Self-synchronization of radiation due to stimulated scattering of light of a Rayleigh line wing in an external cavity

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A generation of picosecond pulse trains due to SSW in the external transverse cavity was observed. Two regular groups of pulses each less than 40 psec in duration and spaced 160 psec apart were observed in the axial period. The generation conditions for individual pulses are determined.

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In this paper we report the first direct observation of the generation of a periodic sequence of picosecond light pulses due to stimulated scattering of a wing of a Rayleigh line (SSW) in carbon disulfide in an external transverse cavity. Under certain conditions we observed two regular groups of pulses with a repetition interval equal to half the axial period of the cavity; each of these pulses in turn was comprised of several pulses with a spacing of about 160 psec. We also determined the excitation conditions for a single picosecond pulse of the SSW in the axial period.

1. SSW[1] was excited by a single-mode ruby laser pulse of up to 150 MW power and 30 nsec duration. A 20-cm-long cell with carbon disulfied was inserted into the cavity with an optical length $L = 45$ cm, which was formed by spherical mirrors with a radius of 20 cm and reflection coefficient of 96%. The exciting light polarized in the scattering plane was focused into the cell by a cylindrical lens ($f = 6$ cm) whose generatrix was directed along the cavity axis. For this geometry of the experiment the scalar-type stimulated scattering along the axis of the cavity was not excited by the pump light. The light spectrum of the SSW was analyzed by using a Fabry-Perot interferometer with a dispersion range of 16.7 cm^{-1}, and the time-dependent characteristics were analyzed by using a ÉOX-2 electron-optical camera with a limiting time resolution of about 20 psec for a 2-nsec sweep across the entire 4-cm-diam screen.[2]

2. Under the described conditions of the experiment and a pump power of 80 MW in the scattered light (for a time resolution of 0.2 nsec), we observed two trains of short SSW pulses (Fig. 1a). The spacing between the pulses in each pulse train is 3 nsec, which corresponds to the time required for the light to pass the cavity twice $T = 2L/c$. The pulses in one train are shifted by approximately $T/2$ relative to those in the other train. In analyzing the time-dependent structure of these pulses with a higher time resolution (40 psec), we noticed that each of the pulses indicated above is comprised of several pulses (Fig. 1b), each less than 40-psec duration, spaced 160 psec apart. The time sweep of the SSW spectrum, which was accomplished by means of ÉOK-2, showed (Fig. 1c) that at the start of generation the narrow, scattered-light spectrum is

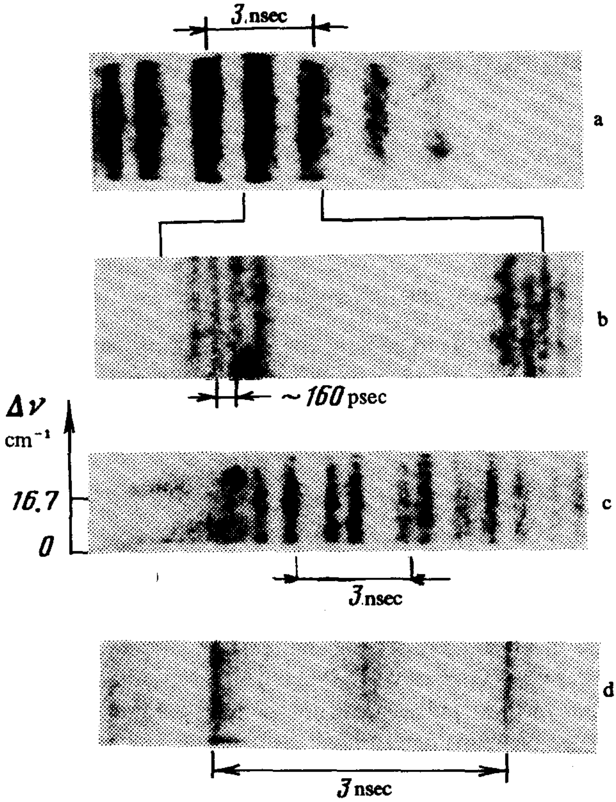

FIG. 1. Time sweep of the SSW radiation for a symmetrical excitation (a) and (b) and asymmetrical excitaton (d); c, time sweep of the SSW spectrum.

shifted by 2–3 cm^{-1} relative to the frequency of exciting light, in agreement with the value calculated on the basis of linearized SSW theory[3] $\delta\omega = 1/\tau$ and the data for anisotropy relaxation time τ, which were determined from the thermal scattering of light ($\tau = 2$ psec). The SSW spectrum subsequently was broadened in the Stokes direction at the same time the maximum in the spectrum was shifted in the same direction and 5–6 nsec after the onset of generation a time-periodic pulse structure, which filled the spectral region that exceeded the dispersion region of the interferometer, appeared.

3. The periodic time-dependent structure with a period $T = 2\,L/c$ observed in Ref. 4 in the SSW radiation excited in an external transverse cavity is accompanied by anomalously large shift of the maximum and an intense broadening of the scattered-light spectrum. It was assumed[4] that the limiting duration of the individual pulses in such time-dependent structure was of the order of the anisotropy relaxation time τ. The appearance of two groups of pulses, displaced relative to each other by half the axial period and propagating toward each other, is reasonable to expect in a symmetric cavity.[5] It was rather surprising that these pulses in turn are comprised of several short pulses spaced 160 psec apart.

4. We assume that the regular time-dependent structure of the SSW radiation in the axial period is attributable to the diffraction of short pulses of scattered light by a hypersonic wave which is excited in the medium by wide-band SSW radiation because of nonlinear strictional susceptibility of the medium. If the optical length L of the external cavity is sufficiently large so that the spectral interval between its modes $\Delta\omega = \pi c/L$ is smaller than the spectral width of the strictional susceptibility $\Delta\Omega$ (Ref. 6) determined by the lifetime of the hypersonic photons $\tau_p(\Delta\Omega = 1/\tau_p)$, then there is a pair of modes ω_i and ω_{i+j} whose beating corresponds to the frequency of a hypersonic wave Ω that can be excited in the medium $(\omega_i - \omega_{i+j} = \pm\Omega)$. Moreover, when all the cavity modes are phased in, all the pairs of modes ω_i and ω_{i+J} have the same phase difference, and hence the sonic wave is excited coherently.

Because of the spatial synchronism, only the light waves propagating in the cavity toward each other can excite such hypersonic wave. We could assume, therefore, that by introducing asymmetry into the SSW excitation along the axis of the cavity, which reduces the intensity of one of the groups of pulses that has an axial period,[5] we can suppress the mechanism for the onset of hypersound. In this case, only a single SSW pulse must be excited in the axial period.

In fact, as a result of shuttering a part of the beam of the exciting light incident on the cylindrical lens, one of the groups of pulses in the axial period is much less than 40 psec in duration was separated the exciting light incident on the cylindrical lens, one of the groups of pulses in the axial period is much less intensive than the other. As a result, an individual pulse less than 40 psec in duration was separated out in the axial period (Fig. 1d). We could not measure the true time of the individual pulses because of inadequate time resolution of our equipment. We can expect, however, that the duration of such pulses will correspond to the first anistropy relaxation time (2 psec) or the second (0.2 psec) in carbon disulfide.[7]

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