RING RUBY LASER FOR ULTRASHORT PULSES

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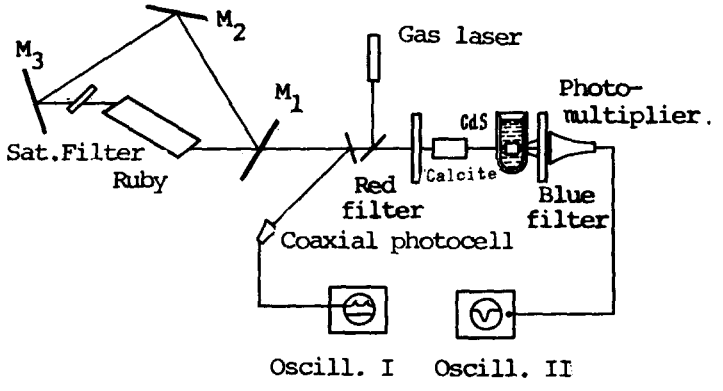
Pulsed lasers operating in the mode-synchronization regime have attracted much attention of late [1,2]. The output emission of such lasers is a sequence of very short light pulses with very large peak power. The use of such lasers will apparently make it possible to formulate anew many problems in the field of nonlinear optics and multiphoton processes in engineering.

Light pulses of duration $\Delta t = 2 \times 10^{-12}$ sec have been obtained by now in lasers using glass and garnet with neodymium. The luminescence line width of ruby makes it possible, in principle, to obtain pulses of duration on the order of 10^{-11} sec [3]. According to the literature data, however, no such duration has yet been realized in ruby lasers.

Diagram of experimental setup



We present in this paper the results of measurements of the characteristics of a ring ruby laser, in which the mode symchronization was effected with a saturating filter based on a solution of cryptocyanine in ethyl alcohol. A diagram of the experimental setup is shown in the figure. The ruby rod was 120 mm long and 15 mm in diameter, and its ends were cut at the Brewster angle. The traveling-wave generator resonator was made up of a system of three mirrors with reflection coefficients $R_2 = R_3 = 0.96$ and $R_1 = 0.72$. A cell 3 mm thick containing the saturating filter, with initial transmission coefficient 0.77, was mounted at the Brewster angle.

An oscillographic investigation of the output signal, performed with an FEK-15 photocell and a high-speed oscilloscope, showed that the radiation consisted of a series of pulses spaced $L/c = 6$ nsec apart, where L is the resonator length. The real duration of the individual pulses could not be estimated, since the signal observed on the oscilloscope had a duration equal to the time constant of the registration system, 0.4 nsec.

In [4-6] they used an original duration-measurement method involving a superposition of two time-shifted light pulses. The method is based on the quadratic dependence of the power of the second harmonic (generated with the aid of GaAs, KDP, or ADP) on the incident-radiation power.

In our investigation, the nonlinear element needed for the measurement of the duration of the pulses generated by the ruby laser was a semiconducting CdS crystal in which the luminescence at 0.49 μ wavelength was produced by two-photon excitation of the ruby-laser emission [7]. Thus, we made use of the quadratic dependence of the CdS crystal luminescence power on the power of the exciting ruby laser.

The time delay was produced by an Iceland spar crystal cut perpendicular to the optical axis. The crystal was so oriented that the angle between its optical axis and the plane of polarization of the ruby emission was 45°.

With such a geometry, the radiation was split into ordinary and extraordinary waves of equal intensity, propagating in the spar at different velocities, and the relative time shift between two pulses amounted to 0.57×10^{-11} sec/cm.

The CdS radiation was registered with the aid of an FEU-36 photomultiplier used in conjunction with an S1-29 oscilloscope. The measurement result has shown that a photomultiplier signal reduction by one-half, corresponding to a relative shift of the pulses by an amount equal to the total pulse duration, occurs when the spar is 2.5 cm thick. This yields for the duration a value $\Delta t = 1.4 \times 10^{-11}$ sec. There was no control of the ruby-laser power simultaneously with the measurements with the spar, since numerous observations of the CdS radiation signal have shown that the generator radiation power did not change during a sequence of 5 - 7 flashes.

The registration of the CdS radiation with the aid of a photomultiplier and a low-frequency oscilloscope makes it possible to measure the "average" pulse duration in the series.

Preliminary results of measurements with high-speed registration show that the pulse duration changes from the start to the end of the run by not more than a factor of 1.5.

Simultaneous measurement of the spectral width of the ruby emission with the DFS-8 instrument yielded a value $\Delta\nu = 3.7$ cm^{-1}, which agrees well with the measured pulse duration $\Delta t = 3/\pi\Delta\nu \simeq 0.9 \times 10^{-11}$ sec. Inasmuch as the distance between the longitudinal modes was $\omega\Omega = 1/L = 0.0055$ cm^{-1}, it can be concluded on the basis of these measurements that synchronization of $N \simeq 670$ longitudinal modes occurs in the investigated generator. Calorimetric measurements of the emission energy yielded a value $E = 0.25$ J. Since the total number of pulses in the series was $\simeq 10$, an estimate of the peak power yields a value $P = 2.5 \times 10^{9}$ W.

We also measured the divergence of the ruby ring laser operating in the mode-synchronization regime. To this end, the laser radiation was focused with a lens of $F = 100$ cm and measured with a calorimeter. The measurements showed that 75% of the entire radiation energy is emitted in an angle of 3'.

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NEGATIVE PARTIAL MOLAR VOLUME OF SOLVENT IN DILUTE CRITICAL PHASES OF A BINARY SOLUTION

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It is known that in dilute solutions the partial molar volume of the solvent v_1^* is usually close to the molar volume of the pure solvent and becomes comparable with it in the limit when $N_2 = 0$; this limit, naturally, does not depend on the path along which the molar fraction N_2 of the dissolved substance vanishes:

$$\lim_{N_2 \to 0} v_1 = v_1^0 \tag{1}$$

We shall show that this general statement is incorrect at least in one case. Indeed, let us write down the general expression for the partial molar volume

$$\bar{v}_1 = v + N_2 \frac{(\partial p / \partial N_2)_{v,T}}{(\partial p / \partial v)_{T,N_2}}. \tag{2}$$

Al all finite $(\partial p/\partial v)_{T,N_2}$ and $(\partial p/\partial N_2)_{v,T}$ this expression yields (1) in the limit as $N_2 \to 0$, but in the case when one of these derivatives has a singularity, further investigation is necessary [2]. We know that at the critical point of the pure substance $(\partial p/\partial v)_T = 0$. This means that the limit of v_1 as $N_2 \to 0$ can differ from $v_{1,cr}^0$ in different manners, depending on the path along which the critical point of the pure solvent is approached. Two of us (L. A. M. and E. S. S.) obtained p-v-T-N data for binary dilute solutions of carbon dioxide (solute) in sulfur hexafluoride (solvent). From these data we calculated the partial molar volumes of the solvent for the initial section of the critical liquid-vapor equilibrium curve, i.e., for dilute critical phases [3]. The partial molar volume of the solvent for these phases was not only not close to the molar volume of the pure solvent but, varying along the critical curve, it was not comparable with the molar volume even in the limit, at the critical point of the pure solvent.

In the dilute critical phase, the partial molar volume of sulfur hexafluoride is so far from the molar volume of the pure sulfur hexafluoride, that it even has a negative value [3]. According to Eq. (1), of course, the partial molar volume of the solvent in