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Abstract

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AN OPTICAL GENERATOR BASED ON $CaF_2 : Dy^{2+}$ OPERATING IN THE REGIME OF REPETITIVE GIANT PULSES UNDER CONTINUOUS PUMPING

Generation of giant pulses in $CaF_2 : Dy^{2+}$ was first achieved in work (1), where a ruby laser served as the excitation source. We have realized a regime of generation of repetitive giant pulses in $CaF_2 : Dy^{2+}$ under continuous pumping by xenon lamps. Q-switching was carried out by means of a rotating prism. A similar technique for obtaining giant pulses in YAIG : Nd was used in work (2).

The layout of the setup on which the experiments were carried out is shown in Fig. 1.

The $CaF_2 : Dy^{2+}$ crystal was fabricated in the form of a cylinder 70 mm long and 7 mm in diameter, with plane-parallel end faces. The concentration of Dy^{2+} in CaF_2 was $\sim 10^{17}$ cm^{-3}. Cooling of the crystal, mounted in a Dewar, was carried out by flowing supercooled liquid nitrogen. Optical pumping of the crystal was produced by means of two continuously burning xenon lamps, enclosed together with the Dewar in a tight illuminator.

Fig. 1. Layout of the setup. 1 —$CaF_2 : Dy^{2+}$ crystal; 2 —continuously burning xenon lamps; 3 —multilayer dielectric coating; 4 —rotating total-internal-reflection prism; 5 —plane-parallel quartz plate, extracting radiation from the resonator; 6 —calorimeter; 7 —radiation detector (InSb photodiode).

One of the resonator mirrors was a multilayer dielectric coating deposited on one of the end faces of the crystal. The reflection coefficient of this mirror was $\sim 100\%$. As the second, external mirror of the resonator, a quartz total-internal-reflection prism was used, which could be installed motionless relative to the

Fig. 2

Figure 2: Fig. 2

crystal or rotated at a frequency adjustable from 50 to 500 Hz.

Radiation was extracted from the resonator by means of a plane-parallel quartz plate (angle of incidence 23°) and fell simultaneously on a calorimeter and on an InSb photodiode placed in liquid nitrogen and having a time resolution of $\sim 20 \cdot 10^{-9}$ sec.

The average radiation power was measured with the calorimeter. The dependence of the radiation intensity on time was recorded by means of an InSb photodiode and DEO-1 and S1-11 oscillographs. The average radiation power, in both directions (see Fig. 1), measured with the prism installed motionless, was 0.05 W. The average radiation power at the same pump power, but with the prism rotating at a frequency of 200 Hz, also proved to be 0.05 W. The equality of the average powers in both operating regimes ···

operation of the oscillator indicates that the prism rotation frequency is close to the optimum frequency $f \sim 1/(2 \div 3)\tau_{\Lambda}$, where $\tau_{\Lambda} \simeq 20$ msec is the lifetime of the Dy^{2+} ion in the excited state (^{7}).

In this case the radiation was a regular sequence of pulses with a repetition frequency of 200 Hz and a duration of each pulse $\tau = 1.2 \cdot 10^{-7}$ sec.

Oscillograms of the laser radiation in the modulated-Q regime are shown in Fig. 2.

Fig. 2. *a*—oscillogram of repeated giant pulses under continuous pumping; pulse repetition frequency 200 Hz, time constant of the recording device ~ 5 μsec. *b* —oscillogram of a giant pulse; sweep speed 0.25 μsec/cm, resolution time ~ 20 nsec.

From measurements of the average radiation power in the modulated-Q regime and of the pulse duration τ, we find the peak radiation power P in a pulse:

$$P = P_{\mathrm{av}}/\nu\tau = 2 \cdot 10^{3}\ \mathrm{W},$$

where $P_{\mathrm{av}} = 0.05$ W is the average power, $\nu = 200$ Hz is the pulse repetition frequency, and $\tau = 120 \cdot 10^{-9}$ sec is the pulse duration.

On the basis of existing theories of giant-pulse formation ($^{3-5}$), one can estimate the duration of a giant pulse by using the approximation of instantaneous switching-on of the Q. For this it is sufficient to know the ratio of the initial inversion n_i to the threshold inversion n_p (^{4,5}). The threshold inversion n_p is found by calculation from the formula

$$n_p = \gamma / l\sigma = 1.7 \cdot 10^{15} \text{ cm}^{-3},$$

where $l = 7$ cm is the length of the crystal, $\sigma = 5 \cdot 10^{-18}$ cm^2 is the effective cross section of the Dy^{2+} ion at the lasing frequency (see (^{6}), Table IV, $T = 78$°K), and $\gamma = 0.06$ is the resonator loss parameter (^{8}). In calculating the parameter γ, it was assumed that there were no internal losses in the resonator.

The initial inversion n_i can be estimated from the energy E of the radiation in one pulse

$$E = \frac{1}{2}\hbar\omega V(n_i - n_p).$$

For $E = 2.5 \cdot 10^{-4}$ J, $\hbar\omega = 0.84 \cdot 10^{-19}$ J, $V = 2.8$ cm^3, the initial inversion is $n_i = 3.8 \cdot 10^{15}$ cm^{-3}. For $n_i/n_p = 2.2$ and a resonator length $L = 50$ cm, the calculated pulse duration according to formulas (5)

$$\tau = \frac{2.5}{\sqrt{\varphi_m/n_p}}\frac{L}{c\gamma}, \qquad \varphi_m = (n_i - n_p) - n_p \ln(n_i/n_p)$$

turns out to be $105 \cdot 10^{-9}$ s, which is in good agreement with the experimental value of τ (see Fig. 2).

It should be noted that the creation of high-intensity sources of monochromatic radiation at a wavelength of 2.36 μ is of interest for a number of physical and chemical studies. In particular, with the aid of this laser it is proposed to investigate two-photon excitation of semiconductors with a narrow forbidden band.

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Note: Figure translations are in progress. See original paper for figures.