LASING CHARACTERISTICS OF NOVEL ACTIVE MEDIA FOR DUE LASERS

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In this study we have investigated fifteen novel lasing media of organic compounds, which are series of organic molecules with different substitutes, capable of producing laser emission in the region from 600 *to* 680 nm *if pumped by radiation of a* XeCl*–laser. Ten lasing characteristics of each compound are compared to those of a rhodomine 6G solution. It is shown that although the lasing efficiency (or the efficiency of the* XeCl*–laser emission conversion) of these compounds is lower they provide longer lifetimes of lasing media compared to that of rhodomine 6G. The relation of an active medium lifetime to light absorption by the photodissociation products in the spectral regions of generation and pumping is analyzed.*

Stable frequency conversion of excimer laser emissions into emissions of the visible and IR regions is still a topical applied problem. In this connection we have studied lasing properties of some novel organic compounds (see Fig. 1) soluble in ethanol. Excitation of these lasing media was performed with a XeCl–laser radiation at the 308 nm wavelength and 30 – 70 mW mean power at a repetition rate of 2 Hz. The technique of measuring parameters of laser emission we used in our study had been described earlier in Ref. 1. Table I presents the values of absorption coefficients $K_{\lambda p}$ of lasing media at the wavelength of pumping radiation, interval of the emission wavelengths $\Delta\lambda_g$, wavelength of the emission maximum λ_{le}^{max}, the value of the initial efficiency $\eta_0 = P_{le}/P_p$, where P_{le} is the mean power of laser emission and P_p is the mean power of pumping radiation. The values P_{80} and P_{50} are the lasing lifetimes defined as the energy pumped into 1 cm^3 of a lasing medium during the time interval from the beginning of lasing till the moment when the starting efficiency of lasing η_0 decreases by 20 or 50 percent, respectively. Normally, the decreases of η_0 is assumed to be due to photochemical transformations.

TABLE I. Lasing caracteristics of the compounds under study.

Designation	Concentration	$K_{\lambda p}$,	λ_{le}^{max},	$\Delta\lambda_{le}$,	η	P_{80}		P_{50}		$\varphi_{ph}\cdot10^4$	$P_{ph}\cdot10^2$	c/c_0	η/η_0	$\Delta D\lambda_{le}/E_t$,
	c_0, mM	cm^{-1}	nm	nm	%	J/cm^3	phot/mol	J/cm^3	phot/mol					1/(phot/mol)
II (1)	2	32	667	657–675	6.7	220	260	550	715	3	2.5	0.73	0.68	$2.0\cdot10^{-5}$
II (2)	2	23	676	667–686	6.8	440	572	875	1138	2.4	1.4	0.69	0.58	$0.9\cdot10^{-6}$
I (2)	2	11	627	611–647	4.1	35	455	350	455	2.4	3	0.93	0.55	$3.4\cdot10^{-5}$
II (3)	2	21	675	662–683	3.6	280	364	750	975	2.9	1	0.86	0.73	$4.5\cdot10^{-5}$
II (4)	2	21.6	665	657–673	3.8	225	293	625	813	3	1.2	0.82	0.61	$4.2\cdot10^{-5}$
I (3)	2	9.2	621	605–644	0.6	20	26	130	169	3.6	8.7	0.94	0.52	$1.5\cdot10^{-4}$
II (7)	2	32	668	656–677	3.5	75	98	225	293	8.4	3	0.75	0.49	$1.3\cdot10^{-4}$
I (7)	1.7	12.4	614	603–625	14.3	17	26	57	87	4.3	46	0.96	0.49	$1.8\cdot10^{-3}$
I (8)	2	12.8	618	605–631	12.7	20	26	70	91	8	29	0.91	0.48	$1.2\cdot10^{-3}$
II (9)	2	33	674	663–681	2.5	80	104	200	260	12	2.4	0.68	0.50	$9.6\cdot10^{-5}$
II (5)	1.8	21.2	671	658–681	8.3	200	289	475	686	1	3.2	0.78	0.61	$1.0\cdot10^{-6}$
I (5)	2	9	622	609–635	10.0	25	33	90	117	4.6	18	0.93	0.46	$8.0\cdot10^{-5}$
II (6)	1.9	7.6	667.5	656–678	1.0	4.5	6	11.5	16	58	14	0.80	0.10	$5.8\cdot10^{-4}$
I (6)	2	10	618	600–642	6.6	13	17	40	52	18	29	0.87	0.37	$1.2\cdot10^{-2}$
I (10)	2	5.5	612	600–625	2.2	15	20	45	59	17	7.7	0.88	0.47	$2.9\cdot10^{-4}$
P 6Zh	2	12.4	585	575–595	20.0	17	22	85	110	2.8	47	0.97	0.49	$2.0\cdot10^{-3}$

* Structures of the designated compounds are presented in Fig. 1.

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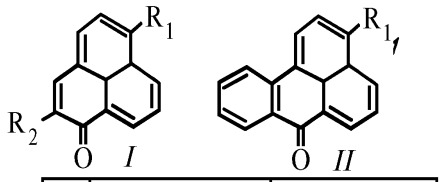

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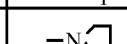
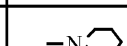
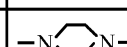
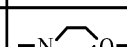
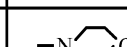
1		H
2		H
3		H
4		H
5		H
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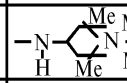
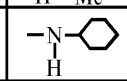
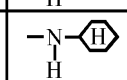
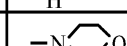
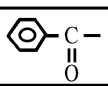
7		H
8		H
9		H
10		

FIG. 1. Structures of the molecules under study.

Based on the experimental data we calculated the molecular yield of photochemical transformations

$$\varphi_{ph} = \frac{(1 - c/c_0)\, c_0}{E_t} = \frac{\text{the number of dissociated molecules}}{\text{the number of absorbed photons}},$$

where c_0 and c are the initial and final values of the concentration of molecules, respectively, E_t is the total (in number of photons) energy pumped into the lasing solution during the time when the concentration of molecules decreased from c_0 down to c. In addition we calculated the lasing yield of the photochemical transformations

$$P_{ph} = \frac{1 - \eta/\eta_0}{E_t},$$

where E_t is the total energy pumped into 1 cm^3 of the lasing solution during the time when the lasing efficiency decreases from the initial value η_0 down to η_0. From the absorption spectra (see Fig. 2) we determined the increase of the optical density of the lasing solution in the spectral region of lasing emission normalized by the number of absorbed photons $\Delta D_{le} / E_t$.

Comparison of the lasing properties of these media shows that the efficiency of an excimer laser radiation conversion is 2–5 times lower than that of a rhodomine 6G solution. At the same time it is obvious that the lifetime of the most efficient media is about 10 times as long as that of rhodomine 6G.

In our experiments we have obtained that addition of a fused ring shifts the laser emission spectrum towards longer wavelengths by about 50 nm and makes the lasing lifetime 3–5 times longer compared to that of similar but 3–ring compounds (see Fig. 1 and Table I). The molecule with a substitute of an alkylated cyclic aminogroup has the longest lifetime. At the same time the change of oxygen for sulphur in a morfoline substitute results only in a small shift of the laser emission spectrum towards shorter wavelengths ($\approx$ 5 nm) while sharply decreases the lasing efficiency and the lifetime.

The correlation between the lifetime and the light absorption by photodissociation products at λ_{lasing} is higher than that between the lifetime and the quantum yield of photochemical transformations φ_{ph}, though the relation is not unique. The latter means that the lifetime is determined by both these processes.

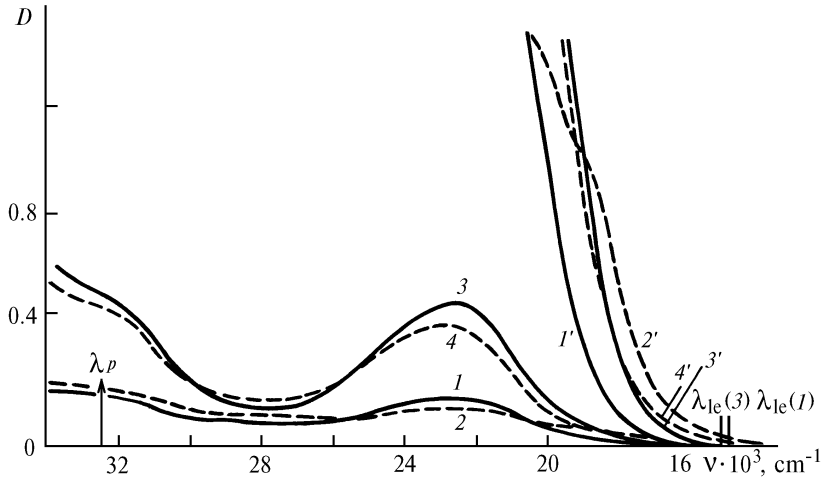


FIG. 2. Absorption spectra of the compounds II (6) – curves 1 and 2; and II (4) – curves 3 and 4; spectra 1 and 3 were observed prior to lasing while the spectra 2 and 4 after its termination. The thickness of the layer was 0.025 cm *(curves 1–4) and* 1 cm *(curves 1′–4′).*

In this study we have also revealed that the rate of the lasing efficiency P_{ph} fall off occurring during the photochemical transformations for all media, is higher than the rate of the corresponding fall off of the number density of lasing molecules $\varphi_{ph} = \frac{(1 - c/c_0)\, c_0}{E_t}$. This means that the light absorption by the products of photochemical dissociation at the wavelengths λ_{le} and λ_p additionally affects the lifetime of the lasing media. In the case of media with higher photochemical durability the absorption of light at λ_p decreases during the lasing process while in the case of media with lower photochemical stability this absorption either increases or keeps unchanged.

Light absorption by the products of photochemical dissociation at the wavelengths of laser emission λ_{le} is the weakest in the case of media with the longest lifetime. By the way, the shortest lifetime has the most unstable dye, though its light absorption at λ_{le} is not the strongest one (see the table). However, the data presented in Fig. 2 show that in this case the longwave absorption band of the photochemical dissociation products is most intensive.

In addition to certain practical recommendations which can be drawn from the experimental results obtained in this study of lasing properties of the above substances such investigations could be useful for seeking for regularities in dissipation of the pump energy in complex organic molecules using, for example, methods of quantum chemistry. Such studies could facilitate our understanding of the role of a substitute in related series of compounds in physics and photochemistry of molecules.

REFERENCES

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