MODE SELF-SYNCHRONIZATION IN GIANT PULSE OF A RUBY LASER WITH BROAD SPECTRUM

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Interest in mode self-synchronization in lasers with passive shutters [1-3] is continuously increasing in connection with the potential feasibility of obtaining ultrashort light flashes by this method. One of the main problems, besides ensuring full synchronization of all the excited axial modes with the aid of the passive shutter, is to excite a maximum number of axial modes, in other words, to obtain a maximum width $\Delta\nu$ of the laser emission spectrum, since it is precisely this width which determines (if all the axial modes of this spectrum are synchronized) the limiting duration $\tau_{lim} = 1/c\Delta\nu$ of the light flashes (c = speed of light).

We report here observation of mode self-synchronization in the giant pulse of a ruby laser whose emission spectrum was narrower by only a factor 3-4 than the spontaneous-luminescence line. Our earlier investigations of the spectral and temporal characteristics of a neodymium-glass laser with passive shutter [4] have enabled us to estimate the influence of mode discrimination by various resonator elements on the spectral composition of the radiation. By eliminating such discrimination through the use of resonator mirrors on wedge-shaped backings, and by mounting the active rod and the saturable filter at the Brewster angle, we obtained with a neodymium-glass laser a giant pulse with a continuous spectrum of width $\Delta\nu = 50 - 80$ cm^{-1} (at a spontaneous-luminescence line width $\sim$250 cm^{-1} [5]).

We have therefore undertaken, using the same method to eliminate the mode discrimination, to obtain mode self-synchronization in a ruby laser having a spectral width close to the width of the spontaneous-luminescence line, $\sim$10 cm^{-1} [6]. We have accordingly used the following experimental setup: A ruby rod of 15 mm diameter and 120 mm length, having plane-parallel end surfaces cut at the Brewster angle to the resonator axis, was placed near the output mirror R_2. The mirror reflection coefficients at the emission wavelength were $R_1 = 0.86$ and $R_2 = 0.55$. The mirror backings were glass wedges with angle $\sim 3.6°$. A cell with a solution of cryptocyanine in nitrobenzene (passive shutter) was placed near R_1 and was inclined to the resonator axis at the Brewster angle. The transmission coefficient of the solution at the working wavelength was 38%. The optical length of the resonator was L = 850 mm. A diaphragm of 4 mm diameter was mounted inside the resonator. The divergence angle exceeded the diffraction angle by a factor 4-5. The emission spectrum was investigated with a Fabry-Perot interferometer with plate separation t = 1 mm and with resolution not worse than 0.25 cm^{-1}. In addition, the emission was registered simultaneously by an FEK-09 coaxial photocell, the signal from which was fed to the tube of an I2-7 oscilloscope.

Under the experimental conditions indicated above, the width of the giant-pulse spectrum was $\Delta\nu \sim 3$ cm^{-1} (Fig. 1), corresponding to simultaneous excitation of approximately 500 modes. A time sweep of the giant pulse shows a train of individual pulses of duration $\tau_p \approx 0.8$ nsec (Fig. 2) spaced a distance T = 5.7 nsec $\approx$ 2L/c apart, thus indicating the presence of mode synchronization. The total duration of the giant pulse was 50 - 70 nsec, and the output energy was 0.2 J.

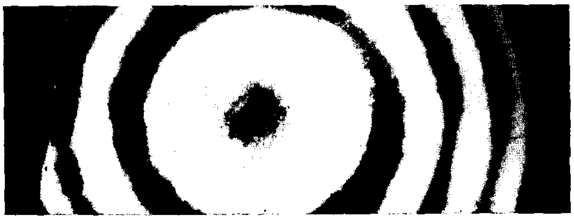

Fig. 1. Interference pattern of emission spectrum of a ruby laser with passive shutter (t = 1 mm).

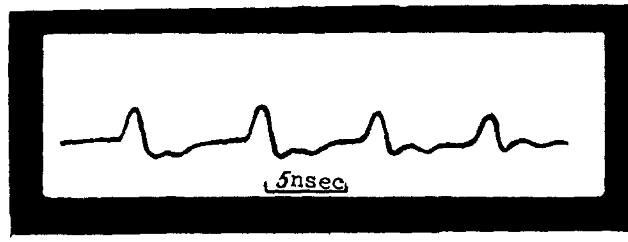

Fig. 2. Time sweep of giant pulse. The oscillogram was retouched in order to improve the contrast.

It must be noted that the pulse duration measured by us, $\tau_p \approx 0.8$ nsec, is apparently determined by the resolution of the recording system*, whereas the limiting pulse duration, at a spectral width $\Delta\nu = 3\ \text{cm}^{-1}$ and under the condition that all the axial modes of the investigated spectrum are synchronized, would amount to $\tau \approx 10^{-11}$ sec, with a corresponding peak power $\sim 2 \times 10^9$ W.

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*This is also evidenced by the fact that investigations of self-synchronization in a neodymium-glass laser with a broader emission spectrum ($\Delta\nu = 50 - 80\ \text{cm}^{-1}$) have revealed pulses of the same duration when the same experimental setup was used.

EXPERIMENTAL INVESTIGATION OF STIMULATED LIGHT SCATTERING IN THE WING OF THE RAYLEIGH LINE

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A powerful light beam of a giant ruby-laser pulse propagating through a medium consisting of anisotropic molecules gives rise to stimulated scattering of light in the wing of the Rayleigh line (SRWS) [1].

A theory [2] developed for plane waves shows that if the Stokes and anti-Stokes components of the scattered light do not interact, then the anti-Stokes component in SRWS is attenuated, and the Stokes component increases, when the threshold indicated in [1,2] is exceeded, in accordance with an exponential law with a coefficient [2]

$$g = -2K_\omega + A|K_1||E_0|^2 \frac{\Omega\tau}{1 + \Omega^2\tau^2}, \quad (1)$$

where $A = \varepsilon_2/2\,\varepsilon_0$ is a constant for any given substance [2], $\vec{K}_1$ is the wave vector of the