Anomalous backscattering of optical radiation in a stratified solution

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Temperature-selective generation of a powerful pulse, initiated by seed laser radiation, is observed. The experiment is performed with a system that includes a regenerative amplifier and a cell containing the solution (water–γ–collidine), in which the scattering provided the feedback.

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1. In this paper we describe an experiment, arranged according to the scheme in Fig. 1, for investigating the optical properties of stratified liquid solutions (see, for example, Ref. 1). The pulsed radiation [ruby laser (RL) pulse with duration 1 ms and energy 1 J] was directed into a cell (C) with the γ–collidine–water solution at the critical concentration. From the cell, the radiation entered a ruby amplifier (A) through a lens L_2, which was the active element inside the cell. A selector, formed by a stack of plane parallel plates, was located at the amplifier output. The amplifier axis was turned relative to the RL beam. A diaphragm (D), which prevented the RL beam from falling directly on the selector, was located in front of the selector. Thus the intitiating radiation did not participate in the process of exciting the amplifier. The spectral, temporal, and energy parameters of the output radiation of the amplifier were

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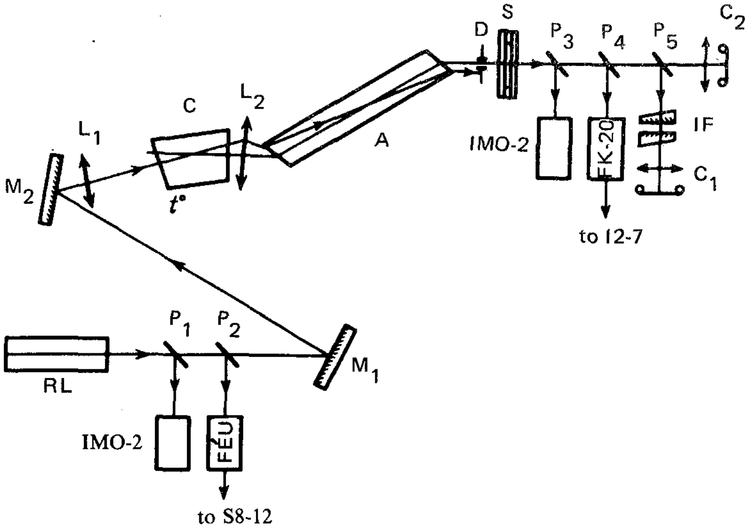

FIG. 1. Experimental setup. RL—Ruby laser ($E_{out} \sim 1$ J, $\tau_{imp} \sim 10^{-3}$ s; P_1–P_5 are dividing plates; L_1 is a lens with $f = 100$ cm; L_2 is a lens with $f = 10$ cm; C is a thermally stabilized cell with the solution; A is the amplifier ($L = 240$ mm); D is a diaphragm; S is a selector; $C_{1,2}$ are cameras; If are interferometers with base lines $A_1 = 0.6$–150 mm.

measured as a function of the temperature of the cell (from $T_c = 5.7$ °C to $T = 65$ °C, where T is the lower critical stratification point of the solution).

2. In the temperature range 44–47 °C, self-excitation of A was observed when RL radiation was focused onto the γ–collidine layer of the solution and a giant pulse with duration 50 ns, energy 1 J, and smooth spatial distribution was generated. The spectrum of the output radiation of this pulse was not frequency-shifted relative to the spectrum of the initiating RL pulse, and no additional lines were observed in it.

3. It was established that the giant pulse was generated only when the following threshold values were attained simultaneously: 1) temperature (Fig. 2); 2) RL pulse energy; 3) pumping energy E_p of the amplifier; 4) distance between the cell and the lens (Fig. 3); 5) height h at which the beam passed above the interface in the solution.

Thus the scheme in Fig. 1 has a positive feedback. In our experiment, the cell

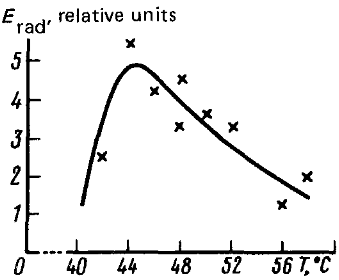

FIG. 2. Temperature dependence of the energy of the radiation leaving the amplifier A.

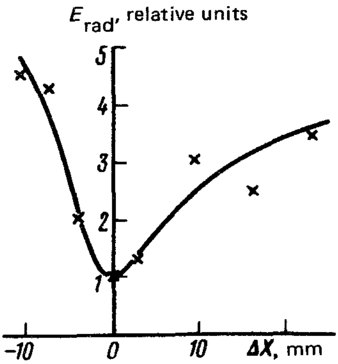

FIG. 3. Energy of the radiation leaving the amplifier A as a function of the displacement of the cell.

with the solution is responsible for the feedback. The appearance of feedback cannot be explained by the critical opalescence, since temperature detuning from the separation point ($T_{gen} - T_c$) was large (44 °C). In the control experiment with the single-component fluid (water or γ–collidine), self-excitation of A did not occur over the entire temperature range from T_c to 73 °C. Therefore, mechanisms that are not related to the concentration effect must also be ruled out.

4. The experimental data show that anomalous backscattering by concentration fluctuations was observed. This backscattering accounts for the temperature-selective feedback. We can safely assume that a component with a period $\lambda/2$, whose mean-square amplitude has a maximum near $T \sim 40$ °C, is present in the spatial Fourier spectrum of the concentration fluctuations. It is significant that the indices of refraction of water and γ–collidine differ appreciably ($\Delta n \sim 0.2$). The strict excitation regime, characteristic of generators with distributed mirrors (with a small reflection coefficient), is also attributable to this scattering. The coefficient of reflection of a distributed mirror is proportional to the thickness l of the scattering medium; in the experiment, l was changed by displacing the cell (Fig. 3). The sharp temperature dependence (as well as h dependence) indicates a possible structural transition in the solution being studied. Transitions of this tupe are used, for example, to explain the distinct anomalies in the concentration dependence of light scattering in water solutions of some alcohols.[2] In our experiment the threshold laser mechanism permitted observing the fine structural characteristic of the solution, whose detailed investigation will be the subject of a separate paper. We note that in the present experiment, in addition to observing the characteristic anomalous backscattering, a new mechanism for generating giant laser pulses with a smooth spatial distribution is realized.

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