GENERATION OF NEARLY TRANSFORM-LIMITED SUBNANOSECOND LIGHT PULSES BY LONG CAVITY DYE LASER

By

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A long cavity dye-laser-amplifier system for generating single subnanosecond light pulses was investigated. The pumping light source was a TEA nitrogen laser with duration of 1 ns. The duration of the pulses obtained of the dye-laser-amplifier system was 155 ps. The spectral bandwidth was narrower than 0.01 nm. The spectrum band was modulated with a period equal to the FSR of a Fabry—Perot interferometer of 3.8 cm spacing. In the dye laser the optical pathlength between the wall of the oscillator cell and the output coupler was equal to this spacing.

From the point of view of spectroscopic applicability, lasers producing light pulses with short duration and narrow bandwidth are preferable. The simultaneous reduction of duration and bandwidth are limited by the Fourier-transform-limit. Up to now, subnanosecond transform-limited light pulses were generated only by mode-locked lasers and distributed feedback lasers. Recently, it has been reported by several authors [1, 2, 3] that nitrogen-laser-pumped dye lasers can generate subnanosecond transform-limited light pulse. The time behaviour of these long-cavity dye lasers are also described [4, 5] by a time-space dependent model. It is interesting to note that in [1, 2, 6] the authors did not distinguish their method from relaxation oscillations, and they used long cavity in order to get narrow linewidth. The effect of cavity length was made clear in [3]. Table I lists the results achieved by long cavity dye lasers.

Fig. 1 shows the experimental arrangement. The pumping source was a TEA nitrogen laser with 250 kW output power and 1 ns pulse-duration. The UV light was divided by a beamsplitter and focussed on to the oscillator and amplifier cell by cylindrical lenses. The application of an amplifier was necessary, because we were not able to produce single pulses with the dye laser. Therefore, with the aid of the amplifier a single pulse was selected from the cavity round-trip-time modulated pulse train. The pumping of the amplifier cell was delayed so (with 2 ns) that the amplifier amplified only the first pulse of the pulse train. The oscillator and amplifier cell was a 1 cm long silica cell, tilted by about 15°. The laser and amplifier dye was Rhodamin 6G $3 \cdot 10^{-3}$ mol/l in ethanol. The output coupler was a 2 mm thick uncoated planparallel glass flat. The distance between the output coupler and the centre of the oscillator cell was 2.7 cm. Lens 1 with a 25 cm focal length was at a distance of 25 cm from the dye cell, and so it reduced the divergence of the light

Table I

Generation of subnanosecond narrow-band laser pulses in nitrogen-laser-pumped dye lesers (The values in brackets are valid in case of single shot)

Authors	Pump pulse duration (*ns*)	Dye laser pulse duration (*ns*)	Time-bandwidth product / Transform limit
S. A. Borgström [6]	4	1	20
R. Wyatt [1]	3	0,6	6 (2,4)
G. Veith—A. J. Schmidt [2]	0,6	0,04	3,6*
B. Rácz et al. [3]	7	0,55	3
The present work	1	0,15	3 (1)

* The above value was calculated by us from the described pulse-duration and linewidth data in [2], but these data may probably not been obtained simultaneously because from Fig. 2 of [2] a larger product than 5 can be calculated for this value.

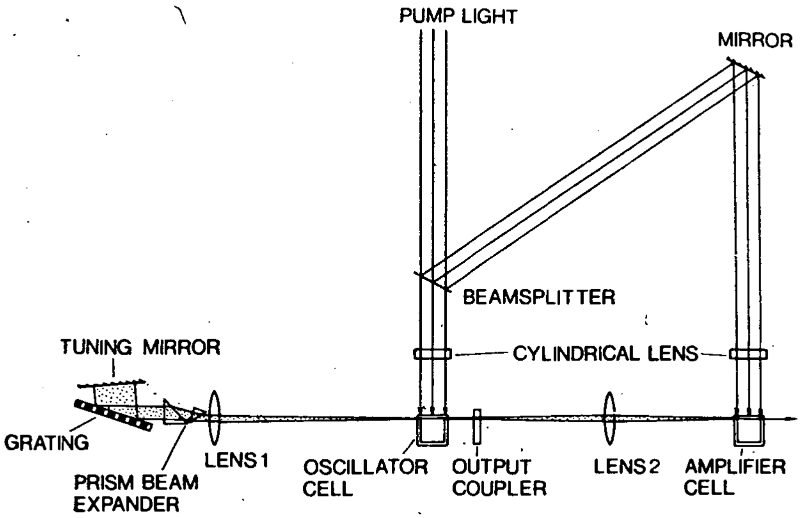

Fig. 1. The long cavity dye laser-amplifier arrangement

coming from the oscillator cell output coupler system to

$$\delta\theta = \frac{a}{f} = \frac{0.02\ \mathrm{cm}}{25\ \mathrm{cm}} = 8 \cdot 10^{-4}\ \mathrm{rad},$$

where $a = 0.02$ cm is the absorption depth of the dye.

Two prism were used as beam expander (×10). The diffraction grating was 1300 lines/mm operating as grating expander with the angle of incidence $\alpha = 67.5°$ and $\alpha = 78°$, respectively. With the above data from the Eq. (7) of [7] the resultant passive bandwidth $\delta\lambda = 0.012$ nm and $\delta\lambda = 0.006$ nm, respectively. The light of the dye laser was focussed by lens 2 ($f = 10$ cm) on the amplifier cell.

The duration of the amplified pulses was measured by one of the usual non-linear optical correlation techniques, using SHG with collinear, identically polarized beams [8] in a phase-matched ADP-crystal. The SH signal was measured and averaged by a LP—20 laser photometer. Assuming a Gaussian pulse shape, a pulse duration of (155 ±25) ps and (228 ±16) ps could be deduced from the measurements of the autocorrelation function if $\alpha = 67.5°$ and $\alpha = 78°$, respectively.

The linewidth of the pulses was measured by a Fabry—Perot etalon of 8 mm spacing. $\delta\lambda = 0.010$ nm and $\delta\lambda = 0.006$ nm linewidths were obtained by taking photographs from an interference pattern of 20 pulses if $\alpha = 67.5°$ and $\alpha = 78°$, respectively. These linewidths well correspond to the above-calculated passive linewidths. The measured time-bandwidth product is 3.1 and 2.9 times the Fourier-transform-limit for a Gaussian pulse. Some of the interference pattern of a single pulse showed a single narrow spectrum line, and the other part of the interference pattern showed a double spectrum line. The linewidth of the single spectrum line was 0.003 nm if both $\alpha = 67.5°$ and $\alpha = 78°$. This linewidth value was the transform-limit-pair of 155 ps, and 1.4 times the transform-limit-pair of 228 ps. The frequency difference of the two lines of the double spectrum line was equal to the FSR of a Fabry—Perot interferometer of 3.8 cm spacing. In the dye laser the optical pathlength between the left wall of the oscillator cell and the output coupler was equal to this spacing.

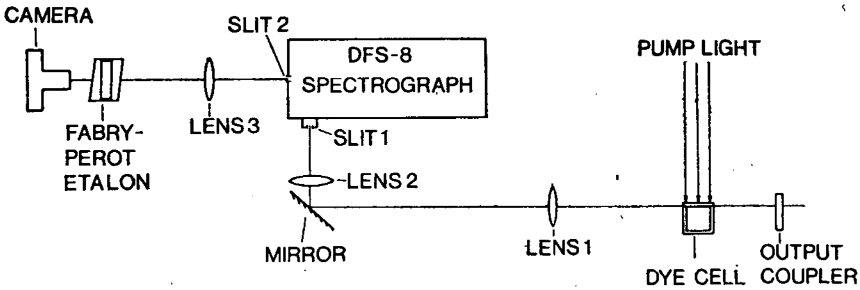

Fig. 2. Experimental arrangement for the measurement of the spectral modulation of the light of the dye cell-output coupler system

We demonstrated that this agreement is no accident using the arrangement shown in Fig. 2. The grating and prism were removed and the light of the dye-cell output-coupler system was focussed by lens 1 ($f_1 = 25$ cm) and lens 2 ($f_2 = 10$ cm) on the entrance slit of DFS—8 spectrograph. The DFS—8 spectrograph had 0.6 nm/mm reciprocal linear dispersion, and was used as a monochromator. The entrance and exit slitwidths were 100 μm. The output of the monochromator was analysed by a Fabry—Perot etalon having a 5 mm spacer. The interference pattern of 800 shots was photographed by a camera having an objective with a focal length of 250 mm. Fig. 3 shows the results of the measurements, where d_{FP} is the spacing of such a Fabry—Perot interferometer, having an FSR equal to that calculated from the interference pattern, and d_G is the — geometrically determined — optical pathlength between the left wall of the dye cell and the right side of the output coupler. Fig. 3 demonstrates that the difference of measured results from the solid line, expressing that d_{FP} and d_G are equal, is smaller than the limit of error. Consequently, the light of the long-cavity dye-laser observed spectrum-line structure is attributable to interference phenomena produced between the wall of the dye cell and the output coupler. On the basis of this, the spectral evolution of our dye laser can be explained as follows: In consequence of the interference phenomena, the Fabry—Perot lines modulated light beam is propagated into the direction of the spectral selective system. From these lines several are selected and fed back to the spectral selective system. Between the FSR of Fabry—Perot "interferometer" $\Delta\nu_{FSR}$ and the selectivity of the spectral selective system $\Delta\nu_{SS}$, obtained the following relation: $\Delta\nu_{FSR} < \Delta\nu_{SS} < 3 \cdot \Delta\nu_{FSR}$. This inequality is valid for the measured value,. too.

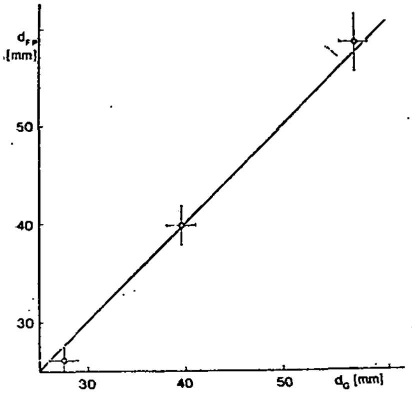

Fig. 3. The distance between the left wall of the cell and the right side of the output coupler measured by Fabry—Perot analyser versus calculated distance

References

[1] *Wyatt, R.:* Opt. Commun. **26,** 429 (1978).
[2] *Veith, G., A. J. Schmidt:* Opt. Commun. **30,** 437 (1979).
[3] *Rácz, B., Zs. Bor, G. Szabó, S. Szatmári:* Acta Phys. et Chem Szeged (to be published).
[4] *Wyatt, R.:* Appl. Phys. **21,** 353 (1980).
[5] *Rácz, B., G. Szabó:* Acta Phys. et Chem. Szeged (to be published).
[6] *Borgström, S. A.:* Phys. Scripta **14,** 92 (1976).
[7] *Shoshan, I., U. P. Oppenheim:* Opt. Commun. **25,** 375 (1978).
[8] *Gloge, D., T. P. Lee:* Appl. Phys. **42,** 307 (1971).

ГЕНЕРАЦИЯ ТРАНСФОРМ-ЛИМИТАЦИОННЫХ ИМПУЛЬСОВ С СУБНАНОСЕКУНДНОЙ ДЛИТЕЛЬНОСТЬЮ ИЗЛУЧЕНИЯ ДЛИНОРЕЗОНАТОРНОГО ЛАЗЕРА НА КРАСИТЕЛЕ

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Исследован длинорезонаторный лазер-усилитель на красителе с целью генерации импульсов с субнаносекундной длительностью. Возбуждающий свет был получен из лазера на атмосферном азоте с поперечным разрядом длительностью 1 нс. Длительность импульсов генерированнихся из лазер-усилителя на красителе был 155 пс. Спектральное уширение импульсов было меньше чем 0,01 нм. Спектр был модулирован периодом постоянной эталона Фабри—Перо, толщиной 3,8 см. Длительность оптического пути в лазере на красителе между стеной и окном осциллятора выла равна этой толщине.