INVESTIGATION OF SPECTRAL NARROWING OF NITROGEN LASER PUMPED DYE LASERS

By

B. RÁCZ.

Institute of Experimental Physics, Attila József University,
Szeged, Hungary

The present paper is discussing N_2 laser requirements of pumping tuned dye lasers, and is presenting an improved nitrogen laser construction suitable for pumping dye lasers. The fundamental dye laser parameters; such as the beam divergence an efficiency, are investigated in a broad-band resonator. Using the optimum resonator and pumping geometry, the spectral narrowing is realized with grating, prism, and intracavity etalon.

A simple untuned dye laser can be produced by a cylindrical lens, a spectrophotometer cuvette and, of course, a nitrogen laser. The pumping of a tuned narrow-bandwidth dye laser is not simple since, because of the short excited-state lifetime of dyes, a short exciting pulse is necessary, but the spectral selection requires that photons should make many round trips in the resonator *i.e.* a long exciting pulse is needed. Practically 5 to 10 round trips can be achieved, hence the gain of the active medium must be high enough, but not as high as to prevent an uncontrolled amplified spontaneous emission. The energy of excitation must be above 1 mJ.

In order to excite tuned dye lasers, we constructed a transversally excited nitrogen laser. The 75 cm long tube is fed by a series of doorknob capacitors. The electric circuit of the exciting system can be seen in Fig. 1. C_1 and C_2 capacitors are charged to the same voltage through R_1 and R_2 resistors. When the S spark gap discharges C_2 high voltage appears between the E electrodes of the laser tube and excites nitrogen gas. This nitrogen laser gives 2 mJ energy at optimum gas pressure, at 10 kV. The pulse duration is 6 nsec at half-width. According to the geometry of electrodes and discharge, the laser beam is 3×10 mm, with a divergence of 11 millirad and 1.5 millirad.

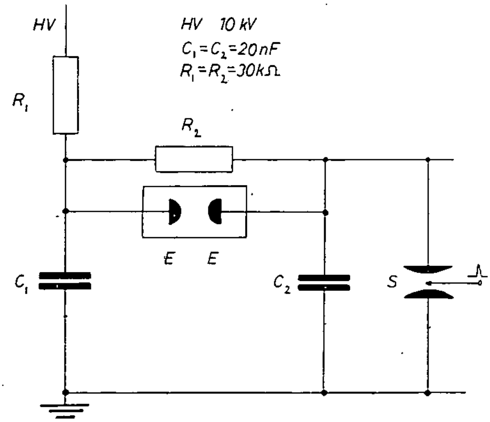

Fig. 1. Electrical circuit of a N_2 laser

The bandwidth of tuned dye lasers is basically determined by beam divergence [1, 2] this is why we first investigated the divergence and efficiency of a rhodamine 6G solution in a broad-band cavity consisting of a 1 cm cuvette, and two plane mirrors with 40% and 90% reflectivity. The beam divergence did not change in case of 5 cm, 15 cm and 30 cm long cavities, and it was 1.6 mrad full angle. The following investigations were carried out on a dye concentration of maximum efficiency ($5 \cdot 10^{-3}$ mol/l). The 1.6 mrad divergence and 1800 line/mm diffraction grating with 30° blaze angle gave experimentally 1.3 nm bandwidth. In order to reduce this bandwidth, we used a prism beam expander proposed by MYERS [3]. The experimental arrangement can be seen in Fig. 2. The magnification is determined by the angle of α and the refractive index of the prism, the typical value of magnification being 10 to 50. The magnification is limited by reflection losses on the front surface of the prism and by the size of the grating. The calculated and measured bandwidth at different α values, at fixed wavelength can be seen in Fig. 3. The minimum spectral

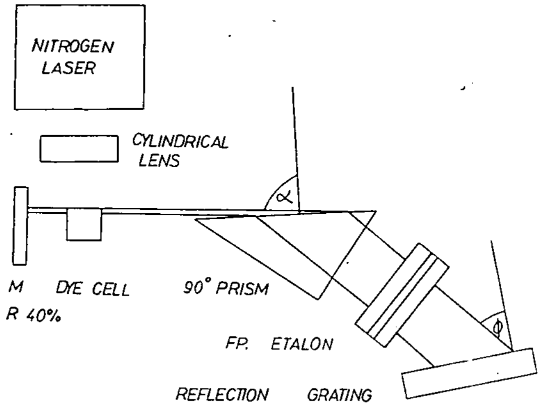

Fig. 2. Experimental arrangement

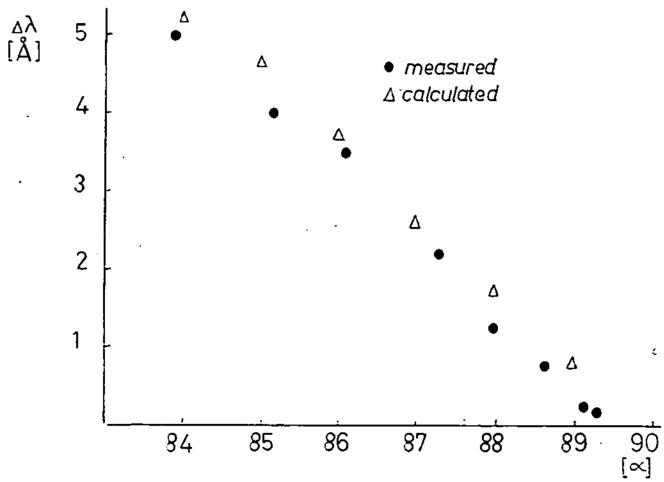

Fig. 3. Dye laser bandwidth as a function fo angle

width was determined by the diameter of grating, then we calculated 0.3 Å and measured 0.18 Å. Inserting a 2 mm thick Fabry-Perot etalon with a 0.9 Å free spectral range (FSR), we obtained further narrowing. The dye-laser spectrum was analysed by another FP etalon having 0.36 Å FSR. By densitometric measurements of the fringes, we obtained 0.03 Å. This result shows that nitrogen laser pumped dye lasers can produce a narrow bandwidth without any technical excellence.

A narrow-bandwidth tunable emission can be produced without cavity by periodical structures, by so-called distributed feedback lasers (DFB) [4].

One can produce a DFB structure by inducing a spatial modulation of the refractive index or the gain, or both such as

$$n(x) = n + n_1 \cos Kx, \quad k(x) = k + k_1 \cos Kx,$$

where x is measured in the direction of the optical axis, $K = \frac{2\pi}{d}$, d is the period of modulation, and k_1 and n_1 are the amplitude of modulation. This system will oscillate in the vicinity of wavelength $\lambda = 2fd$.

Chandra *et al.* proposed a simple arrangement for gain and refractive index modulation [5], by an interference pattern of the pumping beam. The arrangement can be seen in Fig. 4. The fringe spacing is determined by the angle as

$$d = \frac{p}{2n_p \sin\alpha}$$

and so the laser emission wavelength as:

$$\lambda_e = \frac{n_s}{n_p} \frac{\lambda_p}{.\sin\alpha}.$$

This laser can be tuned by varying the angle i *i.e.* the angle of incidence, or n_s.

Because of the poor spatial coherence of the nitrogen laser, this arrangement seems to be of no use in our case; however we tried to excite DFB laser by nitrogen

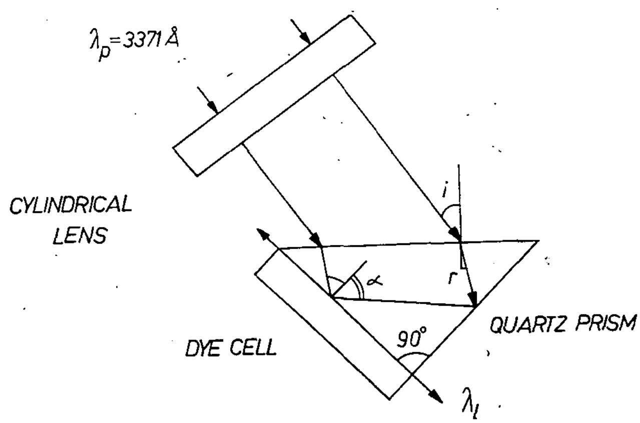

Fig. 4. Experimental arrangement of a N_2 laser pumped DFB laser

laser. The dye cell was 1 cm, the focal length of the cylindrical lens 8 cm, and the angle $i=18°$. The active material was Rhodamine 6G, and the laser emission was obtained at 5800 Å with 1.2 Å bandwidth. The laser emission was tuned by varying the angle i as seen in Fig. 4.

As this type of DFB laser is the simplest of tunable dye lasers, a further investigation seems advisable to reduce threshold and bandwidth.

References

[1] *Hänsch, T. W.:* Applied Optics **11**, 895 (1972).
[2] *Lawler, E., W. A. Fitzsimmons, L. W. Anderson:* Applied Optics **15**, 1083 (1976).
[3] *Myers, S. A.:* Optics Communications **4**, 187 (1971).
[4] *Kogelnik, H., C. V. Shank:* Applied Physics Letters **18**, 152. (1971).
[5] *Chandra, S., N. Takeuchi, S. R. Hartmann:* Applied Physics Letters **21**, 144 (1972).

ИССЛЕДОВАНИЕ СУЖЕНИЯ СПЕКТРА ЛАЗЕРА НА КРАСИТЕЛЯХ ПРИ НАКАЧКЕ АЗОТНЫМ ЛАЗЕРОМ

Б. Рац

В работе обсуждены требования к N_2 лазеру для накачки перестраиваемых лазеров на красителях и приведена надёжная конструкция N_2 лазера. Измерены расходимость и КПД генерации лазера на красителях в неселективном резонаторе. Исследовалось сужение спектра генерации с помощью решетки, призмы и эталона при оптимальных условиях генерации накачки.