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CHARACTERISTICS OF DYE LASERS IN AN IR SPECTRUM REGION

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Abstract

Spectral characteristics and conversion efficiency of 6 organic fluorescent dyes and the influence of solvents used (aceton, dimethylsulfoxide and ethylenglycol)are reported.

The conversion efficiency was found to depend strongly on the type of solvent; it is maximal for the case of 1:1 mixture of DMSO and ethylenglycol (over 60%). The spectral characteristics are just weakly dependent on the particular solvent used, but sufficient for the spectral tuning of IR dye lasers.

I. Introduction

The first report on possibilities of stimulated emission from the solutions of organic fluorescent dyes in IR part of the spectrum was given by Schäfer et al. in 1966.[1] The dyes were pumped by ruby laser[1,2] and later on also by fast flashlamps[3,4]. Hilderbrand[5] reported the nitrogen laser excitation of polymethine dyes from which he obtained the laser emission in the region from 760 to 950 nm.

In the atomic physics and spectroscopy the lasers that emit in the near IR are of special interest. In this experiment we have investigated the basic characteristics of IR dye lasers, and possibilities of spectral tuning.

II. Apparatus

The Q- switched ruby laser radiation was used as the excitation source for the solutions of six different dyes in three different solvents: acetone, dimethylsulfoxide (DMSO), and ethylenglycol. Its pulse energy ranged from 0.5 to 1.0 J, pulse length being about 20 ns. The block scheme of the apparatus on which the experiment was performed is shown in Fig. 1.

A cuvette with dye was placed in the resonator consisting of two mirrors with the reflectivity of 100% and 90%. He-Ne laser was used for optical aligment of the system, and a ruby laser for dye pumping in the direction normal to the resonator axis. The energy of the pumping source was recorded by the calibrated monitor, while the IR emission was detected and measured by means of a radiometer, with sensitivity of 1 mJ per division. Part of the dye laser radiation was directed towards spectrograph by a beam splitter where it was registrated on the photoplate.

Before recording of spectra , the optimum working conditions of a dye solution used were investigated i.e. the concentration at which the highest degree of energy conversion was obtained. Because of the poor photochemical stability of the pure ethylenglycol solution, we used 1:1 mixture of DMSO and ethylenglycole.

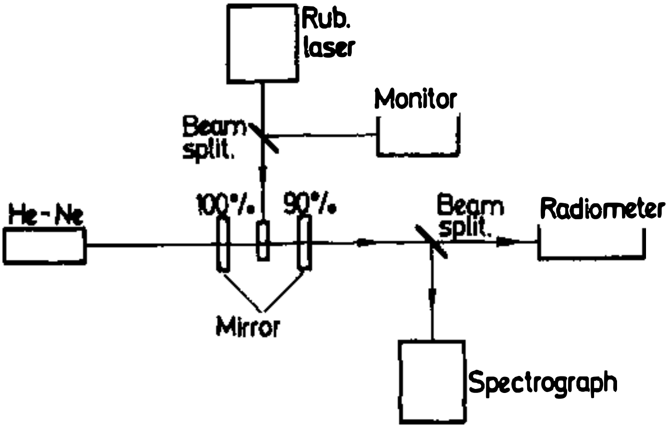

Fig. 1. Block scheme of a dye laser.

III. Experimental results

Concerning the optimum dye concentration it was found that the maximum efficiencywas achieved at the exact value of molarity regardless of the solvent. It suggested that the solvent does not affect the absorption spectrum of a given dye. This was later proved by the spectrophotometer results. Table I shows positions of absorption bandy maxima for the investigated dyes in each of the solvents used. Besides that, the table also containes the data of the working efficiency of a dye solvent used. It is evident that even the concentration of a dye remains constant the efficiency varies significantly regarded the solvent used. The efficiency of the pure acetone solution is usually the lowest, follows DMSO and the highest is in the case the solvent is a mixture. It was experimentally proved that the ratio of 1:1 of DMSO and ethylenglycol is optimal, and the efficiency of these solutions may reach very high values (ex. over 60% for DOTCI). The differences in positions of the absorption bands maxima of solvents are negligible when compared to the total width and, therefore, can not account for so great differences in the efficiency. This is probably a consequence of a polarity of DMSO and ethylenglycol solvent molecules i.e. of the fact that they have a higher refraction index than the acetone (1.479 for DMSO, 1.427 for ethylenglycol and 1.359 for acetone) what affects the excitation cross section and thus increases quantum yield. This is also evident from the relation defining absorption coefficient in the system of two discreet levels.[6]

$$k_\nu = - \frac{1}{I_\nu} \frac{dI_\nu}{dx} = \frac{h\nu n}{c} (B_{01}N_0 - B_{10}H_1)$$

where I_ν is the radiation intensity at the frequency of ν, B_{01} and B_{10} are the Einstein coefficients for stimulated emission and absorption, N_0 and N_1 are the levels populations, and $\underline{n}$ is the refractive index.

The spectral characteristics of laser emission from these solutions were also investigated. Spectra were recorded on photographic plates on which spectral widths and laser emission maxima were determined by microphotometering (Table I).

IV. Conclusion

Analysing the results obtained it was found that the difference in the peak spectral emission obtained from the pure DMSO and a mixture was not as significant as between the pure DMSO and acetone solutions. However the mixture seems to be more interesting as a medium that gives laser emission of a high conversion efficiency.

From experimental data it is also evident that the spectral tuning is possible by the change of the solvent. In this way a relatively broad range of wavelengths can be covered by few organic fluorescent dyes and a few solvents. In the wavelength range obtained the choice of frequency can be done by changing the concentration, pumping source, dye mixing, temperature as well as by means of the standard methods (grating, prism, Fabry-Perot etalons, filters etc.). These investigations and results were obtained in the near IR region of the spectrum, however one should mention that there is also possible to use simultaneously the appropriate nonlinear optical crystals by which the frequency may be doubled, broadening thus the range of application.

TABLE I

No	Abbre-vation	conc. mol/ℓ	solvent	effi-ciency %	emission band λ (nm)	output max. λ (nm)	absorb. peak λ (nm)
1	DQTC iodide	$7x10^{-4}$	aceton	3,0			750 822
		"	mixture	5,5			755
		"	DMSO	4,0		960,0	750
2	DDTTC iodide	$3x10^{-4}$	aceton	3,5	845,0-851,5	847,0	802
		"	mixture	4,5			798
		"	DMSO	3,0		880,0	800
3	HITC iodide	$4x10^{-4}$	aceton	5,0	747,0-818,0	803,0	745
		"	mixture	10,0	837,0-848,5	843,0	750
		"	DMSO	8,5	833,0-847,5	844,0	746
4	DTTC iodide	$4x10^{-4}$	aceton	5,0	822,5-837,5	832,0	765
		"	mixture	32,0	842,5-858,0	851,0	768
		"	DMSO	20,0	847,0-857,0	853,5	766
5	DSTC iodide	$2x10^{-4}$	aceton	0,5			672
		"	mixture	1,5			663
		"	DMSO	1,0		830,0	669
6	DMOTC iodide	$2x10^{-4}$	aceton	8,0	750,4-759,4	754,0	694
		"	mixture	63,0	754,5-763,0 774,5-781,0	760,0 777,0	705
		"	DMSO	25,0	757,0-762,5 774,5-782,0	758,0 779,0	705

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