CONVERSION OF A COPPER-VAPOR LASER RADIATION IN DYE SOLUTIONS AT LOW LEVELS OF EXCITATION

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The possibility of efficiently converting the copper-vapor laser radiation in dye solutions is studied to extend the laser application to solving the medical and biological problems.

At present large-scale implementation of lasers into different areas of national economy is observed. Besides, much work is in process on equipping practical medicine with laser facilities. Lasers on dye solutions (DL) tunable in the entire visible region including UV and IR ranges are used for selective action at the wavelengths which provide maximum effect. At the same time application of dye lasers to solving medical and biological problems is limited to a great extend by the absence of simple, mobile lasers free of special conditions for operation.

The present paper has been stimulated by the availability of small-scale copper-vapor laser "Malakhit" developed at the Laboratory of Laser Physics whose radiation converted by dye solutions into different wavelengths could considerably extend the application of this laser. The main factor hampering improvement of the conversion efficiency is a relatively low intensity of the pumping laser. Its average power is less than 1 W. Thus, the purpose of the present work was to investigate a possibility of efficiently converting of copper-vapor laser radiation in dye solutions at a typical pumping power of 0.5 W, pulse repetition rate of 12–15 kHz and pulse energy of 30–40 μJ.

Most of our experiments on conversion of radiation of metal vapor lasers (MVL) in dye solutions (see Refs. 1–3) and that by other authors (see Refs. 4 and 5) were conducted at pumping power of 1–5 W and pulse energy of 150–500 μJ. One of the most important parameter of a dye laser responsible for its efficiency, homogeneity of output beam and tuning range is the concentration of active media. Figure 1 shows the efficiency as a function of dye concentration (see Ref. 1).

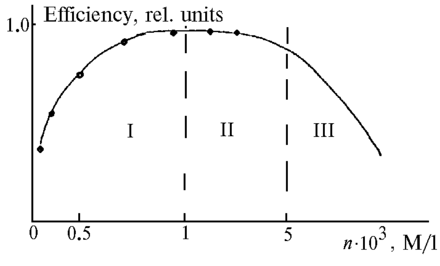

FIG. 1. Conversion efficiency of dye laser versus active medium concentration (Rhodamine 6G in ethanol).

The dependence is characterized by a sharp increase of the efficiency in some concentration range (I). Then, saturation of the efficiency is observed over a wide range of concentration (II). Finally, if the concentration increases further the fall off of the efficiency is observed starting with $n\sim10^{-2}$ mol/l due to the dimerization losses of dye molecules. As a rule, concentrations near the boundary between regions I and II are considered to be working. Therewith the laser efficiency approaches its peak while the output beam is relatively uniform that allows one to obtain a narrow-band radiation using a selective resonator. Figure 2 presents the efficiency of various dye lasers versus pumping power obtained in our previous experiments. Transverse excitation and non-selective laser cavity were used. A copper-vapor laser equipped with an unstable resonator ($M = 30$) operated at a pulse repetition rate $f = 8$ kHz.

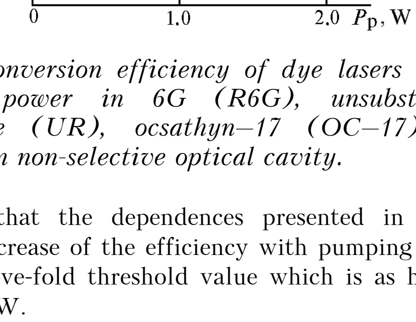

FIG. 2. Conversion efficiency of dye lasers versus pumping power in 6G (R6G), unsubstituted Rhodamine (UR), ocsathyn–17 (OC–17) dye solutions in non-selective optical cavity.

Note that the dependences presented in Fig. 2 show an increase of the efficiency with pumping power up to its five-fold threshold value which is as high as 200–300 mW.

Based on the analysis of the above results let us state the ways for improving dye laser efficiency at low-power excitation.

The main criterion providing high conversion efficiency is obtaining laser action at the near-threshold pumping power (less than 100 mW). This problem is solved in two methods. First, decrease of lasing

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threshold is achieved by increasing dye concentration in solution. Second, the threshold depends on *Q*-factor of a dye laser resonator. On this basis, further experimental investigations have been carried out to determine the effective concentration of a dye solution and on the optical arrangement of the laser cavity.

After experiments with different resonators the scheme presented in Fig. 3 was chosen. Transverse pumping geometry was used. Pumping beam was focused with a cylindrical lens *CL* onto a cell with dye solution near its output window. Spherical resonator was used instead of a plane-parallel one because of high diffraction losses in it. Actually, transverse size of dye excitation zone under given conditions is 0.15×0.15 mm^2. Small cross size of the active zone at the resonator length of 100 mm can be presented as an aperture inserted into the resonator. This leads to high diffraction losses and, as a result, to extremely low conversion efficiency. The spherical resonator used in further experiments included plane-parallel mirror (with the reflectivity of 50%) deposited on the inner surface of the output window of the cell, spherical lens, and grating. The resonator was tuned by alignment of the output window and displacement of the lens in the direction perpendicular to the resonator axis. This axial displacement is used to fit the size of the active zone with the resonator caustic. Rotation of the grating provides tuning of DL wavelength.

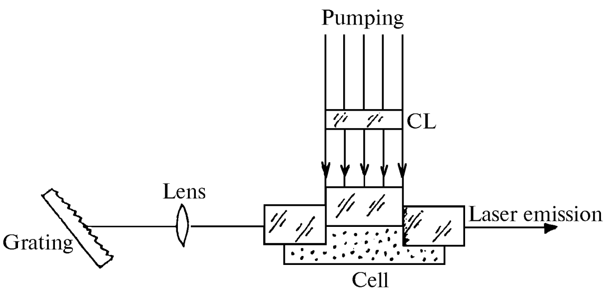

FIG. 3. Optical arrangement of a dye laser.

A number of experiments on choosing dye concentrations in ethanol (unsubstituted Rhodamine (UR), Rhodamine 6G (R6G), Rhodamine B (RB), ocsathyne–17 (OC–17)) by seeking maximum efficiency indicates that working concentration falls within the range 0.3–0.5 g/l ($1.2–3\cdot10^{-3}$ mol/l).

At that concentration the losses due to concentrated quenching of the laser effect are insufficient, while the main process competing with the development of laser action is superluminescence.

Figure 4 shows the output power and efficiency of a dye laser on R6G versus pumping power. The dye concentration in ethanol was less than 500 mg/l. Threshold pumping power in this scheme was as low as ~50 mW. Sharp increase of the efficiency (see curve *2*) and its further saturation even at pumping power of 500 mW (ten-times exceeding the lasing threshold) should be noted.

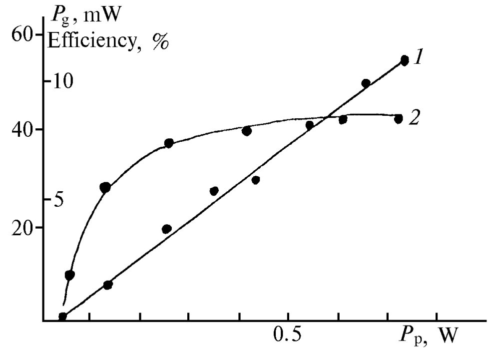

FIG. 4. Output power (1) and conversion efficiency (2) of a dye laser as a function of pumping power.

Thus, the investigations done demonstrate the feasibility of conversion in dye solutions of low-intensity copper-vapor laser radiation ($P < 1$ W) into yellow-red spectral interval with the efficiency of 5–10%. Based on the experimental data obtained operating models of dye laser of MLK–0.2 type and its modification were developed for medical and biological applications.

REFERENCES

1. L.V. Masarnovskii, A.N. Soldatov, and V.B. Sukhanov, Kvant. Elektron. **6**, No. 7, 1536–1539 (1979).
2. A.N. Soldatov and V.B. Sukhanov, *ibid.* **10**, No. 1, 157–161 (1983).
3. S.Yu. Mirza, A.N. Soldatov, and V.B. Sukhanov, *Forecast and Control over Optical-Meteorological State of the Atmosphere* (Design and Technology Institute “Optika” of the Siberian Branch of the Russian Academy of Sciences, Tomsk, 1982), pp.81–107.
4. A.M. Rubinov, in: *Problems in Modern Optics and Spectroscopy* (Minsk, 1980), pp. 156–172.
5. A.I. Zherikhin, V.S. Letokhov, V.I. Mishin, et al., Kvant. Elektron. **8**, No. 6, 1340–1343 (1981).