INVESTIGATION OF PARAMETRIC GENERATOR WITH FEEDBACK IN ONLY ONE OF THE WAVES

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Recent investigations show that parametric light generators (PLG) can be used as powerful sources of coherent radiation with tunable frequency and a large conversion coefficient. However, the establishment of a quasistationary state at a signal-wave power conversion coefficient η_p of approximately 20% was observed only in PLG with feedback in the two generated waves [1,2]. In systems with feedback in only one of the waves, on the other hand, the quasistationary state was not attained and η_p did not exceed 6% [2]. At the same time, PLG with feedback in one wave can occasionally have certain advantages, for example the possibility of a smoother tuning [2,3] and a larger maximum conversion coefficient [3,4]. In addition, the problem of reducing the width of the radiation spectrum of a PLG with a large conversion coefficient to a value lower than one reciprocal centimeter has not yet been solved.

In this paper we present the results of an experimental investigation of a PLG with feedback in the idling wave only; the investigation demonstrates the possibility of obtaining conversion coefficients η_p up to several dozen per cent in such systems, at sufficiently small widths of the frequency spectrum. It follows from the estimates that to obtain a small spectral width it is necessary for the waves to pass through two interaction regions in the PLG resonator.

The investigated PLG operated with a KDP crystal in the nondegenerate regime. The reflection coefficient did not exceed 10% for the signal wave and amounted to practically 100% for the idling wave, although the feedback coefficient R_2 was approximately 60% for the idling wave, owing to absorption and reflections. The pump was the second harmonic of a neodymium laser operating with a saturable shutter in the single-frequency regime without transverse-mode selection. The pump radiation beam, with energy 0.05 - 0.2 J, was reduced to half-size by a telescope, to approximately 4 mm diameter. The waveform of the pump radiation pulses at the input and output of the PLG were registered with an I-2-7 oscilloscope receiving input pulses, at different delays, from appropriately arranged FEK-le coaxial photocells. The resolution time of the system did not exceed 2 nsec. We measured separately the energy W_{p1} of the pump pulse at the input to the PLG. Simultaneously with these measurements, we

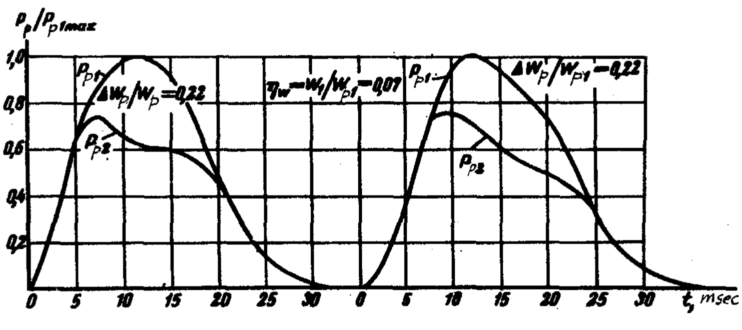

Fig. 1. Characteristic time dependences of the pump power at the input (P_{p1}) and output (P_{p2}) of the PLG.

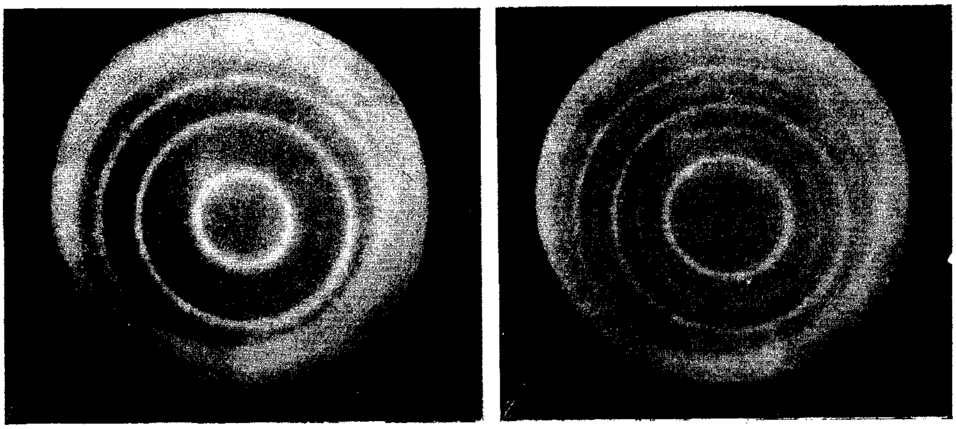

Fig. 2

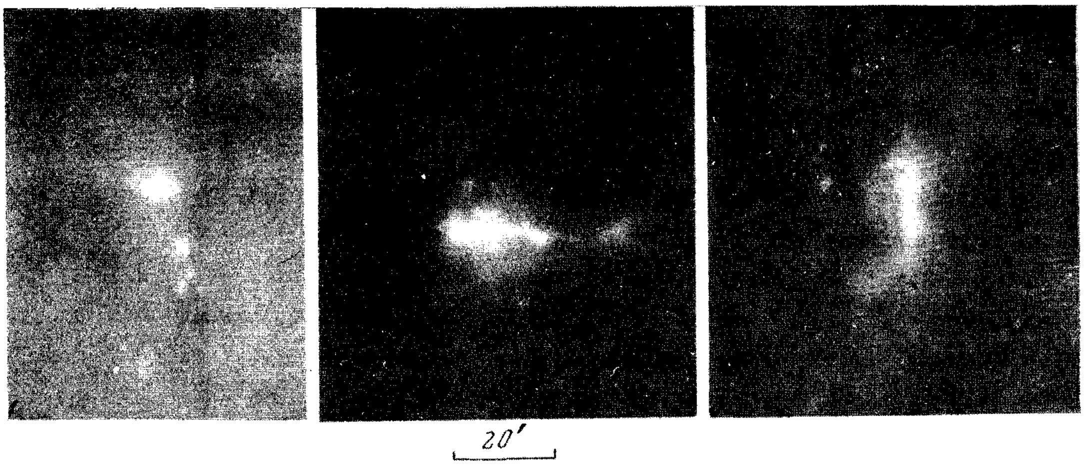

Fig. 3

Fig. 2. Characteristic radiation spectra of the signal wave at a distance of 5 mm between the Fabry-Perot interferometer mirrors.

Fig. 3. Three types of directivity patterns of signal-wave radiation: 1 - directivity pattern in the case when waves are generated with one-dimensional interaction; 2 - when different types of modes are excited in the plane of the wide synchronism angle; 3 - when different types of modes are excited in the plane passing through the pump-beam axis and the optical axis of the crystal (plane of the narrow synchronism angle).

could register the radiation energy of the signal wave W_1 (by means of an IEK-1 meter), the waveform of its pulse (using an S-1-11 oscilloscope with a signal from an FEU-22 photomultiplier), and the cross section of its beam. An investigation of the frequency spectrum of the radiation of the signal wave or of its directivity pattern could be carried out instead of registering its power, pulse waveform, and beam cross section.

The threshold pump energy W_{p1} was 0.05 - 0.07 J (the power threshold was 3 - 5 MW). When this value was exceeded by 1.5 - 2 times, the signal-wave energy conversion coefficient η_W reached 7%. The waveform of the pump radiation pulse passing through the PLG resonator differed greatly in this case from the waveform of the input pulse (Fig. 1), and the change of the pump energy ΔW due to the nonlinear processes amounted to 22% of W_{p1}. The peak radiation power of the signal wave was not measured directly. It is obvious, however (this follows also from the relations of [4]), the η_p could be estimated from the formula $\eta_p \geq \Delta P \bar{P}_{p1}^{-1}(\eta_W W_{p1} W_{p2}^{-1})$ 1). Here $\Delta P = (\bar{P}_{p2} - \bar{P}_{p1})$ is the pump radiation power difference between the input and the output of the PLG, connected with the generation process, after the quasi-stationary regime is established, and $W_{p2} = (W_{p1} - \Delta W)$. From the data shown in Fig. 1 we find that $\eta_p \geq 14\%$. This agrees with the estimate of η_p based on the measurement of the signal-wave pulse duration τ_1, which turned out to be approximately half the duration of the pump pulse τ_p ($\eta_p \simeq \eta_W \tau_W \tau_1^{-1} \simeq 14\%$).

The difference in the character of the change of the pump pulse waveform at the PLG output in different experiments, and the fact that η_p is smaller by a factor 2 - 3 than the theoretical value [4], are apparently connected with the inhomogeneity of the pump beam and the existence in some cases of certain generation regions. This is confirmed by an investigation of the structure of the signal-wave radiation beam, which could be divided into two types. The radiation of the first type was a beam of regular shape, with approximately 2.5 mm diameter. The power flux density reached in these cases 50 mW/cm^2. The photographs of the beam cross section of the second type consisted of sets of spots of irregular shape.

The signal-wave radiation spectrum consisted in most cases of one or two lines (Fig. 2). The width of each individual line did not exceed 0.1 cm^{-1}. The distance between lines ranged from a fraction of an **Angstrom** to several Angstroms. The directivity patterns of the signal-wave radiation in individual experiments can be grouped in three types (Fig. 3).

This character of the frequency and angular radiation spectrum can be explained as follows. From the frequency dependence of the mode increment, obtained in [3] for one-dimensional interactions in a PLG with one interaction zone, it follows that the spectrum width $2\Delta\omega$ should be not smaller than 2 - 4 cm^{-1} in such a PLG 2). In our case, however, the waves passed through two interaction zones separated by a region in which their phase difference was linearly dependent on the frequency. This circumstance makes the dependence of the mode increment on the frequency more rapid, as a result of which, as shown by estimates, the width of the spectrum in one-dimensional interaction should decrease to a fraction of a reciprocal centimeter. The appearance of lines separated by an interval of several Angstroms in the generation spectrum is apparently connected with the excitation of waves with an essentially non-one-dimensional interaction (photo 3 in Fig. 3), in spite of their partial selection by the weakly-reflecting surfaces in the PLG resonator. It should be noted that the use of wave transmission through two interaction regions with crystal axes oriented in a definite manner (for example,

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1) The equal sign should be used, obviously, only if no pump energy is lost to absorption and reflection from the PLG resonator.

2) The estimate can be based on the formula for a rectangular pump pulse at a large gain $(\gamma_0 l > 1)$

$$2\Delta\omega = 4\gamma_0 |v_1^{-1} - v_2^{-1}| [2(\gamma_0 l + \ln(R_2/2))(\gamma_0 l - 1)^{-1}(P_0\tau_c)^{-1}]^{1/2}.$$

Here v_i - group velocities of the waves, $(P_0\tau_c)$ - gain of the central mode during the time of establishment of the stationary state τ_c, l - length of interaction region, and γ_0 - wave-interaction coefficient, corresponding to the peak value of the pump-power flux density S_0 $(\gamma_0 = \bar{\chi}\sqrt{S_0})$.

a double pass through one crystal after reflection of the waves from the mirror) makes it possible in principle to suppress the generation of waves with two-dimensional interaction (inasmuch as synchronism in both passes occurs only for one-dimensional interactions). Thus, the results presented above demonstrate the possibility of producing a PLG with a large conversion coefficient and large power at a small width of the radiation spectrum.

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INVESTIGATION OF THE TEMPORAL STRUCTURE OF NEODYMIUM-LASER EMISSION IN THE MODE SELF-LOCKING REGIME

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The development of lasers with mode locking and self-locking [1,2] has confronted experimenters in quantum electronics with the task of measuring time intervals of duration $\sim 10^{-12}$ sec. The time resolution of oscillographic procedures is presently limited to $\sim 3 \times 10^{-10}$ sec, i.e., at least two orders of magnitude lower than the required value. An original procedure proposed in [3,4] has demonstrated that short durations can be measured by nonlinear-optics methods. Nonetheless, methods of measuring the durations of light pulses, based on the observation of nonlinear optical effects, do not make it possible, in their present form, to determine uniquely the temporal structure of the radiation [5]. Naturally, a direct answer to this question can be obtained only by a direct measurement method, and such a method, in our opinion, is electron-optical high-speed photography. While the experimental temporal resolution of this procedure, $\sim 10^{-11}$ sec [6], does not make it possible to measure the duration of ultrashort pulses (we can estimate only the upper limit of their duration), it does make it possible to solve many problems.

In this paper we dwell essentially on the question of the temporal structure of the generation of a neodymium laser operating in the mode self-locking regime with Q switching by means of a saturable filter. We also compare the results obtained by investigating the same laser with the aid of an electron-optical camera and by the method of two-photon luminescence.

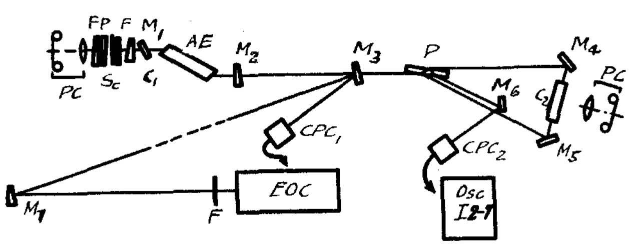

Fig. 1. Diagram of experimental setup.

The experimental setup, which makes it possible to register simultaneously the temporal and spectral characteristics of the neodymium-laser emission, is shown in Fig. 1. Here M_1 and M_2 are the resonator mirrors, which are coated on wedge-like substrates (~5°), with reflectances 99 and 50% respec-