorbed. This absorption tends to heat the laser active medium, which is the laser dye solution. In view of this the correlated property of that active medium well change tends to shift the operated frequency and wavelength. Therefore, one of most interested dielectric, nonpolar, laser dye solvent was selected for this investigation, which is Benzene. A laser interferometer known as Mach Zhender Interferometer (MZI) is constructed and used to measure the refractive index of the investigated solvent by counting the interfering fringes as a function of the angle of incidence of the incident laser beam. The temperature of that solvent is raised within the range 293-373 K by using a constructed heating system. The thermal behavior of the refractive index of Benzene is studied to estimate the thermo-optical coefficient of the refractive index, which is important to know the state convergence or divergence of the pump laser beam within the laser dye medium. Also, the dielectric constant of the dye solution is an important parameter for the laser operation. Therefore the dielectric constant and its thermal behavior of Benzene are calculated through the Maxwell's relation to determine the thermal coefficient of the dielectric constant. The value of the number density which is equal the specific polarizability of the investigated solvent is estimated by using the obtained values of the refractive index and its variation with the temperature is studied too. Because the dependence of the mean polarizability of the dielectric constant through the Clausius-Mossotti relation the values of both mean polarizability and its thermal behavior are studied. In addition, since the molecular polarizability depends on the mean polarizability the value of it is determined. By using the values of mean polarizability the molecule radius is determined and using the Clausius-Mossotti relation the actual volume occupied by all molecules per unit volume are estimated. The volume expansion, through Murphy and Albert equation is calculated.

Key words: Laser Interferometry, Laser Dyes, Dye Laser, Dye Solvent, Active Medium

INTRODUCTION

The heart of any dye laser is the laser dye. Either dissolved in an appropriate solvent or in its vapor phase these very often highly colored substances play the major role in the overall performance of any dye laser. Both pulsed and continuous operation is possible. In addition, their unique photophysical properties make them ideal candidates for the generation of ultra short light pulses. With moldy-looking pulses shorter than 100 femtoseconds have been obtained. Hyperfine tuning of the output has permitted many exciting experiments in spectroscopy.

Prepared laser dye solutions usually contain very small quantities of dye: Typical dye concentrations are 10^2 to 10^5 molars. For this reason the solvent in which dye is dissolved plays an important role when defining physical properties and potential hazards.

Lasing wavelength and energy are very sensitive to the choice of solvent. Most laser dyes are polar molecules and excitation into their low-lying singlet state is accompanied by an increase in the dipole moment. Accordingly, solvent polarity plays an important role in shifting the lasing wavelength. In a majority of circumstances, increasing solvent polarity will shift the gain curve toward longer wavelength. In the case of more polar dyes, the shift can be as high as 20-60 nm[1].

The solvent is an important component of the active medium. One must take the role of the solvent into account in the examination of the laser generation characteristics of the solution. Solvents are often organic compounds. They may be divided into polar and nonpolar types. Polar solvents have molecules whose electric charges are unequally distributed, leaving one end of each molecule more positive than the other. Nonpolar solvent, of which Benzene is an example, have molecules whose electric charges are equally distributed[2].

Benzene is a solvent with many applications, including paints, dyes, plastics and rubber and is regarded as one of the least environmentally hazardous of organic solvent. It is both highly effective and easily broken down in both air and water.

By interacting with the excited molecules in the dye, the solvent may both decrease and increase the generation energy and shift the generation in the long wavelength region. In addition, the solvent determines the thermo-optical properties of the solution and this affects the characteristics of the resonator.

Inevitably during the leasing process a certain amount of thermal energy is released, giving rise temperature gradients in the solution that may cause optical inhomogeneities. In this respect, the best media appear to be water and its deuterated relative, heavy water. Therefore the ideal laser dye should be soluble in water and still maintain its leasing properties, which generally means that it must not form dimmers at the leasing concentrations or that it responds readily to desegregating agents.

It is important to mention that the photochemical stability as a property relevant to laser dyes. Whereas this is about the lesser importance in dye lasers employing liquid solutions, the poor stability of many laser dyes is a serious problem in lasers where the dye is important in a solid matrix and therefore cannot be circulated.

For various applications of laser light in the UV there is an interest to search for better UV laser dyes. However, in the near UV spectral range under 400nm, the demand on the photochemical stability is high because the energy of the pumping laser light is on the order of the binding energy of covalent carbon-carbon and carbon-hetero atom bonds of the laser dye.

The most efficient source of coherent radiation in the UV range for dye laser pumping is the excimer laser operating on Xe Cl (308 nm) or Kr F (248nm) emission. In view of the photochemical stability of the laser dye, it is preferable to use the longest wavelength for dye laser pumping. This requires a proper matching of the wavelength of the single absorption maximum of the laser dye with the emission line of the pump laser.

The solvent on stability and the photo-product interaction. The presence of oxygen accelerates the photodegardation of the dye and the solvent of increasing polarity. The dye degraded more rapidly in solvent of low polarity and that low polarity had a dramatically different solvent. The Coumarin 120 with different solvents. The Coumarin 120 decomposition rate was about 10 times faster with cyclohexane solvent than with methanol.

As an example of the effect of the decomposition rates one can give a comparison between the decomposition rates for methanol, ethanol, isopropanol and cyclohexane showed that the decomposition rates increased in the same order as the dielectric constant for these solvents.

Optical interferometry uses interference between light waves to make extremely accurate measurements. The father of optical interferometry was undoubtedly Michelson who gave contributions to interferometry during the half century from 1880 to 1930 dominated the field to such an extent that optical interferometry was regarded for many years as virtually a closed chapter[3].

However, the last three decades have seen a major resurgence of interest in this field. This transformation has been largely due to several new developments. The most important development was the invention of the laser, which made available, for the first time, an intense source of light with a remarkably high degree of spatial and temporal coherence. Lasers have removed most of the limitations of interferometer imposed by thermal sources and have made possible many new techniques[3]. The observation of beats produced when the beams from two lasers were mixed at a photodetector led to the development of a range of heterodyne methods for fringe interpolation. Since measurements in the frequency domain can be made over a wide range with high precision, such techniques have greatly increased the accuracy and scope of optical interferometry.

In terms of current applications of optical interferometry include measurements of distances, displacements and vibrations, tests of optical components and systems, studies of surface structure, studies of fluid flows, measurements of temperature, pressure, electrical and magnetic fields, rotation sensing and high-resolution stellar imaging.

MATERIALS AND METHODS

Prior to the development of the laser, the only light sources available for interferometry were spectral lamps. Such sources only gave a crude approximation to coherent illumination and their intensity was quite low. Intense sources of light with almost perfect spatial coherence and a coherence length of several meters became available for the first time with lasers.

The light source that we used in the present paper for the laser interferometry is the Argon ion laser (Ar^+). The Argon ion laser is one of a class of noble-gas ion lasers that operate in the visible and ultraviolet spectral regions. The argon ion laser can provide approximately 25 visible wavelengths ranging from 275 to 363.8 nm. Wavelengths as short as 229 nm are also produced by intracavity frequency doubling of a visible argon ion laser[4].

The used Ar^+ laser is a multiline light the wavelengths 515, 502, 497, 488, 476 and 458 nm. In the present study, an air-cooled Argon Ion Laser (Uniphase Co. Product 2013 argon ion laser system consists of a model 2213 held incorporating a 2313 argon ion laser tube, powered by a 2113 power supply) is used.

The experimental arrangement of Mach Zehnder Interferometer (MZI), which is used to determine the refractive index of benzene as a non-polar solvent and its dependence with temperature, is explained in details in my literature[5].

RESULTS AND DISCUSSION

Earlier Studies[6-8] showed that the photo physical properties of many laser dyes are affected by the solvent polarity. Where the Stokes shifts $\Delta\nu=\nu_{abs.}-\nu_{em.}$, quantum yields and fluorescence lifetimes show more or less linear correlation with the solvent polarity function:

$$\Delta f=\{(\varepsilon-1)/(2\varepsilon+1)\}-\{(n^2-1)/(2n^2+1)\}$$

All these parameters are unusually lower in nonpolar solvents. Unlike in other solvents, both quantum yield and fluorescence lifetime in nonpolar solvents are also strongly temperature dependent.

Because Benzene is a non-polar molecules one can treat it as a dielectric medium inside the laser dye active medium. Therefore when we talk about the macroscopic and microscopic properties of benzene liquid we mean their molecular state. Of much interest the dielectric relations existing between the macroscopic parameters of dielectrics which are permittivity, ε, dielectric susceptibility k_e, refractive index n, density d and molecular mass W and the microscopic parameters, which means polarizability α, number of molecules in a unit volume N of a substance.

Refractive Index (n): The value of the refractive index of Benzene laser dye solvent is determined as a function of temperature T of the medium using the six different laser wavelengths. The refractive index n of Benzene laser dye solvent is measured by the method described by Ghazy[5]. It was noted that the values of n at the different temperature values are evaluated. From the temperature behavior of the refractive index of Benzene one can evaluate what is called the thermo-optical coefficient, dn/dT, of the Benzene laser dye solvent with the values given in Table 1 corresponding to each selected wavelength of the Ar^+ laser source.

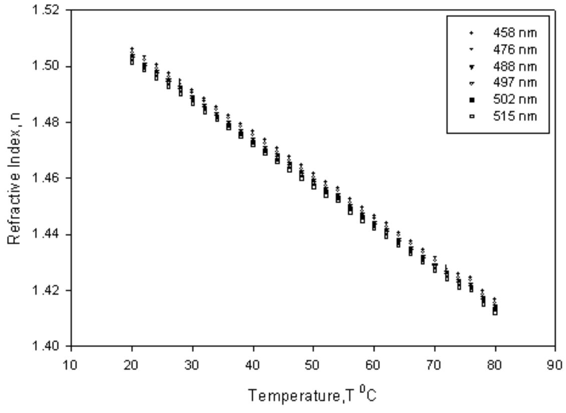

Fig. 1: Temperature Variation of the Refractive Index n (T) of Benzene Laser Dye Solvent

Figure 1 shows that the refractive index n obeys the desperation phenomena at constant temperature. From the Fig. 1 one can estimate the values of thermo-optical coefficient $(dn/dT)_\lambda$ for Benzene as given in Table 1 for each laser wavelength. From the Table 2 notes that dn/dT is a negative value which means that the laser dye solvents under investigation diverges the laser beam inside the cavity, i.e. Each of them are used as a diverging lens inside the laser cavity.

The knowledge of both n and dn/dT for Benzene are very important for their uses as an active medium for a dye laser. It is known that when the pump laser incidence upon the laser dye medium it will be completely absorbed by the medium which re-emits it as a fluorescence from which the dye laser beam comes out. As a result, the absorbed laser beam will heat of the active laser dye medium causing changing its density which tends to change its refractive index and the correlated parameters. Taking into account that any temperature fluctuation in the active medium of the laser dye causes a change in the length of the laser cavity L (mirror separation) tending to change both the laser wavelength λ by the fraction $\Delta\lambda$ which is given by $\Delta\lambda/\lambda=\Delta d/d+\Delta n/n$ and the laser frequency ν by the fraction $\Delta\nu$ which is given by $\Delta\nu/\nu=\Delta d/d+\Delta n/n$.

The refractive index variations can be noticed as a thermal lens effect, which has some astigmatism[9]. Therefore, this thermal lens effect is hard to compensate and reduces the maximum pump power.

Optical Permittivity ε and its thermal Coefficient TC_ε: Since the refractive index n of a matter is defined as the ratio of the velocity of the electromagnetic waves in vacuum, c, to the velocity of these waves in the medium, v, i.e. n= c/v. According to Maxwell's theory of the propagation of electromagnetic waves in a medium, the velocity of propagation is given by:

$$v=1/(\mu_0\mu_r\varepsilon_0\varepsilon)^{1/2}$$

Where:

μ_0	is the magnetic constant whose value is $4\pi x10^{-7}$ Hm^{-1};
μ_r	is the relative permeability of a medium, which equals unity for non-magnetic dielectric materials;
ε_0	is the permittivity of vacuum which equals $8.854x10^{-12}F/m$; and
ε	is the relative permittivity of the medium.

Therefore:

$$v=c/(\varepsilon)^{1/2} \text{ and } n=(\varepsilon)^{1/2}\text{, i.e.}$$

$$\varepsilon=n^2 \tag{1}$$

The term ε is known as dielectric constant related to the dielectric susceptibility through

$$\varepsilon=1+4\pi k_e \tag{2}$$

Table 1: Macroscopic and Microscopic Parameters of Benzene Laser Dye Solvents Determined by a MZI Method

Laser wavelength	$-dn/dT\times10^3$	$-d\varepsilon/dT\times10^3$	$-dk_{e/dT}\times10^4$	$-dg_{/dT}\times10^4$	$-d\rho_{/dT}\times10^3$	$dP_{M/dT}\times10^2$	$D\ d\alpha_{/dT}\times10^{26}$
λ_1: 458 nm	1. 4984	4.4032	3.5058	7.6371	3.0239	3.0322	1.2031
λ_2: 476 nm	1. 4954	4.3857	3.4190	7.6383	3.0296	3.0079	1.1934
λ_3: 488 nm	1. 4939	4.3799	3.4873	7.6386	3.0322	2.9991	1.1899
λ_4: 497 nm	1. 4934	4.3741	3.4826	7.6390	3.0348	2.9903	1.1865
λ_5: 502 nm	1. 4924	4.3685	3.4782	7.6393	3.0375	2.9819	1.1831
λ_6: 515 nm	1. 4904	4.3566	3.4687	7.6400	3.0427	2.9640	1.1760

Table 2: Some of Macroscopic and Microscopic Parameters of Benzene Laser Dye Solvents Determined by a MZI Method at 20°C and Different Wavelengths

Laser wavelength	n_{20}	$\tau \times 10^{11}$ Sec.	$\beta\times10^3$	$a\times10^8$ cm	R_{20} Ohms	$d\beta_{/dT}\times10^5$	$da_{/dT}\times10^{12}$	dR/dT
λ_1: 458 nm	1. 5140	21.3873	2.7637	2.1973	249.01	1.3135	8.1254	0.2618
λ_2: 476 nm	1. 5110	21.2969	2.7779	2.1942	249.51	1.3236	8.0837	0.2623
λ_3: 488 nm	1. 5100	21.2600	2.7814	2.1930	249.67	1.3270	8.0692	0.2625
λ_4: 497 nm	1. 5090	21.2271	2.7850	2.1918	249.84	1.3304	8.0547	0.2627
λ_5: 502 nm	1. 5080	21.1923	2.7884	2.1906	250.00	1.3337	8.0410	0.2628
λ_6: 515 nm	1. 5060	21.1198	2.7957	2.1881	250.34	1.3408	8.0109	0.2632

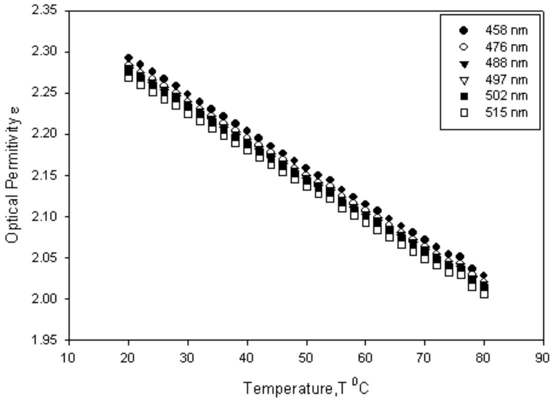

Fig. 2a: Temperature Behavior of the Optical Permitivity ε_λ (T) of Benzene Solvent at Constant Values of Laser Wavelength

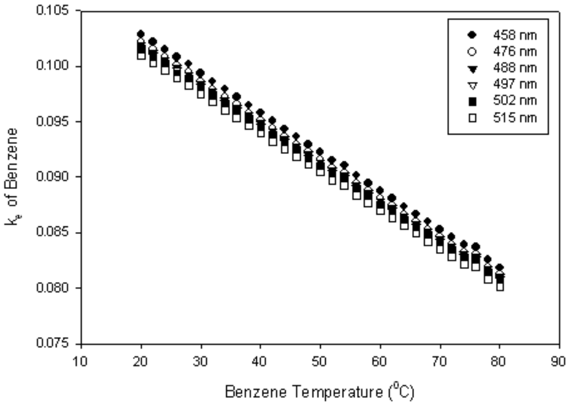

Fig. 2b: The Change of the Determined Dielectric Susceptibility with the Temperature k_λ (T) of Benzene

Physically the optical permittivity ε (dielectric constant) or, the dielectric susceptibility k_e, which is closely related to ε, is the basic parameter of a dielectric which describing the properties for the viewpoint of the process of its polarization or propagation of the electromagnetic waves in it, or more generally for the viewpoint of the processes of its interaction with an electric field. The term ε or ke reflects the properties of a given substance in a sufficiently large volume but not the properties of the separate atoms and molecules of that substance.

Figure 2 shows the temperature ranges between 293 and 353 K. It is noted that the relationship between ε and T is a decreasing relation, which tends to the negative slope of the curves with the values given in Table 1. This slope gives the value of the thermal coefficient of permitivity TC_ε corresponding to each value of laser wavelengths.

The permittivity ε and dielectric susceptibility k_e are basic parameters of a dielectric describing its properties from the viewpoint of the process of its polarization or propagation of electromagnetic waves in it, or more generally from the viewpoint of processes of its interaction with an electric field.

Attention should be paid to the fact that permittivity and dielectric susceptibility are macroscopic parameters of a dielectric which reflect the properties of a given substance in a sufficiently large volume but not the properties of the separate atoms and molecules in the substance.

Number density g or Specific Polarizability P_{sp}: When the behavior of the molecules is studied under the effect of electric and magnetic fields. There are two kinds of fields one is the effective electric or magnetic and the second is the observed electric or magnetic field obtained by averaging over a region which contains a great number of molecules. The difference between these two fields is due to the gaps between the molecules and depends on the number of molecules per unit volume, which is known as their number density.

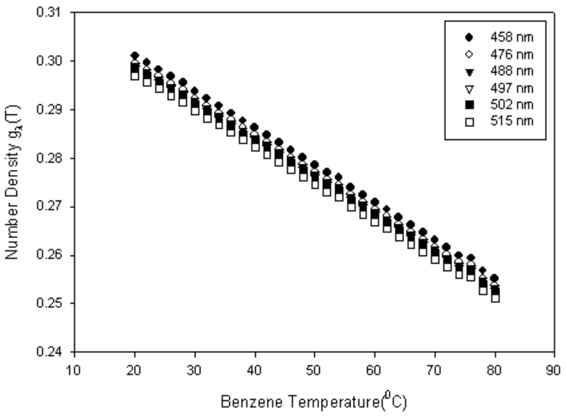

Fig. 3: Rate of Change of the Number Density g (T), Specific Polarizability P_{sp} with respect to T at Selected Wavelengths for Benzene

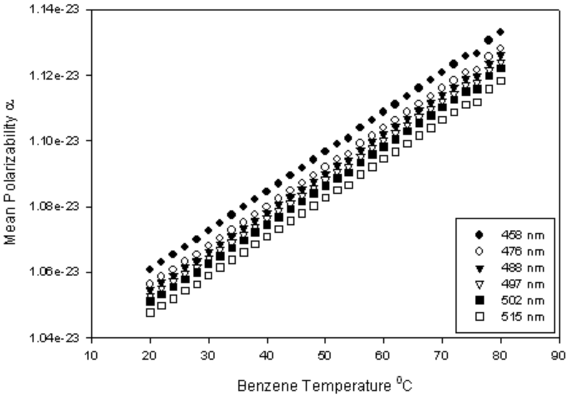

Fig. 4: The Dependence of the Mean Polarizability (α) on the Temperature (T) of the Benzene Laser Dye Solvent at Constant λ

Clausius[10] and Mossotti[11] tried to explain the dielectric properties of insulators on the assumption that the atoms (monatomic molecules) are small conducting spheres whose mutual distances are large compared to their diameters and derived the following expression for the number density g of the spheres in terms of the dielectric constant[12] which is also known the specific polarization of a dielectric. This is a dimensionless magnitude because ε is dimensionless:

$$P_{sp}= g(T) = \frac{\varepsilon(T)-1}{\varepsilon(T)+2} \qquad (3)$$

As mentioned above, the dielectric constant depends on the temperature; T. Therefore the number density g must depend on the same parameters. According to Eq.3 the values of g are calculated and plotted as a function of T, as shown in Fig. 3 from which the rate of change of g with respect to, dg/dT is calculated by the value in Table 1.

The mean polarizability α and Molar Polarizability P_{Mol}: It is known that the non-polar molecules have no permanent dipole moment in the absence of the field. For each molecule, the electric dipole moment established under the influence of the field is proportional to the effective field. We have assumed that the molecule under investigation is isotropic. But we are interested only in the average effect over all possible orientations of the molecule therefore it will not necessary to assume that each individual molecule is isotropic. Since the electric dipole moment has the dimensions equal to charge multiplied by the length therefore the mean polarizability is seen to have the dimensions of a volume. If N is the number of molecules per unit volume, we can get informations about the dependence of the mean polarizability α on both optical permittivity ε and N_m in case of Maxwell's relation $\varepsilon=n^2$ is used through the following relationship:

$$\alpha =(3/4\pi N_m)P_{Mol}= \{(\varepsilon-1)/(\varepsilon+2)\}(M/\rho)\ (3/4\pi N_m) \qquad (4)$$

where, N_m is the Avogadro's number that equals 6.02 x 10^{23}, i.e. The number of molecules in a mole.

This relation is known as the Clausius-Mossotti[10, 11], which is seen to be bridged, which connects Maxwell's phenomenological theory with the atomistic theory of matter. The values of the mean polarizability α of Benzene are calculated as a function of the refractive index n of different values of temperature T as shown in Fig. 4 and the rate of its variation dα/dT at each wavelength.

Instead of α we could use another quantity known as molar polarizability P_{Mol} which is known as the atomic refractivity in the case of monatomic molecules. This is essentially the total polarizability of a mole of the substance, defined as:

$$P_{Mol}= \{(\varepsilon-1)/(\varepsilon+2)\}(M/\rho) \qquad (5)$$

The molar polarizability P_{Mol} of Benzene is determined as a function of temperature at each laser wavelength as shown in Fig. 5 and its variable rate with temperature dP_{Mol}/dT is given in Table 1 at each corresponding wavelength. For the calculation of both α and P_{Mol}, the calculated values of the density of Benzene as a function of temperature are used.

Molecular Radius (a): If each molecule were to be regarded as a perfectly conducting sphere of radius a, the polarizability α would be given by[13]:

$$\alpha=a^3 \qquad (6)$$

Substituting the value of α in Clausius-Mossotti relation, one can find that the quantity $\frac{\varepsilon-1}{\varepsilon+2}$ is equal to the actual volume occupied by all the molecules per unit volume.

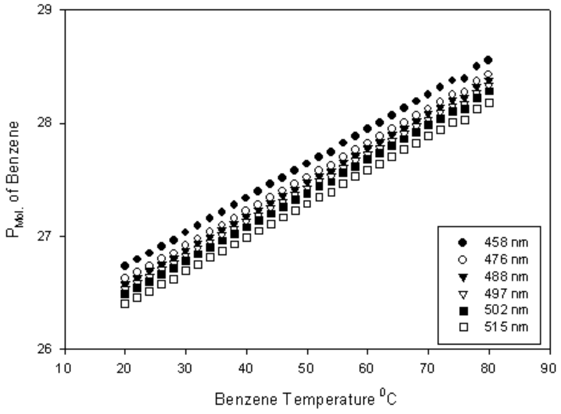

Fig. 5: The Change of the Estimated Molecular Polarizability (P_{Mol}) with the Temperature (T) of the Benzene Laser Dye Solvent

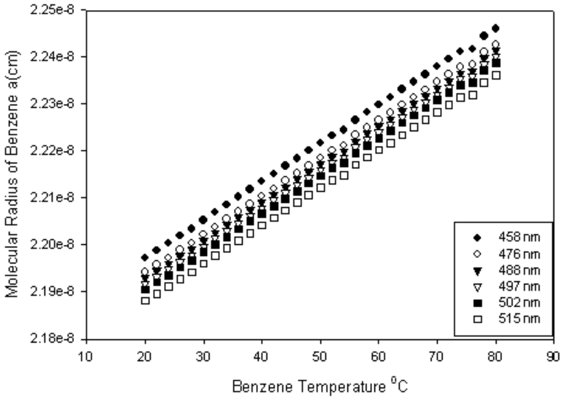

Fig. 6: The Calculated Molecular Radius (a) of Benzene Solvents and its Change with the Temperature (T)

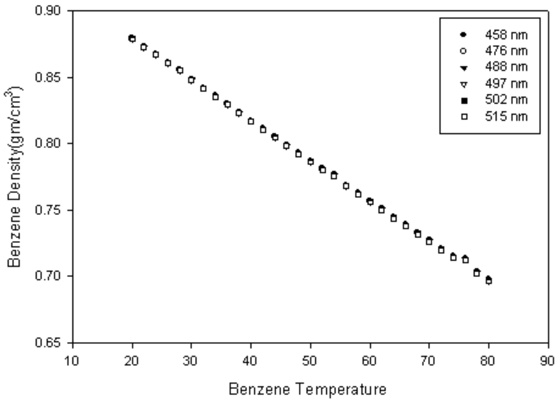

Fig. 7: The Behavior of the Determined Density ρ_λ (T) of Benzene at Constant Wavelength λ

The values of molecular volume calculated in this way and those obtained from the kinetic theory are found to agree within close limits.

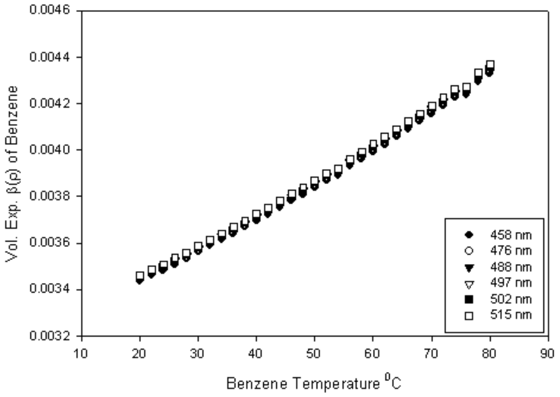

Fig. 8: The Change of the Calculated Values of the Volume Expansion (β) with the Temperature (T) of Benzene Laser Dye Solvent

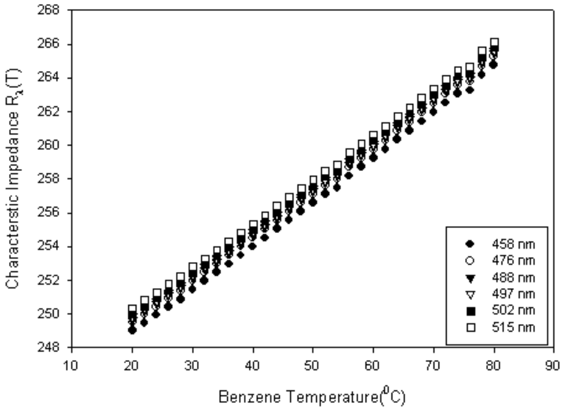

Fig. 9: Change of the Characteristic Impedance of Benzene Laser Dye Solvent with the Temperature

The obtained value of the molecular radius, a, of Benzene is plotted as a function of solvent's temperature at a constant laser wavelength. The rate of change of a with the temperature $(da/dT)_\lambda$ is calculated from Fig. 6 and is given in Table 2. The results show that the molecular radius of the Benzene becomes larger with increasing temperature. This means that the volumes of the molecules become larger which tends to the volume expansion of the laser dye solution during the dye circulation process.

Relaxation Time Effect τ: On the molecular scale one can look at the friction and viscosity of the dye solution. If molecular obstructions are taken into account, for pure liquids, the effect of friction is very different, the ellipsoids of revolution being pressed against each other, rotating about or oscillating along the major axis. The effects, although very small in the first case, are considerably in the second. In practice there will be as many viscosity effects as there are modes of oscillation[12, 14].

Table 3: The Evaluated Values of $dn/d\lambda$, $dA/d\lambda$ and $dB/d\lambda$ at Constant Temperature of Benzene as a Laser Dye Solvent

Temp. (°C)	$(-dn/d\lambda)\times10^4$	$(-dA/d\lambda)\times10^4$	$dB/d\lambda$
20	1.34520	2.0160	45.9331
50	1.30729	3.9081	46.3541
80	1.26659	2.7800	44.9110

Table 4: The Evaluated Values of dA/dT and dB/dT at Constant Wavelength of Benzene as a Laser Dye Solvent

Wavelength (nm)	$(-dA/dT)\times10^3$	$-(dB/dT)$
458	1.3333	6.2935
488	1.4150	7.6130
515	1.4133	8.978

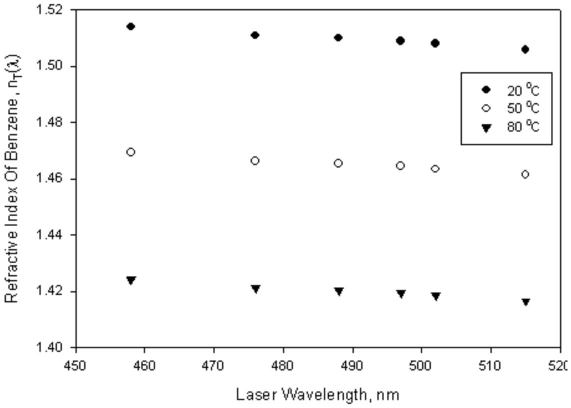

Fig. 10: The Dispersion Behavior of the Refractive Index of Benzene Laser Dye Solvent at Constant Temperature 20, 50 and 80°C

Under these conditions it is evident that the term η which in the expression for τ is related to the molecular viscosity and molecular radius[13, 15]:

$$\tau = 4\pi\, \eta\, a^3/kT \qquad (7)$$

Cannot be calculated from a macroscopic measurement of viscosity (rate of outflow a capacity or viscosity of fall of a sphere).

Where:
A: is the molecular radius;
K: Boltzmann’s constant; and
T: absolute temperature.

By knowing the values of both η and at the ambient the values of τ are calculated and given in Table 2.

Effect of Density Fluctuations ρ: The emission line width of CW single-mode dye laser is broadened by fluctuations of the optical path length of the laser cavity. The fluctuations are caused mainly by the density and thickness fluctuations of the dye jet and buy some insignificant mechanical instabilities of the laser cavity.

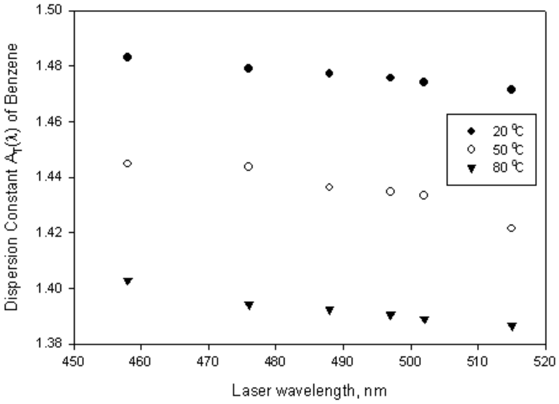

Fig. 11a: Wavelength Dependence of Benzene’s Dispersion Constant A_T (λ) at Constant Temperature Values

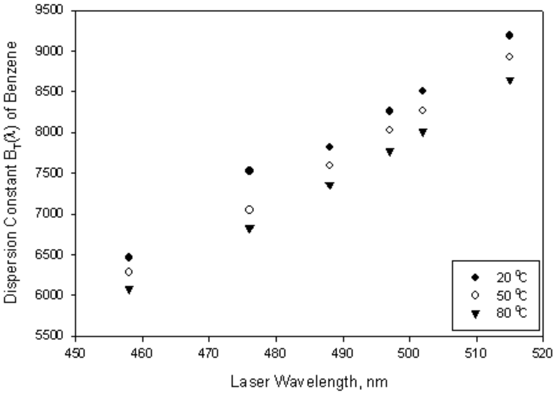

Fig. 11b: Wavelength Dependence of Benzene’s Dispersion Constant B_T (λ) at Constant Temperature Values

The density and thickness fluctuations are created by the thermal fluctuations of the dye solution, power fluctuations of the pump laser, pressure fluctuations and surface waves of the dye jet.

Of the statistical effects, which influence the line width, three have been considered[16] spontaneous emission or phase diffusion, Brownian motion of the resonator and statistical fluctuations in the density of the active medium. Only the last of these is large enough to be important in practical systems.

The density fluctuations due to temperature change in benzene laser dye solvent is estimated by the aid of Clausius-Mossotti relation from which:

$$d\varepsilon/d\rho = (\varepsilon-1)(\varepsilon+2)/3\rho \qquad (8)$$

By substituting with ρ at 20°C and ε at each wavelength at the same temperature the value of $d\varepsilon/d\rho$ is determined. Consequently the values of ρ as a function of the solvent’s temperature are calculated and plotted as shown in Fig. 7 at each selected wavelength

λ. From the figure the $(d\rho/DT)_{\lambda}$ values are estimated and tabulated in Table 1 showing a decrease behavior of Benzene laser dye solvent. These determined values of ρ (T) are used to calculate the values of both polarizability α and P_{Mol}.

Volume Expansion Coefficient β: As it's shown from the molecular radius determination and its thermal increase which must tend to the increase of the molecular volume. Therefore the volume expansion of the Benzene laser dye solvent must be studied. By knowing the values of the thermal coefficient of the optical permitivity, TCε, of Benzene the volume expansion of the solvent can be determined by using an expression[17] given by:

$$\beta=-\{(2\varepsilon+1)/3\varepsilon(\varepsilon-1)\}(d\varepsilon/dT) \qquad (9)$$

Where:
$d\varepsilon/dT$ is the thermal coefficient optical permitivity of the solvents;
ε is the optical permitivity; and
β is the volume expansion coefficient.

The thermal behavior of β is shown in Fig. 8 showing an increase in the temperature corresponding to each selected wavelength. The rate of thermal change of β, $(d\beta/DT)_{\lambda}$, is given in Table 2 for Benzene.

Characteristic Impedance R: Because its known that when a plane electromagnetic wave moving without dying out in Eyhylacetate as a dielectric material in a selected direction may be X, Y, or Z-axis. Here the vectors of the intensity of both electric and magnetic fields E and H, respectively, are mutually perpendicular to each other in such that the ratio of their moduli E/H stay constant with the dimension of resistance known as the characteristic impedance R_0 of matter. This characteristic impedance R_0 of a dielectric is related to it permitivity ε and permeability μ through the equation[13]:

$$R_0=(\mu\mu_0/\varepsilon\varepsilon_0)^{1/2} \qquad (10)$$

In case of vacuum $\varepsilon=1$ and $\mu=1$ so that $R_0=(\mu_0/\varepsilon_0)^{1/2}=377$ Ohms therefore the Benzene solvents which is a dielectric nonmagnetic material has the characteristic impedance R given as:

$$R=377/n \qquad (11)$$

where, n is the refractive index. Consequently by using the measured values of the refractive index of Benzene laser dye solvent at different temperatures and constant wavelength n_{λ} (T) the values of its R as a function of T and constant laser wavelength R_{λ} (T) is determined as shown in Fig. 9 and its rate of change $(Dr/DT)_{\lambda}$ is given in Table 2.

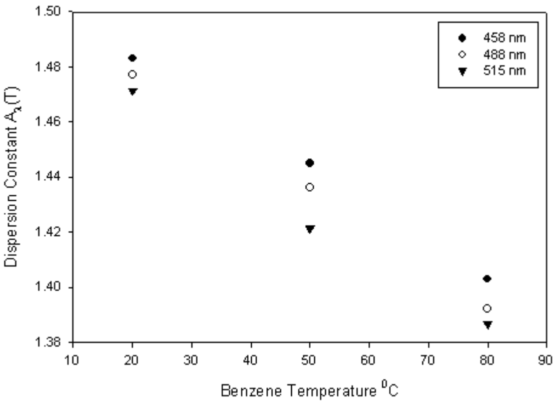

Fig. 12a: Temperature Behavior of the Dispersion Constant A_{λ} (T) of Benzene at Constant Wavelength

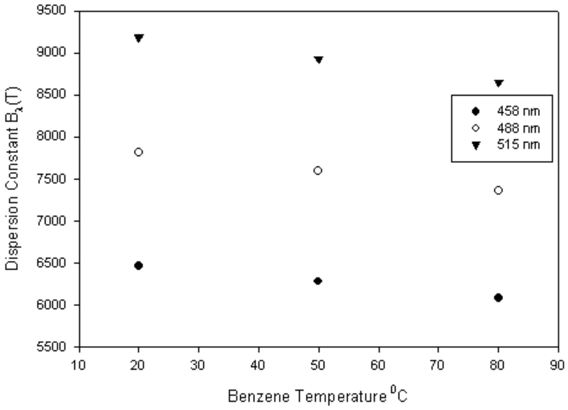

Fig. 12b: Temperature Behavior of the Dispersion Constant B_{λ} (T) of Benzene at Constant Wavelength

Wavelength Effect: It is known that the relationship between the refractive index n the wavelength λ of the incident laser beam through what is called the Cauchy's equation[12]:

$$n(\lambda)=A+B/\lambda^2 \qquad (12)$$

Practically, the refractive index of Benzene solvent was measured at each selected wavelength λ at constant temperature 20, 50 and 80°C. This relation was shown graphically in Fig. 10 from which $(dn/d\lambda)_T$ was evaluated as given in Table 3. By differentiating Eq.12 with respect to λ we got

$$(dn/d\lambda)_T=-2B_T/\lambda^3 \qquad (13)$$

By substituting with the values of $(dn/d\lambda)_T$ in Eq.13 the value of dispersion constant $B_T(\lambda)$ corresponding to each λ at constant temperature T were calculated. By using the calculated values of $B_T(\lambda)$ in Eq. 12 and the corresponding values of $n_T(\lambda)$ the values of the dispersion constant $A_T(\lambda)$ were calculated. The dispersion behavior of both $A_T (\lambda)$ and $B_T (\lambda)$ is studied during the Fig. 11a and b from which $(DA (\lambda) /d\lambda)_T$ and $(dB (\lambda) /d\lambda)_T$ were estimated as given in Table 3. From Fig. 11a and b the values of $A_\lambda (T)$ and $B_\lambda (T)$ were evaluated and plotted in Fig. 12a and b from which the rate of change of both $A_\lambda(T)$ and $B_\lambda(T)$ with respect to temperature were estimated as, $(dA(T)/dT)_\lambda$ and $(dB(T)/dT)_\lambda$, given in Table 4.

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