Resonatorless generation of a giant laser pulse

O. P. Zaskal'ko and I. G. Rudoĭ
P. N. Lebedev Physics Institute, Academy of Sciences of the USSR, Moscow

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Resonatorless generation has been arranged in a ruby laser with feedback through molecular light scattering in an optically transparent medium. Lasing was achieved in two types of operation: single-pulse free-running generation due to thermal Rayleigh scattering and giant pulse generation due to stimulated Brillouin backscattering of the free-running generation.

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In this letter we report generation in a ruby laser which does not have an optical resonator, in the customary sense of the term (one of the mirrors is missing), and in which feedback is arranged through molecular scattering of light by a liquid in the position of the missing mirror. We have studied the spectral, temporal, and energy characteristics of the laser output. Two types of generation have been achieved experimentally.

1. In the first type of operation, a ruby rod with Brewster-angle ends lies between a dielectric mirror (reflectance $r = 0.95$) and an acetone-filled cell (50 cm long). The cell windows are skewed 8° from the cell axis. The light from the ruby is focused into the cell by a spherical lens with a focal length of 20 cm. The beams of ruby light reflected from the cell and the lens are directed away from the ruby. The output energy of this laser is 8 J at a pump energy of 9 kJ. An oscilloscope trace of the output

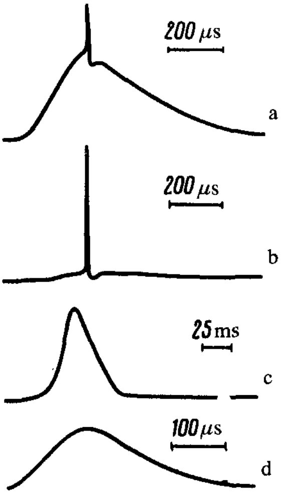

FIG. 1. Oscilloscope traces of the light detected. a,b—Short pulse against the background of the superradiance at two sensitivity levels; c—giant pulse; d—free-running single pulse.

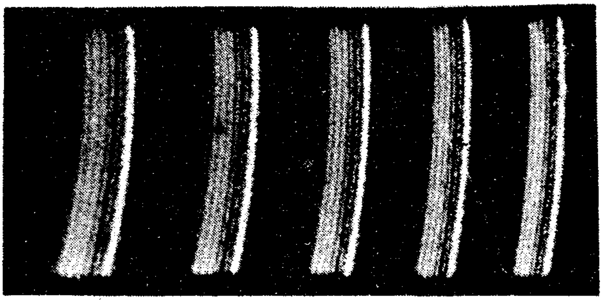

FIG. 2. Interference pattern corresponding to traces a and b in Fig. 1. The dispersion region of the Fabry-Perot interferometer is 2.5 cm^{-1}.

[Figs. 1(a) and 1(b)] reveals a smooth superradiance pulse ~500 μs long, at whose intensity maximum there is a short peak, much more intense, which saturates the detection systems. The width of this short pulse at half-maximum is about 40 ns [Fig. 1(c)]. The output spectrum reveals five or six equidistant narrow lines which are spaced at a distance equal to the shift of the component of stimulated Brillouin backscattering in acetone (Fig. 2). The outer line on the anti-Stokes side has considerably more blackening than the other lines.

In our experiments the ruby rod was of low optical quality. The divergence of the "ordinary" free-running beam (from a resonator consisting of two mirrors and an active element) is 10 mrad. The divergence of the giant pulse on the side of the dielectric mirror, on the other hand, is less than 1.5 mrad. In our case, therefore, the giant pulse generation is accompanied by a cancellation of the distortions introduced in the transverse structure of the beam by the active element.

The mechanism for the appearance of the giant pulse in our case can be described in the usual way[1]: First there is free-running generation, which excites the stimulated Brillouin scattering. The appearance of the stimulated Brillouin light in the focal plane of the lens is equivalent to the appearance of a nonlinear mirror, causing a Q modulation. Since the axial period of the resulting resonator (for which the second mirror is the focal region of the lens) is about 7 ns, the number of stimulated-Brillouin-scattering components observed agrees well with the first measurement of the length of the giant pulse.

We believe that the free-running generation here results from a feedback due to thermal Rayleigh scattering in the acetone. The effective reflection coefficient of this reflection due to the thermal scattering is $R_1 \cong 7\times10^{-6}$. Consequently, the measured gain per back-and-forth passage through the ruby, $G_1 = 2\times10^5$, is sufficient to reach the threshold for this free-running generation: $G_1 \gtrsim 1/(\Gamma R_1)$. From this standpoint, the most intense component in the spectrum (Fig. 2) corresponds to the time-integrated free-running light, while the other lines correspond to components of the stimulated Brillouin scattering which is subsequently excited during the development of the giant pulse.

2. In the second type of operation, only the free-running generation is excited. In this case there is no focusing into the acetone-filled cell, and two ruby rods are used.

The gain per back-and-forth path in the active elements is $G_2 = 2\times 10^8$, and at a reflection coefficient $R_2 \sim 10^{-8}$ for a reflection from the scattering volume free-running generation occurs, $G_2 > 1/(K_2 r)$, at a pump energy of about 14 kJ with a width of 250 μs at half-maximum [Fig. 1(d)].

If the scattering medium is removed from the cell, and the pump energy is held constant, we detect superradiance from the ruby rods with an energy up to 1 J, an width of 800 μs at half-maximum, and a spectral width $\Delta\omega = 1.9$ cm^{-1}. This contraction of the superradiance spectrum, $\Delta\omega = \Delta\omega_0\sqrt{\ln 2/\ln G_2}$, where $\Delta\omega_0 = 11$ cm^{-1} is the half-width of the luminescence line, agrees well with the back-and-forth gain measured by us in the active element.

Comparison of these results shows that the light detected by us is a free-running single pulse with a power of 20–30 kW, roughly 30 times the superradiance power. The apparent reason for the single-pulse nature of the generation here is the nonresonant nature of the feedback.[2]

The resonatorless feedback achieved in these experiments can be used in high-gain systems to produce both free-running single pulses and giant pulses.

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