DESIGN AND DEVELOPMENT OF A SYSTEM FOR REGENERATION OF ACTIVE MEDIA FOR HIGH-POWER DYE LASERS

T.N. Kopylova, G.Y. Mayer, L.G. Samsonova, Yu.P. Morozova, O.N. Chaikovskaya, K.M. Degtyareuko, and E.N. Tel'minov

V.D. Kuznetsov Siberian Physicotechnical Scientific-Research Institute at the State University, Tomsk

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A system is developed for regeneration of active laser media for high powerful dye lasers, using organic and inorganic sorbents of high capacity, chemical resistance, mechanical strength, and high selectivity of absorption of products of dyes photodissociation. The system was tested in a "MZhL–03" high powerful dye laser. It is shown that its using can increase the lifetime of high powerful dye lasers, pumped by excimer lasers, more than tenfold.

The weak point of high–power laser systems with dye, excimer pumped lasers is known to be low photostability of a dye to powerful ultraviolet radiation resulting in low service life and increased costs of laser systems.

Producing a system for dye regeneration could reduce such costs, extend laser lifetimes, and expand their applicability.

Recent introduction of organic and inorganic sorbents of high capacity, chemical resistance, and mechanical strength and the possibilities for producing porous sorbents with surfaces highly selective to chemistry of photodissociation products, stimulate attempts to design systems for regeneration of laser dyes.

Laser dyes, coumaric among them, undergo photochemical conversion when affected by high–power ultraviolet radiation. These are manifested in their absorption spectra and lead to changes of generation characteristics: lasing efficiency decrease, wavelength range changes, threshold power increase, and so on.

Spectral behaviour of photodissociation products is shown in Fig. 1. The appearance of photoproducts absorbing both pump and laser radiation is typical. As a result both the number of active molecules and efficiency of the active lasing medium decrease. Deoxygenation of solutions effectively inhibits photodissociation of molecules,[1] since the formation of singlet oxygen is the principal cause of such dissociation. However, it is not easy to deoxygenize solutions under conditions of generation. To a certain extent dye photodissociation may be resisted by adding inhibitors to the solution. Thus diazobicyclooctane (DABCO) doubles or triples generation lifetime for some aminocoumarins [coumarin 102 (C102), coumarin 1 (C1)] (see Ref. 2). However, the DABCO effect in solutions of coumarin 120 (C120) and coumarin 2 (C2) is insignificant: laser service life increases by 30–50%. Only more complex compositions allow for doubling the lifetime.

Figure 2 shows photodissociation curves for solutions of coumarin 2 in ethanol with different additives. Laser photostability is characterized by energy which must be pumped into 1 cm^3 of active solution to reduce lasing efficiency by 50%. One can see from this figure that the service life of the optimally composed active medium containing coumarin 2 and inhibitor additives doubles, remaining not too high, however (120 J/cm^3).

The use of regeneration filters for such dyes seems to be the most promising way to increase dye laser service life.

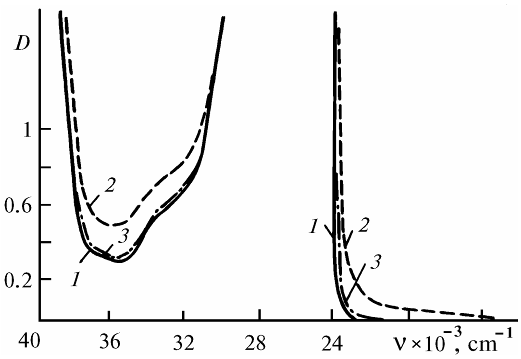

FIG. 1. Absorption spectra for solution of coumarin 2. 1) before and 2) after generation, 3) solution after regeneration.

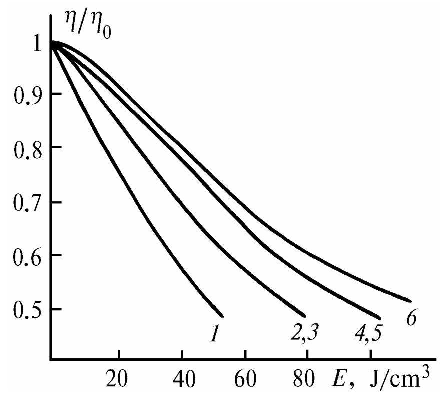

FIG. 2. Relative efficiency (η/η_0) of C2 generation vs energy pumped per unit volume of solution:
1) pure ethanol solution;
2) 10–30% of water added;
3) diacetame 5 (DA5) added, $5\cdot10^{-2}$ mol/liter;
4) ethanol + water (10%) + *DABCO* ($5\cdot10^{-2}$ mol/liter);
5) ethanol + water (10%) + *DA5* ($5\cdot10^{-2}$ mol/liter);
6) ethanol+DABCO($5\cdot10^{-2}$ mol/liter)+*DA5*(10^{-2} mol/liter).

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TABLE I. Regeneration capabilities of different sorbents.

Sorbent, dye, concentration, mol/liter	Solution									PP
	Initial			Irradiated			Recovered			
	Efficiency, % (service life), J/cm^3	D_{λ_p}	D_{λ_g}	Efficiency, %	D_{λ_p}	D_{λ_g}	Efficiency, % (service life), J/cm^3	D_{λ_p}	D_{λ_g}	
GDT's 250/C1, $2.5\cdot10^{-3}$	26–28 (105–111)	0.82	0	13–14	1.08	0.20	30 (136)	0.85	0.06	30
TZ/C1, $2.5\cdot10^{-3}$	27 (110)	0.84	0	13	0.76	0.20		0,81	0.06	30
Zirconium phosphate/C1, $2.5\cdot10^{-3}$	27 (110)	0.84	0	13	0.76	0.17		0.89	0.05*	29
AV17OH$^-$/C102, $2.5\cdot10^{-3}$	23–26 (86)	0.53	0	11–13	0.61	0.10	19	0.52	0.05	43
007/C2, $2.5\cdot10^{-3}$	29–30 (40–50)	0.64	0	14–15	0.75	0.08	24 (35)	0.69	0.01	12
007/C1+DABCO, $2.5\cdot10^{-3}$	32 (240)	0.83	0	16	0.78	0.22	30 (230)	0.84	0.02	9

Notes: * – recover time is 12 hours; PP is the residual photoproduct absorbed at λ_g, %; D_{λ_g}, D_{λ_p} are the optical densities at generation and pump wavelengths, respectively. The solvent is ethanol.

The data presented in Table I show some sorbents to be capable of absorbing the products of dye photodissociation and thus of keeping dye concentration at a constant level. Regenerative capability of sorbents lies in the fact that they absorb photoproducts formed during irradiation (Table I indicates changes of absorption at the lasing wavelength) and keep the concentration of active molecules in the solution at a constant level. For example, a photoproduct absorbing at generation wavelength appears in the ethanol solution of coumarin 1 when energy pumped into 1 cm^3 of the solution reduces the laser efficiency by 50%, so that the optical density D_{λ_g} increases to 0.2. Another photoproduct begins to absorb at pump wavelength too, and D_{λ_p} increases from 0.82 to 1.08. Filtering of the "broken" solution through a cell with GDTs250 sorbent recovers efficiency (up to ~ 30%) and concentration (D_{λ_p} = 0.85), that is, photoproducts are absorbed (D_{λ_g} falls from 0.20 to 0.06). Regenerative capabilities differ from sorbent to sorbent: the residual long–wavelength product varies from 10 to 30% (the AV17 OH$^-$ ion exchange resin is previously employed) and leaves about 43% of photoproduct in the solution.

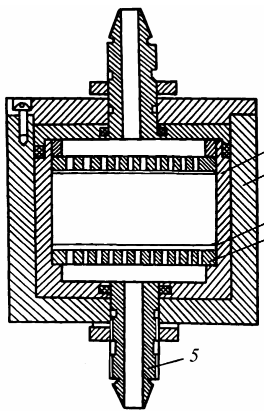

FIG. 3. Regeneration fitter for the active medium.

A regeneration system was designed, constructed and tested for the "MZhL–03* high-power dye laser. Figure 3 gives the developed filter design. Teflon cup *1* is placed in metal casing *2*. Sorbent is filled between the two teflon grids *3* and membrane filters *4*. Exhausted dye solution enters the filter through coupling *5*, passes through sorbent bed and exits through second coupling; the flow rate was 2 mliter/sec in our case.

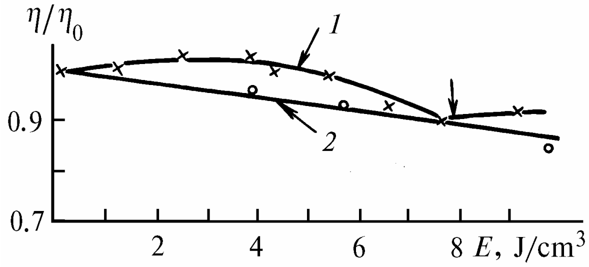

FIG. 4. C2 decay curves in monopulse (2) and repetition (5 Hz) *modes (1). Arrow points the start regeneration in repetition mode.*

The filter was tested with the "MZhL–03" high–power dye laser. Pulse energy of the pumping XeCl–laser was 1 J. The filter was introduced into the circulation system of amplifier with input energy of 550 mJ. The effect of regeneration of active laser medium is shown in Fig. 4.

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