DOI: 10.24996/ijs.2019.S.I.11

ISSN: 0067-2904

Spectral and Linear Optical Characterization of Rhodamine B and Fluorescein Sodium Organic Laser Dyes Mixture Solutions

Noor Al-Huda Al-Aaraji[1], Abdulazeez O. Mousa[2], Ban A. Naser[3]
Physics Department, College of Science, University of Babylon, Babylon,

Abstract
Spectral and linear optical properties for a mixture of Rhodamine B (RB) and Fluorescein Sodium (Na Fl) organic laser dyes were determined at different concentrations 10^{-3}, 10^{-4} M in ethanol solvent at room temperature. The intensity of absorption range is towards longer wavelengths (red shift). The quantum efficiency diminished while the radiative and fluorescence life time increased when increment concentration, organic laser dyes have a spectrum within the range 540-500 nm. Results demonstrate that a mixture of laser dyes are effective optical materials when contrasted with individual laser dyes. It can be utilized as resonator in cavity lasers.

Keywords: Organic laser dye, linear optical characteristics.

الخصائص البصرية الطيفية والخطية لمحاليل خليط صبغات وفلورسين الصوديوم B الرودامين

نور الهدى طالب، عبد العزيز عبيد، بان علي
قسم الفيزياء، كلية العلوم، جامعة بابل، بابل، العراق

الخلاصة
تم تحديد الخصائص البصرية الطيفية والخطية لخليط الصبغات العضوية الليزرية للرودامين B وفلوريسين الصوديوم بتراكيز مختلفة 10^{-3},10^{-4} مولاري في مذيب الايثانول عند درجه حرارة الغرفة. يزاح نطاق شدة الامتصاصية باتجاه الاطوال الموجية الطويلة (ازاحة حمراء) وتقل الكفاءة الكمية بينما يزداد زمن ا لعمرعند زيادة التركيزللمذيب, الصبغات الليزرية العضوية سجلت طيف ضمن المدى 800−250 نانومتر. تظهر النتائج ان خليط الصبغات الليزرية هي مواد بصرية فعالة عند المقارنة مع الصبغات الليزرية المنفردة وبالتالي يمكن استخدامها كأوساط ليزرية فعالة.

Introduction

Laser dyes are perplexing molecules containing various ring structures, which lead to complex absorption and emission spectra. Itcan be sorted into various classes by virtue of their structures that are chemically comparative. Basic examples are the coumarin, xanthenes and pyrromethene. The structure and arrangement of the molecules has an imperative impact on spectral emission [1].

In order to achieve better laser performance such as higher lasing efficiency, wider wavelength tunibility and simultaneous multi-color generation; laser dyes must be mixed by varying donor/acceptor concentration via fluorescence resonance energy transfer (FRET) from the excited donor molecule (D) to the acceptor molecule (A). FRET provides structural information of a complex medium. It has wide applications in the field of physics, chemistry and biology [2]. Energy transfer

*Email: abcabc111.nn@gmail.com

between molecules is a core phenomenon in photosynthesis and an enabling technology for photovoltaic, organic lighting sources or bio sensing [3].

Electronic energy transfer in a dye mixture is set up as an extra effective instrument to broaden the wavelength of lasing and tunability in an energy transfer dye laser (ETDL). Saito et al. discussed improvement or decline in the laser energy output for such dye laser [4]. energy transfer mechanisms are given by Stcrn-Volmer plots as given by the equations. .

$$\frac{I_{od}}{I_d} = 1 + K\ \tau_{od}\ [A] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$\frac{\emptyset_{od}}{\emptyset_d} = 1 + K_{nr}\ \tau_{od}\ [A] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

I_{od} I_d

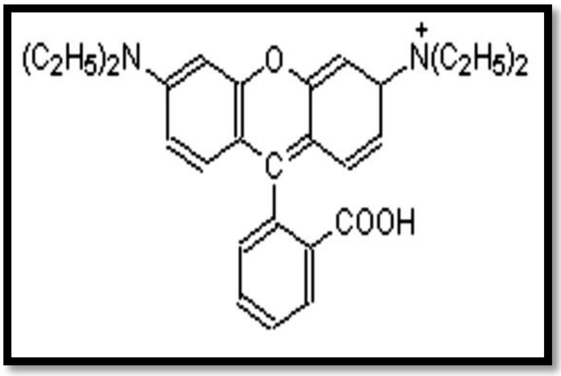
Where I_{od} and I_d are the f1uorescence intensities of the donor in the absence and presence of acceptor, respectivey $\emptyset_{od}$ and $\emptyset_d$ are the corresponding quantum yields. τ_{od} is the fluorescence lifetime of the donor without acceptor and [2] is the acceptor concentration.

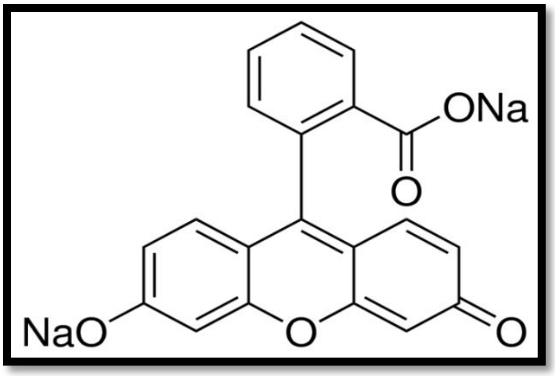
K and K_{nr} are total and nonradiative transfer rate constants, respectively. According to the Forster Dexter theory, the critical radius for resonant energy transfer between the donor and acceptor molecules are The nonlinear optical and spectral properties for a mixture of C480 and R6G laser dyes are obtained by recording their absorption and fluorescence spectra. The absorption and fluorescence spectra of C334 and R6G in ethanol solvent at different concentrations of 10^{-3}, 10^{-4} M were recorded. The absorption intensity of these dyes increases as the concentration increases in addition the spectra shifted towards longer wavelengths (red shift) [5, 6].

The objective of this work is to study the spectral and linear optical characteristics for the mixture solutions of RB and Na Fl organic laser dyes of different concentrations 10^{-3}, 10^{-4} M in ethanol solvent.

Materials and Chemicals

The organic dye RB(Loba Chemie, Mumbai, India), belonging to methyl family, is an important histological and bacterial stain and is used for coloring textiles and leather. Its scientific name is (Tetraethylrodamine) with molecular formula ($C_{28}H_{31}N_2O_3Cl$ [7] d NaFl is an organic laser dye , it has the chemical formula $C_{20}H_{10}Na_2O_5$, of molecular weight 376.27 [8]. As shown in Figure-1.





(a) **(b)**

Figure 1- a- Molecular Structure of RB dye Molecule. b- Molecular Structure of Na Fl dye Molecule.

Experimental work

The linear absorption coefficient ($\alpha_\circ$) was determined by the following formula [9]:

$$\alpha_\circ = \frac{\ln(\frac{1}{T})}{t} \quad \ldots\ldots\ldots\ldots\ldots.. (3)$$

Where t is the thickness of the sample, T is its transmittance, n its refractive index. Can be found from transmittance spectrum of the film according to the following formula [10]:

$$n_{\circ} = \frac{1}{T} + \left[\left(\frac{1}{T} - 1\right)\right]^{1/2} \qquad \text{……… (4)}$$

Transmittance is the relative percent of light that passes through the solvent. Thus, if half the light is transmitted, it can be said that the solution has 50% transmittance [10].

$$T\% = \left(\frac{I}{I_{\circ}}\right) \times 100\% \qquad \text{………… (5)}$$

where $I_{\circ}$ is the intensity of the incident light beam, I is the intensity of the light. coming out of the solvent. The relationship between transmittance T and absorbance A is expressed by the following equation [10]:

$$A = \log_{10}\left(\frac{1}{T}\right) \qquad \text{………… (6)}$$

Through the results of fluorescence spectra , fluorescence lifetime F and fluorescence quantum yield Φ_F can be calculated, using the following Formula [10]:

$$\tau_F = \frac{a \times \tau_{fRB}}{\mathbf{a}_{RB}} \qquad \text{…......(7)}$$

where τ_{fRB} is the fluorescence lifetime of laser organic dye, $\mathbf{a}_{RB}$ represents the area under the curve of the laser organic dye fluorescence [10].

$$Q_r = \frac{\int F(v')dv}{\int \varepsilon(v')dv'} \qquad \text{... ... ... (8)}$$

where ∫F(v')dv' is the area under the curve, ∫ε(v')dv' the area under the absorption curve .

Results and Discussion

Two well-known groups of laser dyes RB as a donor and fluorescein sodium as an acceptor were used .. These two laser dyes were dissolved in ethanol solvent (spectroscopy grade) at different concentrations. The analytic concentrations of the five solutions examined were 10^{-3}, 10^{-4} M. A 1:1 (v/v) pair donor and acceptor solution was mixed to produce three series. At each series, there is a single donor concentration with three concentrations of the acceptor. Absorbance spectra as well as the absorbance, transmittance, absorbance index and refractive index spectrum were measured and plotted for the mixture solutions of RB and NaFl. The fluorescence lifetime and quantum yield were also calculated. These have been determined for the mixture dye solution of different concentrations The effect of concentration was studied on all the properties under study at max wavelengths 540-500 nm as shown in Figure-2.

The Absorption Spectra

The absorbance spectra for pure and mixed dyes dissolved in absolute ethanol at concentrations (10^{-3}, 10^{-4})M were recorded and compared Figure-2. The figure shows that both spectra have two bands, one in UV region which is called B-band at the range of about 300-350 nm which is attributed to the electron transitions from the (HOMO) a2u to the (LUMO) eg, The other band is in the visible region which is called Q-band at the range of about (477-578) nm arising from the electron transitions from the highest occupied molecular orbital(homo) a1u to the lowest unoccupied molecular orbital (LUMO) eg . In the Q-band the high- energy peak is related to the electronic transition from π to π^* orbitals in the mixture of the organic dyes. The increasing of concentration causes increase in absorbance, linear absorbance index and refractive index as well as a decrease in transmittance, it is a good agreement with Beer- Lambert law.

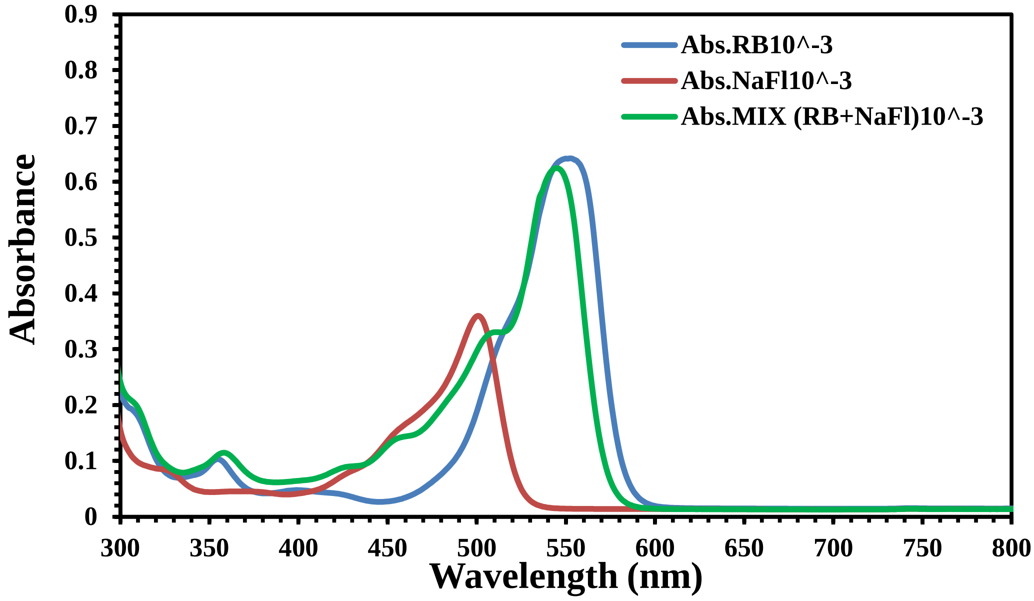


Figure 2-The absorbance spectra for the pure and mixed dyes.

The fluorescence Spectra

In order to get energy transfer from the donor molecule to the acceptor molecule, spectral overlap between fluorescence spectra of the dye donor molecule with the absorption spectra of the RB dye acceptor molecule must occur. The efficiency of energy transfer depends on the amount of spectra overlap. Figure-3 shows that the overlap between the two spectra is very good. This overlap shows that the transfer of energy between these spectra happens with high efficiency.

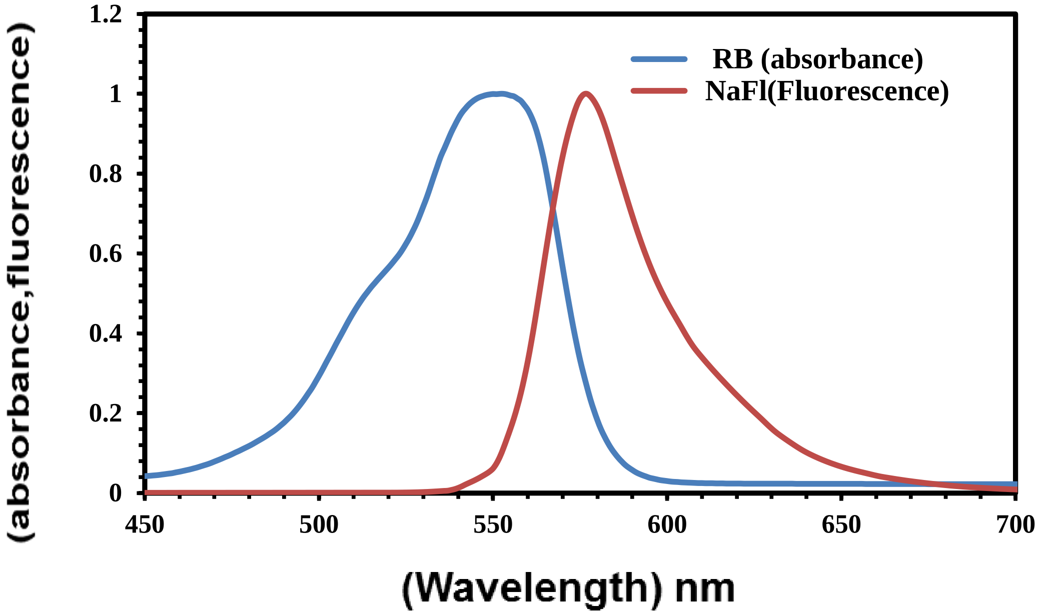


Figure 3-Spectral overlapping between absorbance spectra of RB and fluorescence of NaFl

Figure-4 shows the fluorescence spectra of the pure dyes and the mixture. The high fluorescence of the NaFl dye is very prominent. The low fluorescence of the mixture which is caused by the translation of energy between donor and acceptor after the physical mixing of the dyes.The minor changes occur in the flat region in the range 670-900nm.

. The quantum efficiency decreased, while the radiative lifetime increased with increasing the concentration, as shown in Table-1.

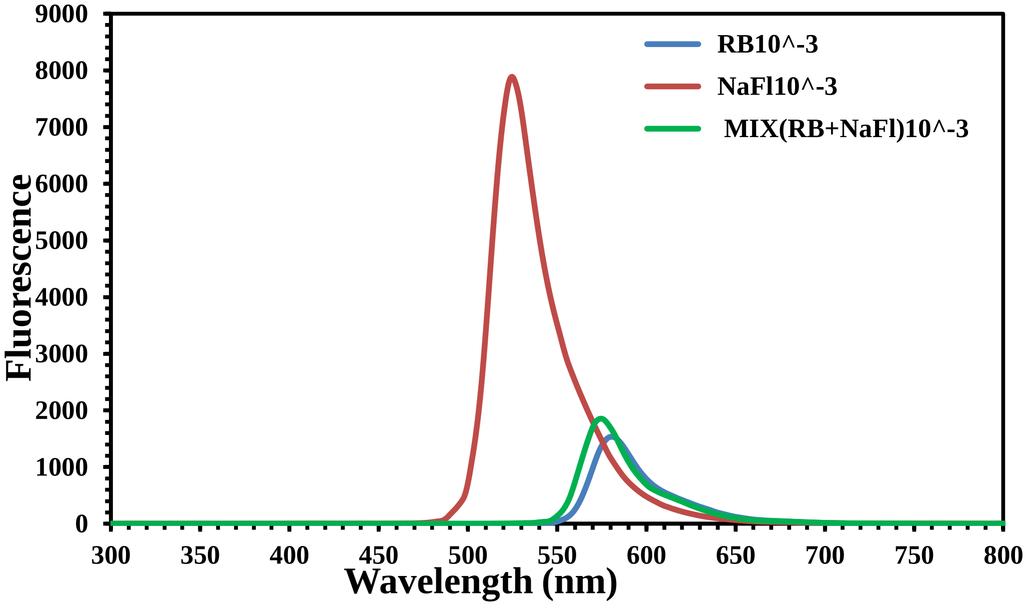


Figure 4-Florescence as a function of wavelength for pure and mixed dyes dissolved in ethanol at a concentration of 10^{-3} M.

Table 1-Values of linear and fluorescence optical properties for pure and mixture dye at different concentrations

Materials	Concentration	λ_{Max} (nm)	Absorbance	Transmittance	$\alpha_{\circ}$ cm^{-1}	$n_{\circ}$	$\tau_{ns\times10^{-3}}$	Q_r %
Rhodamine B (RB)	10^{-3} M	552	0.6015	0.25026	1.38525	1.7567	5.14	63
	10^{-4} M	545	0.179	0.662167	0.41223	1.8266	5.11	65
Fluorescein Sodium (NaFl)	10^{-3} M	501	0.359	0.437457	0.8267	1.085	4.60	66
	10^{-4} M	495	0.0525	0.886116	0.1209	1.073	3.66	68
MIX RB and Na Fl	10^{-3} M	545	0.61	0.245409	1.4048	2.2266	5.43	64
	10^{-4} M	545	0.1555	0.698992	0.3581	2.2330	4.98	67

Conclusions

It is concluded from this studythat the absorption spectra of both dyehas increased with increasing the concentrations As it can be seen that the fluorescence spectra also increased with increasing concentrations. Was obtained at the highest intensity of fluorescence spectra at concentration (10^{-3} M)for both dyes. The transfer of energy from the donor dye to the acceptor dye when mix more efficiently. The quantum efficiency diminished while the radiative life time and the fluorescence life time increased when increment concentration. Results show that mixture of laser dyes are effective optical materials as compared to individual laser dyes, it can be used as active laser medium .

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