Optica Applicata, Vol. IX, No. 1, 1979

Laser emission spectra of two- and three-component solutions of organic scintillators

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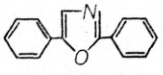
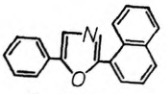
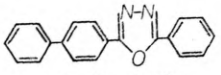
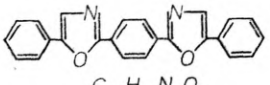
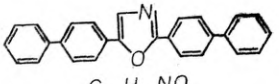
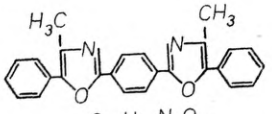
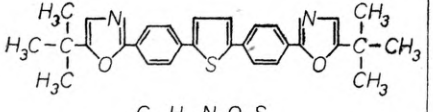
In the paper scintillator oxazole solutions have been investigated in order to obtain laser radiation covering the spectral range 356–440 nm. It has been stated that the laser emission spectra from two-component solutions of seven oxazole scintillators in different solvents do not cover the above range to a satisfactory degree. The gaps occurring in the spectrum may be filled with the emission spectra of properly chosen three-component mixtures.

Aryl derivatives of oxazoles and oxadiazoles, the fluorescence bands of which lie within the violet and near ultraviolet range were first applied to dye lasers in 1968 [1–3]. These heterocyclic compounds called organic scintillators are not organic dyes in the classical sense, as they contain no auxochromic groups [4]. Many of them exhibit high fluorescence efficiency, high absorption coefficient and other parameters advantageous for laser light generation. As the light generated belongs to the short-wave part of the visible spectrum, the oxazole solutions may be applied as the laser sources for excitation of other dyes.

The solutions of seven scintillators examined in the present paper are given in table.

For each scintillator the absorption spectra of two-component solutions (scintillator + solvent) in four solvents have been examined. The obtained absorption curves shown in fig. 1 have been denoted by connective numbers, according to the used solvent. The spectra have been recorded for solutions of concentration of order of 10^{-5} M. The apparature used did not allow to measure the absorption of solutions of lasing concentrations (of order of 10^{-3}–10^{-2} M). The lack of curves for the ethanol solutions in the graphs 1d and 1e is caused by the fact that the BBO and POPOP are practically insoluble in ethanol.

The position of emission line from a nitrogen laser ($\lambda = 337.1$ nm, which corresponds to $\bar{\nu} \cong 29.7 \times 10^3$ cm^{-1}), which is used in excitation of solutions to generate the laser action, is marked in fig. 1. For each solution this line lies within the region of strong absorption.

Chemical formula	Systematic name	Abbreviation presently used	Molecular mass
 $C_{15}H_{11}NO$	2,5-diphenyloxazole	PPO	221
 $C_{19}H_{13}NO$	2-(1-naphthyl)-5-phenyloxazole	α-NPO	271
 $C_{20}H_{22}N_2O$	2-phenyl-5-(4-biphenyl)-1,3,4 oxadiazole	PBD	298
 $C_{24}H_{16}N_2O_2$	1,4-di-(2-(5-phenyloxazolyl))-benzene	POPOP	364
 $C_{27}H_{19}NO$	2,5-di-(4-biphenylyl)-oxazole	BBO	373
 $C_{26}H_{20}N_2O_2$	1,4-di-(2-(4-methyl-5-phenyloxazolyl))-benzene	dimethyl-POPOP	392
 $C_{30}H_{30}N_2O_2S$	2,5-di-(5-tert-butyl-2-benzoxazolyl)-thiophene	BBOT	431

The curves have been obtained from a Specord UV VIS spectrophotometer as functions

$$E = f(\bar{\nu}) = -\lg -\frac{I}{I_0},$$

where I_0 and I denote the input and output fluxes.

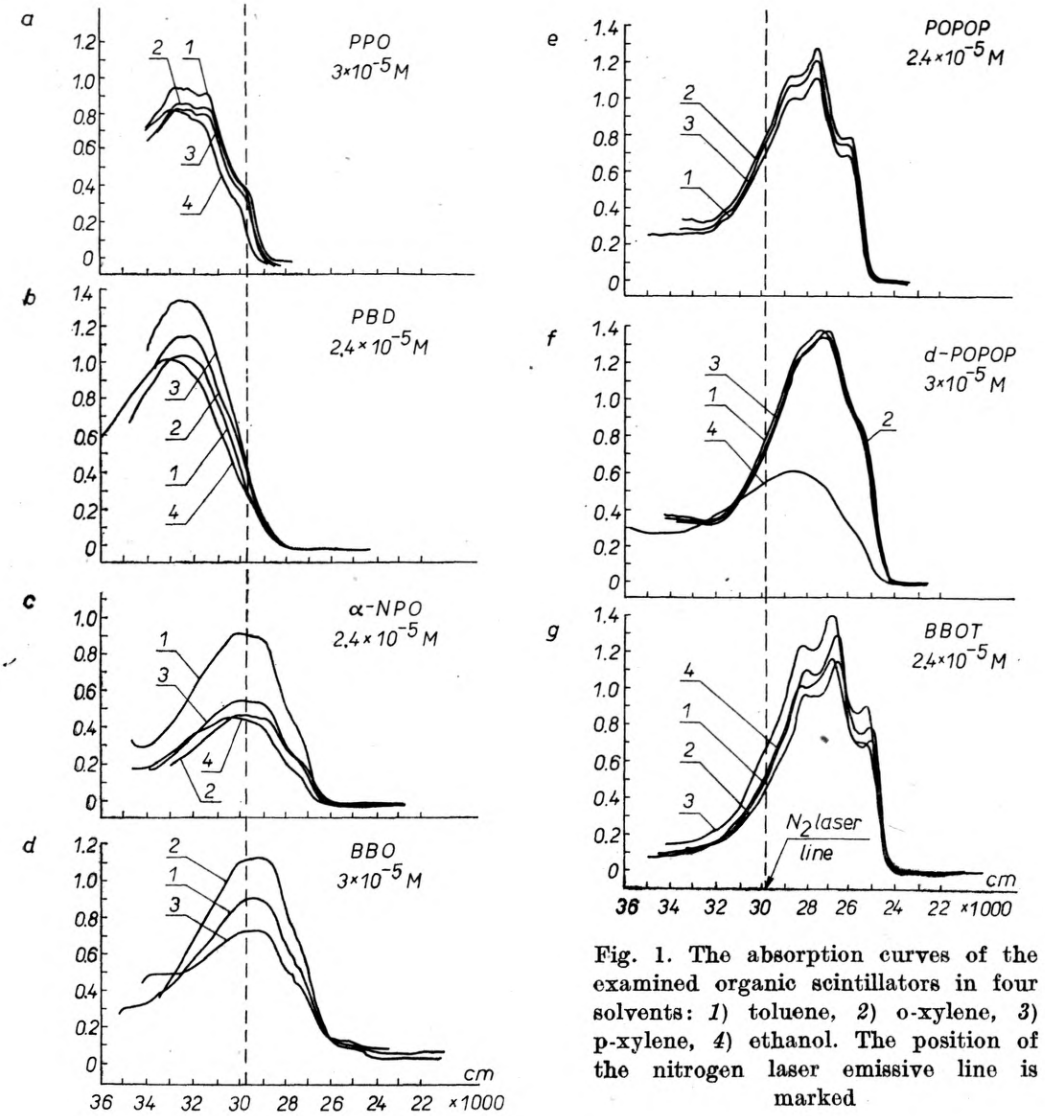


Fig. 1. The absorption curves of the examined organic scintillators in four solvents: *1*) toluene, *2*) o-xylene, *3*) p-xylene, *4*) ethanol. The position of the nitrogen laser emissive line is marked

In the solutions of examined scintillators laser actions have been obtained and the respective emissive curves drawn. Optimal concentrations (varying between 10^{-3} and 10^{-2} M), have been established experimentally for each solution.

Fig. 2 presents the experimental setup used to obtain the emissive spectra. The spectra were recorded in the DFS-13 spectrograph with a 1200 line/mm grating on a Fotopan CD-135 film of 27 Din sensitivity. The parallel sides of a quartz cuvette created a sufficiently good resonator for all the lasing solutions.

The densitograms were produced on a C. Zeiss 32-C-616 microphotometer. The curves obtained are presented in fig. 3. The curves for toluene

and xylene solutions are slightly shifted with respect to each other of order of single nanometers. More pronounced differences occur for ethanol which causes a shift of maxima broadening of emission band by a magnitude approaching several nm (curves 3c, 3d, 3f and 3g).

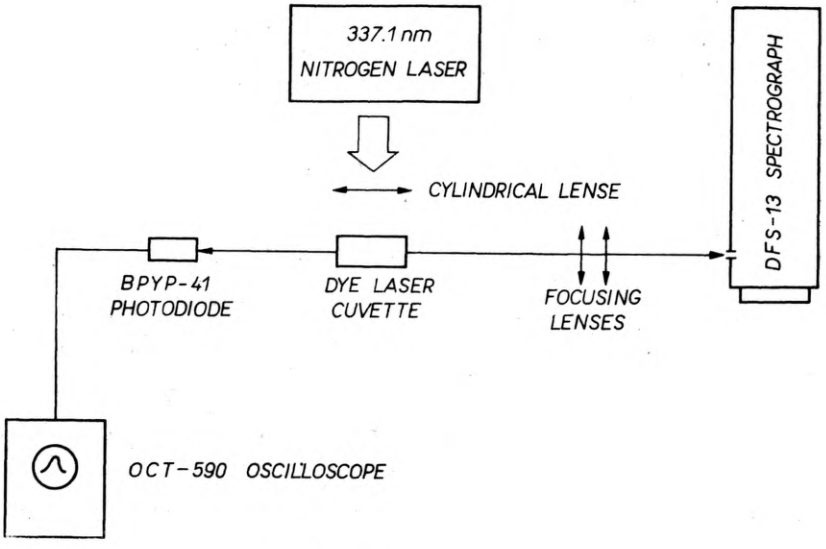


Fig. 2. Experimental setup

In fig. 4 the selected curves from fig. 3 have been combined to cover the whole spectral range. It may be seen that there exist intervals, in which the laser radiation intensity of the examined two-component solutions drops down. Any improvement of this coverage by changing the concentration or the sort of solvents is not possible.

In accordance with the theory of wavelength shifters [5] the emissive spectrum of an organic scintillator solution can be modified by adding another scintillator. Several three-component mixtures of the studied scintillators have been examined in different proportions of the used components. Fig. 5, in which the emissive curves from three mixtures mixed in different proportions of components in the same solvent (toluene) are presented, may serve as an example of the obtained results. These curves complete the unfilled fragments of the spectrum in fig. 4. This, in turn, is illustrated in fig. 6, which shows the possibility of covering the 356–440 nm spectrum range with an intensive laser radiation, if the solutions of several organic scintillators and their mixtures are used. Quite satisfactory results may be obtained by using the following solutions:

a) PBD in ethanol,
b) PPO + α-NPO (6 : 1) in toluene,
c) α-NPO in toluene,

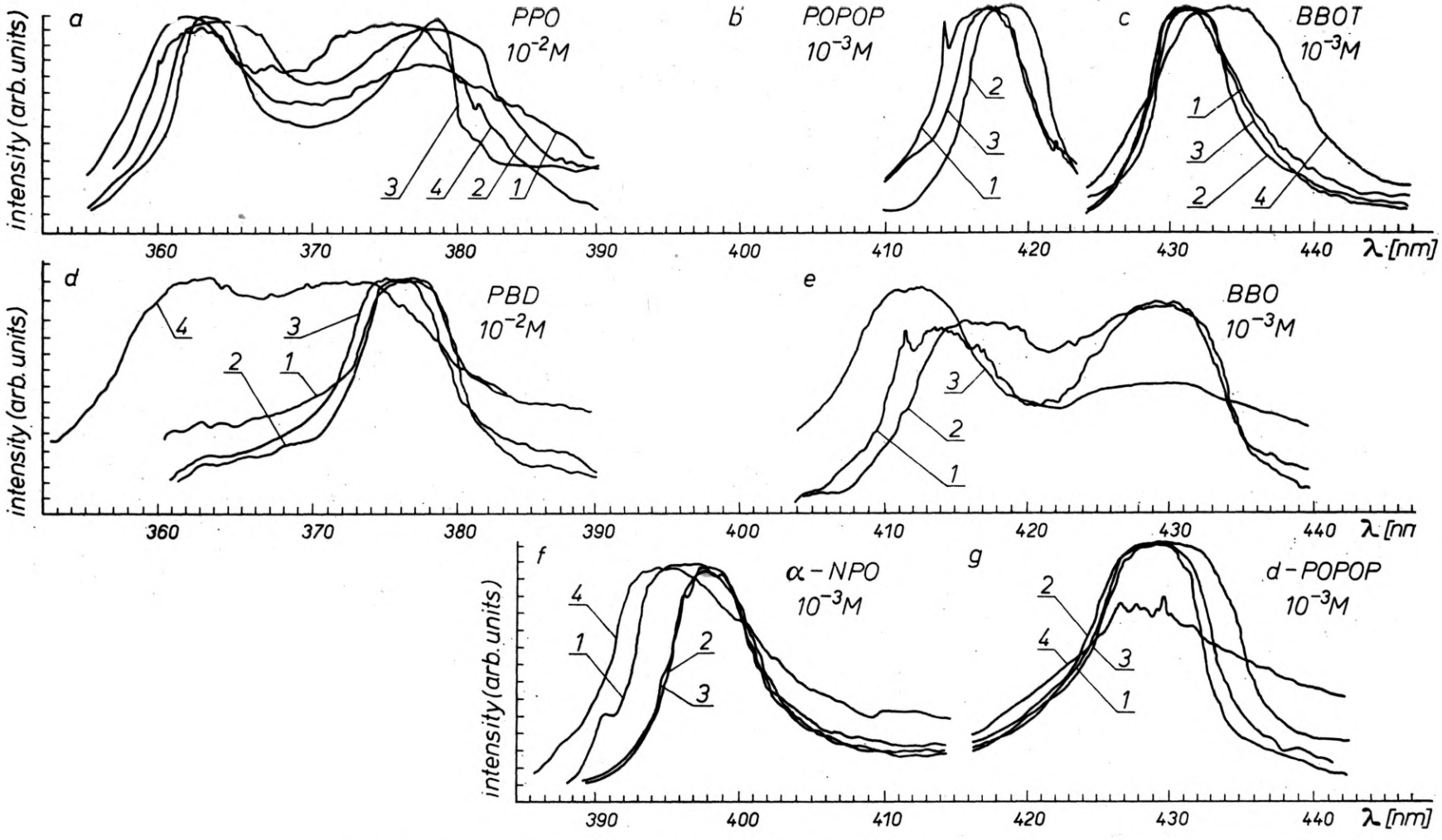


Fig. 3. Laser emission curves for examined scintillators in different solvents

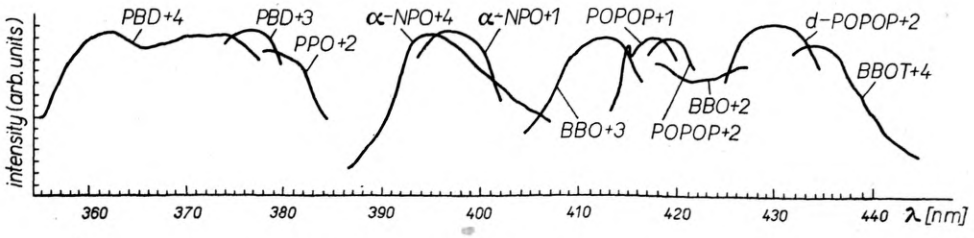


Fig. 4. Selected curves from fig. 3 combined in order to cover the considered spectral range

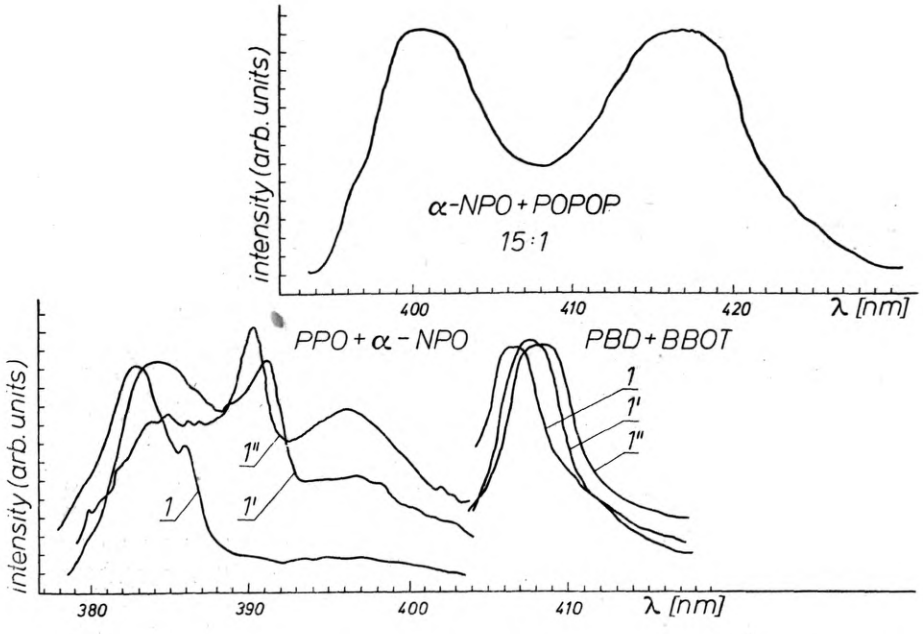


Fig. 5. Curves of laser emission for several three-component mixtures PPO + αNPO – *1* – 10 : 1, *1'* – 6 : 1, *1''* 4 : 1; PBD + BBOT – *1* – 200 : 1, *1'* – 100 : 1, *1''* – 70 : 1

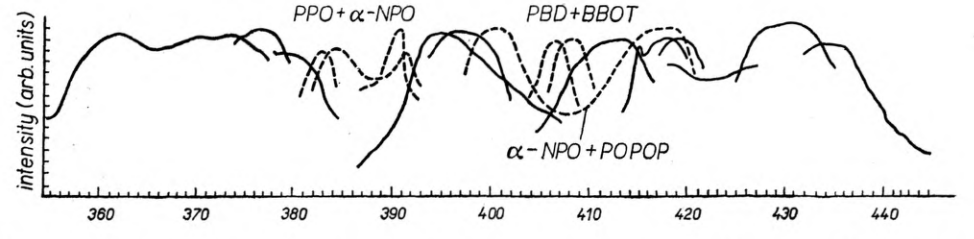


Fig. 6. Completion of unfilled fragments of the spectrum in fig. 4 by curves from fig. 5

d) α-NPO + POPOP (15 : 1) in toluene,
e) PBD + BBOT (70 : 1) in toluene,
f) BBO in o-xylene,
g) BBOT in ethanol.
This is presented in fig. 7.

Fig. 8 shows a typical pulse appearing in all the observed laser actions, which has been found to be completely consistent in shape with the initiating pulse of the pumping nitrogen laser.

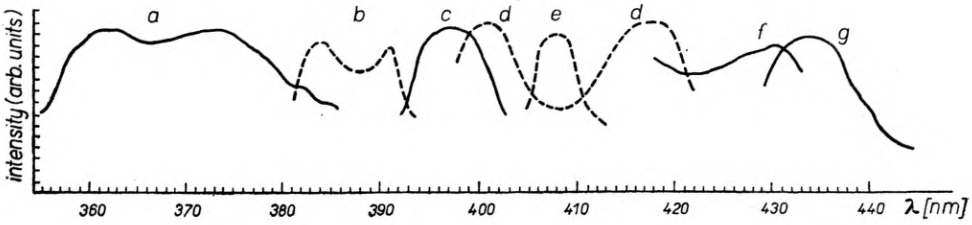


Fig. 7. A possibility of covering by intensive laser radiation of the spectral range 356–440 nm

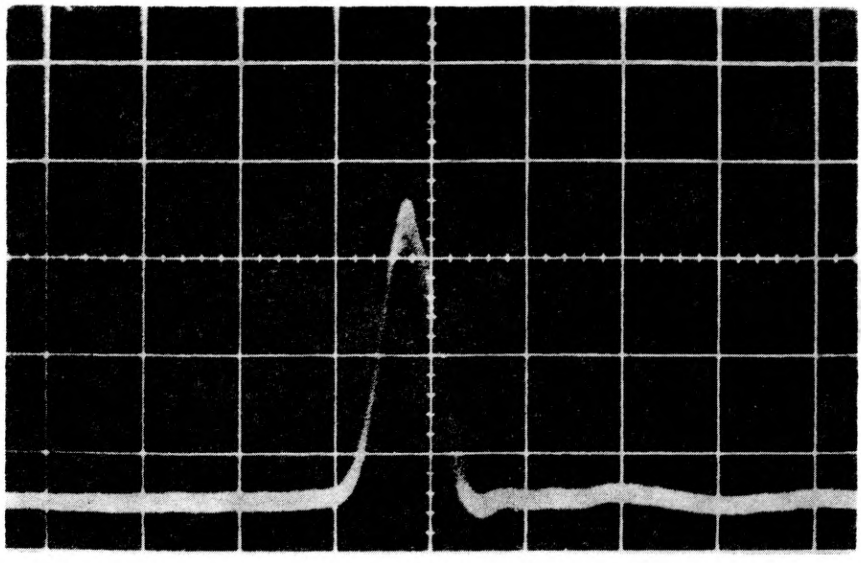


Fig. 8. A pulse of the lasing action of an scintillator excited by a pulse of nitrogen laser. Horizontal scale — 5 ns/cm

References

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Received, February 17, 1978

Эмиссионные лазерные спектры двойных и тройных растворов органических сцинтилляторов

Исследованы растворы оксазоловых сцинтилляторов для перекрытия лазерным излучением области видимого спектра 356–440 нм. Обнаружено, что лазерные спектры испускания двойных растворов семи оксазоловых сцинтилляторов в разных растворителях не дают удовлетворительного покрытия видимого спектра. Пробелы в спектре могут быть удовлетворительно пополнены эмиссионными спектрами соответственно отобранных трехкомпонентных смесей.