BRIEF COMMUNICATIONS

DYE PICOSECOND PULSE GENERATION WITH SELF-MODULATED Q SWITCHING

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A study has been made of picosecond pulse generation by dye lasers working with heavy gain saturation. Several forms of such laser are proposed that differ in reliability and design. Wide-range adjustment is possible in pulse length and spectrum. Spectrum-bounded pulses of length down to 3.5 psec have been obtained.

Some applications of nonstationary laser spectroscopy require high-power adjustable picosecond pulses derived from one or more pumping ones. In that case, self-initiated Q switching is exceptionally effective. The characteristic features of this method were first presented in detail in [1,2]. The physical basis of the self-modulation method is the provision of heavy gain saturation, and this same nonlinearity may lead to the production of picosecond pulses in lasers having thin or ultrathin cavities [3,4]. Here it is necessary for the effective radiation lifetime in the cavity to be small.

We have examined the production of picosecond pulses not only in thin dye cells but also by the use of an external cavity. The cell containing the dye had the construction shown in Fig. 1a. One wall of the cell served as a mirror of high reflectivity ($R_1 \sim 100\%$) and was in direct contact with the solution, while the other wall is a tapered glass substrate or a mirror of low reflectivity (R_2 about 1-10%).

The following is the picosecond lasing mechanism in such a cell. The pumping pulse λ_p produces an inversion in the dye. The spontaneous noise begins to be amplified within the luminescence band. Only a low quality factor occurs in the cavity formed by the virtually opaque mirror on one side and the weak reflector represented by the solution-glass boundary on the other. The gain is very high, $\alpha l \sim 10^2$ (α is gain and l is cell thickness), so the linear state occurs only in a few passes. Then the gain attains saturation, and the λ_g pulse is produced with a duration approximately equal to the cavity transit time. The pulse length may be a few picoseconds for a cell of thickness a few tenths of a millimeter.

Dye lasing has been examined with the pumping provided by second-harmonic SH pulses from a picosecond YAG laser with passive mode synchronization. A single pulse was isolated by an electrooptic shutter working with a discharge gap, and the pumping pulse length was 50 psec with a peak power up to 600 kW. The lasing

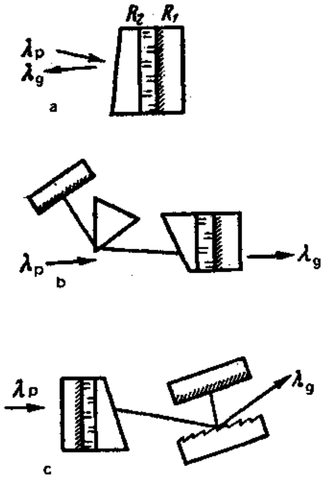

Fig. 1

pulse length was determined by the noncolinear SH generation in the KDP crystal. The background-free autocorrelation function ACF was recorded. Photocells were used to measure the energy and provide analog gates. After selection, the pulses were accumulated in an analyzer. We process 50 pulses for each point.

Figure 2 shows the lasing energy from the cell as a function of pumping power P_p. There is a threshold power above which the cell passes from nanosecond luminescence to lasing. A high-power completely polarized picosecond pulse is then produced. The cavity filled with inverted medium is an active Fabry-Perot interferometer, in which there is effective spectrum selection in the linear stage. Figure 3 shows the lasing spectrum for a cell of thickness 0.10 mm produced slightly above threshold (above by not more than a factor two). The pulse length was measured from the ACF of the SH as 3.5 psec. As the excitation energy increases, the ACF becomes substantially broader, which indicates the production of several pulses per pumping pulse. The product of the spectral width by the duration is $\Delta\nu\Delta t = 0.81$. One can therefore assume that all the spectral components in one mode are correlated. One can tune the lasing band within the peak of the luminescence band either by varying the cavity thickness or by inclining the cell somewhat [5]. The transverse structure corresponds to the TEM_{00} mode.

We used a system with an external cavity (Fig. 1b and c) to tune the lasing line throughout the dye luminescence band. The short pulse produced in the cell was selected on angular and frequency spectra. In the reverse transit, the reflected radiation was additionally amplified, since the population inversion persisted. The output from the laser was a high-power pulse tunable over the spectrum by rotating the opaque mirror. The length of the cavity was 7-12 cm. The dye cells had thicknesses from 0.3 to 12 mm and a slight taper. The pulse lengths were determined by the excess of the pumping over threshold and by the cell thickness. With small excess over threshold, it was found that $\tau_g \sim nl/c$, where n is the refractive index of the dye solution and $c = 3\cdot10^{10}$ cm/sec. For example, cells of thickness 0.3, 4.0 and 12 mm gave pulse lengths measured by means of the SH ACF of 5.5 ± 0.5, 25 ± 3, and 60 ± 5 psec, correspondingly. A diffraction grating in the cavity (Fig. 1c) produced pulses close to spectrally bounded. This is evident from the correspondence between the ACF and the self-diffraction signal in the first order measured by means of a thin film (about 20 μm) of gallium selenide. In the latter case, the width of the curve characterizes the coherence time [6].

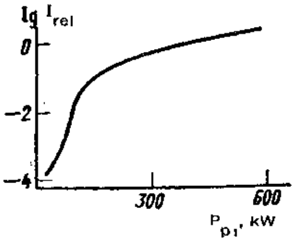

Fig. 2

Fig. 3

Table 1

Radiation source	Wavelength, μm	$\sigma_{\bar{x}}$, %	σ_x, %
YHE-Nd^{3+} laser (single SH pulse)	0,532	1,5	12
Laser cell (C-160 dye)	0,60÷0,62	2,0	15
Laser with external cavity (C-160 dye)	0,60÷0,65	3,0	30

The response to each pumping pulse was a burst of three picosecond pulses of decreasing amplitude separated by the cavity transit time. The burst is due to cavity echo.

The efficiency in converting the SH to tunable radiation was up to 2% (diffraction grating as opaque mirror) or 15% (100% mirror) in energy for dye C-160 with τ_g = 25 psec.

Pulse energy stability is important to the practical use of these lasers. Table 1 gives the standard deviation σ_x and standard error of the mean $\sigma_{\bar{x}}$ for the pulse energy.

High energy stability was also observed in systems employing structures with distributed feedback [7] working with self-modulated Q. The stability occurs because of the heavy gain saturation.

We have therefore examined the production of tunable picosecond pulses in a dye laser with single-pulse excitation. Several forms of such device are described, which are simple in design but differ in reliability. Spectrally bounded pulses of duration down to 3.5 psec have been obtained.

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