of the branch points consists here of only a phase difference between B_0^ρ and B_1^ρ, and it is this difference which leads to the observable polarization.

Thus, if we settle on this variant and assume that $F(t) \to F(t, \log E) \approx F(t)\log E$, then the slope (3) of $1/\log E^{-[2-\alpha_p(t)-\alpha_p'(t)]}$ can change by several times in the 5 - 60 GeV range. Although this estimate may be too optimistic(in particular, B(t, logE) may depend weakly on logE), it does allow us to hope that the nonlinearity effect can be observed in the initial stages without the difficult measurements of $(d\sigma_p/dt)_{ex}$ at high energy, since the contribution of the term $(d\sigma_p/dt)_{ex}$ can hardly exceed ∿ 1% of $[(d\sigma_p/dt)_+ + (d\sigma_p/dt)_-]$, owing to the smallness of $d\sigma_{ex}/dt$.

[1] S.Mandelstam, Nuovo Cimento 30, 1113, 1127, 1138, 1963.
[2] V.N.Gribov, I.Ya.Pomeranchuk, K.A.Ter-Martirosyan, Phys. Rev. 139, 13, 184, 1965.
[3] P.Bonamy, P.Porgeand, O.Guisan et al. Phys. Lett. 23, 501, 1966.
[4] L. Van Hove, Paper at 13th Intern. Conf. on High-energy Physics.
[5] V.N.Gribov, Lecture at 6th Session of Physics School at Erevan, 1966.
[6] A.Pignotti, Phys.Rev. 134, B630, 1964.
[7] K.A.Ter-Martirosyan, Lecture at 6th Session of Physics School at Erevan, 1966.

DETERMINATION OF THE CHARACTER OF MULTIMODE GENERATION AND THE MAGNITUDE OF HOMOGENEOUS BROADENING IN SPECTRALLY INHOMOGENEOUS SYSTEMS

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We investigate in this paper the evolution, during the course of pumping, of quasistationary generation in spectrally inhomogeneous systems in the case of spatially homogeneous distribution of the excitations in the active medium. The purpose of the investigation was to establish the character of the multimode generation and to determine the magnitude of the homogeneous broadening of the luminescence line of an individual center.

We investigated generation in the 1.06-μ band by a sample of silicate glass activated with 6% of neodymium, of 10 mm diameter and 120 mm length. To eliminate the spatial inhomogeneity of the field of the generating modes, the resonator (67 cm long) was converted with the aid of two lenses of 27 cm focal length into an almost concentric resonator, and in addition, one of the plane mirrors was replaced by a triple-prism. To study the generation spectrum in the quasistationary regime, in the most vital region of small pump excess over threshold, double discharge of the pump lamp was used. The discharge parameters were chosen such that the radiation intensities had time to attenuate by the time the instant t_1 of the start of the second increase of the pump power was reached (Fig. 1). This made it poss-

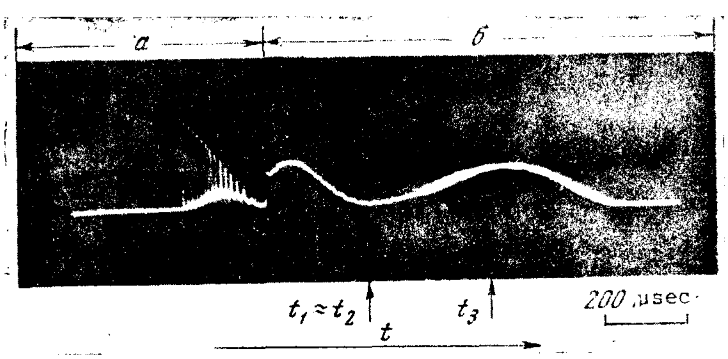

Fig. 1. Laser-emission oscillogram. The gain in section b is 10 times larger than in section a.

ible to start, in the comparison with the theory dealing with the change of the generation spectrum with increasing pump N, from a definite correspondence between N and the generation time t for $t \geq t_1$. By varying the energy fed to the lamp and the delay times between the discharge pulses, it was possible to vary continuously the pump power, up to a complete cessation of the generation at the instant t_1.

Owing to the selective action of the uncoated surface of the output mirror, the generation occurred at frequencies corresponding to maxima R_{max} of the reflection coefficient of the selector-mirror, with a discrete spacing $\Delta\nu = 1/2\ nd\ cm^{-1}$, where d is the thickness and n the refractive index of the mirror base [1]. We sed dielectric mirrors on glass bases (n = 1.5) with $R^{(1)}_{max} = 88\%$ and $R^{(2)}_{max} = 98.6\%$ and thickness $d^{(1)} = 4$ mm and $d^{(2)} = 2$ mm ($\Delta\nu^{(1)} = 0.8$ and $\Delta\nu^{(2)} = 1.6\ cm^{-1}$).

The time variation of the integral intensity of the output emission and its spectral composition is shown in Figs. 1 and 2 (both pictures were almost fully reproducible at a fixed pump power and at the proper thermal laser-operating regime). At low pump excess over threshold $N_1 = N(t_1)$ the laser emission spectrum in the quasistationary regime consists of one "line" at the maximum of the luminescence band, and when $N_2 = N(t_2) \cong N_1$ generation sets in also at neighboring maxima of the resonator Q (Fig.2c). This is followed, in a narrow pump range near $N_3 = N(t_3)$, by satisfaction of the self-excitation conditions for modes located $\sim 10\ cm^{-1}$ from the initial ones, and the generation at the latter stops. When the pump power decreases again, a single generation line returns.

A theoretical analysis shows that in the case of spectral (spatial) inhomogeneity multiple-mode generation sets in at a finite (infinitesimally small) excess above the threshold pumping and has a discrete (continuous) character in the sense of the indices of the generating modes. In the case of spectral inhomogeneity the increase in the number of generation lines may be the result of either splitting of the old lines or the occurrence of new ones.

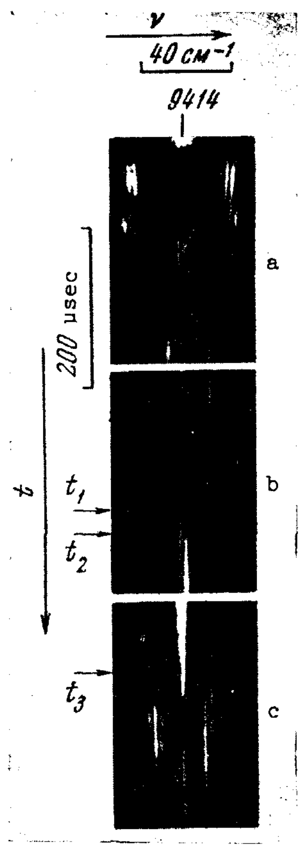

Fig.2. Typical pictures of time development of generation spectrum at the start (a), middle (b) and end (c) of the pump pulse.

The observed character of the generation agrees with that predicted by the theory for spectrally inhomogeneous systems. With this, the pump powers N_2 and N_3 correspond respectively to splitting and occurrence of lines. The multimode behavior at the beginning of the generation and the continuous excitation of neighboring modes as the pump is varied (Figs. 2a and b) are due to the nonstationary nature of the regime when $t < t_1$ (a similar picture was observed in [2] for a fiber laser, where no measures were taken to obtain a quasistationary generation regime). Similar effects should result also from a strong spatial inhomogeneity of the excitation distribution in the active medium.

The theory enables us also to determine the homogeneous broadening. Assuming the very simple model of four-level centers with Gaussian distribution with half-width 2Δ, and a Lorentz distribution for the luminescence line of each individual center, with a half-width 2β, we can show that if $\beta \ll \Delta$

$$2\beta = 1/2\pi \left(\frac{\pi \eta \Delta^2}{\ln 2 \cdot \nu^2} \cdot \frac{q^{(p)}}{V} \right)^{1/3}. \quad (1)$$

Here η is the quantum yield, ν the frequency of the light, $q^{(p)}$ the number of photons in the generating mode at which the splitting in the generation spectrum first occurs, and V is the volume of the mode. In our case $\eta = 0.6$ [3] and $\nu = 9414\ cm^{-1}$. When $\beta \ll \Delta$ we can put $2\Delta \approx \Delta\nu_{lum} \approx 200\ cm^{-1}$.

The output energy was measured with a calorimeter, and the oscillograms were used to determine the output power (the amplitude of the signal at the instant t_2 was determined with a separate beam at increased gain, with 30% error. The photon density $q^{(p)}/V$ was then determined from the cross section of the beam in the sample and on the mirror and from the known value of R_{max}; when the first and second mirrors were used, its value was 4×10^{10} and 2×10^{10} photons/cm^3 respectively, with an error not exceeding 50%. The value of $q^{(p)}/V$ is quite critical. Thus, for the first mirror, three lines remain in the spectrum at the instant t_1 and at 4×10^{10} photons/cm^3. Calculation using (1) yields $\beta = (20 \pm 10)\ cm^{-1}$. This value agrees with the interval of the jump in the spectrum at pump power N_3 (Fig. 2c), which should be of the same order as β. The condition $\Delta\nu \ll 2\beta \ll 2\Delta$ is also satisfied, making the use of formula (1) valid.

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ERRATUM

The title of the article by A. A. Chaban, Vol. 5, No. 1, p. 14, was mistranslated. It should read "Optoelectric Effect in a Laser Beam."