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FLUORESCENCE STUDY ON THE INTERMOLECULAR ENERGY TRANSFER OF DYE MIXTURE C440/C540/SAFRANIN-T

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The fluorescence spectra and lifetimes of the ternary dye mixture C440/C540/safranin-T were studied. Experimental results indicated that there are efficient energy transfer among these 3 components of the dye system. Consequently, this system may be expected to be a potential candidate of laser dye giving out output in extended wavelength region. From the relation of the measured donor fluorescence lifetime as a function of the acceptor concentration, the mechanism responsible for energy transfer in this system was suggested.

1. INTRODUCTION

The output of the nitrogen laser has been shown to be a convenient pump for a wide variety of dye lasers. However, some dyes are difficult or even impossible to pump above threshold with the nitrogen laser because their absorption coefficient at 337.1 nm is too low.

The energy transfer induced in a proper mixture of dyes by a suitable pumping laser is now established as an effective mechanism of improving the conversion efficiency and extending the wavelength region of lasing. The present work was done in this direction by studying the excitation transfer process of the ternary dye mixture of coumarin 440(C440), coumarin 540(C540) and safranin-T.

2. SPECTRAL INVESTIGATION

From the data and tuning curves for nitrogen pumped dyes it is known that C440 is a powerful laser dye, while C540 is not included in the list for laser dyes to be pumped by N_2 laser. It has also been pointed out that attempts made to lase safranin-T using nitrogen laser without a donor were unsuccessful[1].

An efficient energy transfer process occurs in a dye mixture system when the wavelength region of emission of the donor overlaps the absorption of the acceptor. After examining the spectral properties of C440, C540 and safranin-T, we expected that a mixture of these three dyes might constitute a ternary energy transfer system. C440 can be effectively excited by the 337.1 nm radiation of nitrogen laser and its fluorescence region matches the absorption region of C540 excellently; while the fluorescence band of the latter, in turn, overlaps that of safranin-T sufficiently. (Figure1)

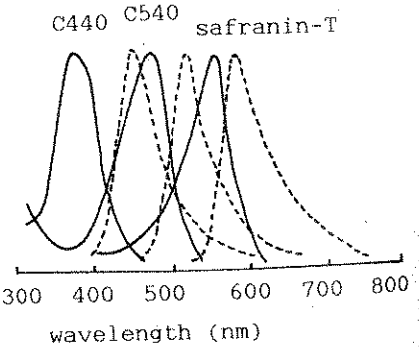

FIGURE 1

Absorption spectra (solid line) and fluorescence spectra (dashed line) of C440, C540 and safranin-T in ethanol

In addition, the quantum yield of C440, C540 and safranin-T are reasonably high, being 0.45, 0.89 and 0.31 respectively.

Our experiments have fully confirmed the above prediction. Fig. 2 shows the fluorescence spectrum of a ternary dye system at the particular concentrations of C440 (0.66×10^{-4}M) C540 (1.1×10^{-4}M) and sasfranin-T (0.58×10^{-4}M) with all three components emitting with comparable intensities.

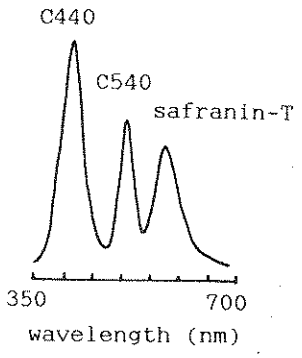

FIGURE 2
Fluorescence spectrum of the dye system

3. LIFETIME INVESTIGATION

It has been pointed out that by measuring the donor fluorescence lifetime as a function of acceptor concentration, distinction can be made between the radiative transfer and resonance transfer mechanisms for the intermolecular singlet-singlet electronic energy transfer in donor-acceptor pairs[2], because the radiative transfer does not affect the donor fluorescence lifetime, while the resonance transfer takes place before the excited donor emits, shortening the lifetime of the donor.

The lifetime values measured on a time-correlated single photon counting spectrofluorometer for the C440/C540 binary system and C440/C540/safranin-T ternary system are listed in Table 1.

Table 1
Lifetimes of dye components in mixtures

Concentration($\times10^{-4}$M)			Lifetime (nsec)		
C440	C540	Safranin-T	C440	C540	Safranin-T
1.3	0.4		4.05	4.93	
1.3	0.9		4.12	4.74	
1.3	1.4		4.03	4.66	
1.3			3.92		
3.5	3.0	0.5		4.77	5.77
3.5	3.0	1.0			5.51
3.5	3.0	2.0			5.28
3.5	3.0	3.0			5.06
3.5	3.0	4.0			5.00

It should be pointed out that the counting rate at the emission wavelength of the donor decreases with increasing acceptor concentration, making the measurement of donor lifetime not practical when the donor and the acceptor have comparable concentrations.

Lifetime results indicate that at 10^{-4}M concaentration, the dominant mechanism responsible for the efficient excitation transfer is that of radiative transfer.

Our experiments have demonstrated the efficient cascading of excitation energy from the excited C440 molecule to unexcited safranin-T through the bridging species C540. There is a possibility of achieving simultaneous laser action from this dye mixture.

REFERENCES

1. P.J. Sebastian and K. Sathianandan, Opt. Commun., 32 (1980) 422.
2. Chin-Lon Lin and A. Dienes, J. Appl. Phys., 44 (1973) 5050.