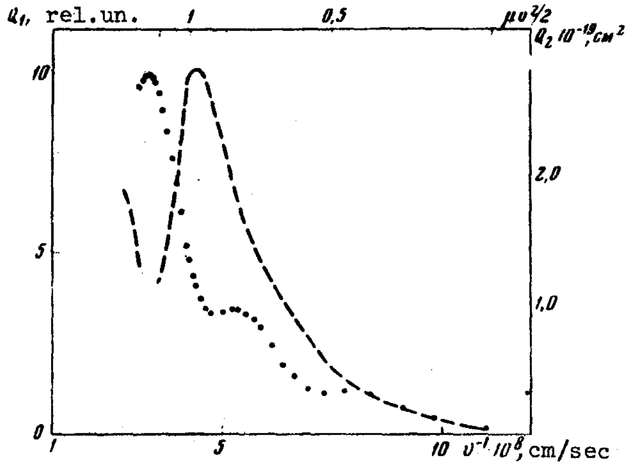

The authors of the present article propose that the structure of both curves shown in the figure is due to interference of the two inelastic channels of the reactions (1) and (2). This conclusion is based on the results of a theoretical paper submitted to Zh. Eksp. Teor. Fiz. (Sov. Phys.-JETP) by Ankudinov, Bobashev, and Perel'. That paper considers the simplest model of collision of two atomic particles, leading to oscillation of the total cross sections of two inelastic processes with a large resonance defect. It was assumed in the model that when the two atomic particles come close together the term of the ground state of the system intersects in succession two vacant energetically-adjacent terms of the quasimolecule. After population of the terms in accordance with the Landau-Zener scheme, their additional interaction at a large internuclear distance, resulting from the intersection or very close approach of the terms, was considered. Expressions were obtained for the amplitude, the period, and the phase of the oscillations. It was established that under certain conditions the oscillations are harmonic in the reciprocal velocity, and that the oscillations in both channels should be in antiphase when only two terms interact. Indeed, the extrema observed on both curves (see the figure) are in antiphase, and the distance between extrema on the curve for the reaction (1) (Q_1) is approximately equal to the distance between the maximum and the minimum of the cross section Q_2.

In this case we can estimate the absolute value of the cross section for the excitation of the 584.3-Å He I line, assuming that the oscillating components of the cross sections Q_1 and Q_2 are equal. Using the absolute values of Q_2, we obtain an estimate for the value of Q_1 at the maximum, $Q_1 \simeq 7 \times 10^{-19}$ cm^2 at an Na$^+$ ion energy 11.5 keV ($v^{-1} = 3.25 \times 10^{-8}$ cm/sec, $\mu v^2/2 = 1.7$ keV, where μ is the reduced mass of the colliding particles).

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EXTENDED SEMICONDUCTOR LASER WITH RADIATING LATTICE

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One of the direct methods of increasing the power of coherent radiation of an injection semiconductor laser (SL) is to increase the area of the p-n junction involved in the stimulated-emission process, either by synchronizing the oscillations of several coupled SL [1 - 4], or by increasing the length L of the Fabry-Perot resonator. In the latter case the phenomenon of gain saturation limits L to a value of the order of the saturation length L_s. In the saturation region, the SL power ceases to increase, since the energy of the stimulated emission is consumed almost wholly by the distributed generator losses, characterized by an effective damping coefficient α_0.

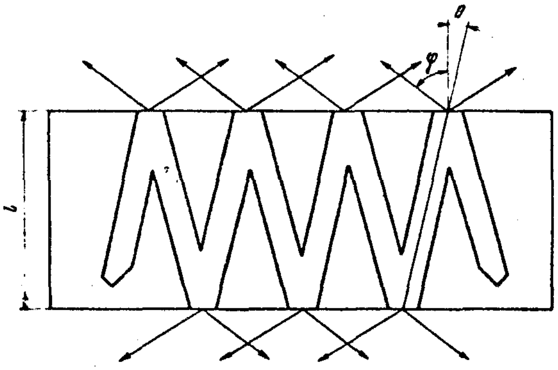

Fig. 1

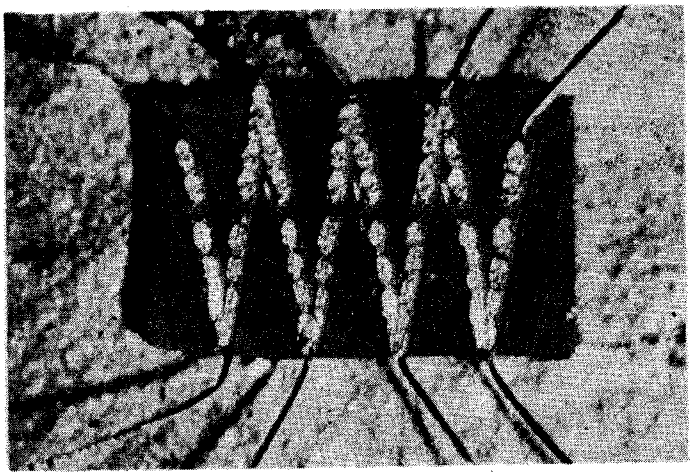

Fig. 2

Limitation of the length L, and consequently also the radiation power, can be eliminated, in accord with [5], by effecting the useful extraction of the radiation energy from the resonator likewise in a distributed manner. The efficiency of the extraction process is then determined by the relation

$$\eta = \frac{\alpha}{\alpha_0 + \alpha},$$

where α is the effective coefficient of useful attenuation introduced by the distributed extraction. There is no need to adhere in the experiment to strict continuity of the extraction over the length of the resonator. It suffices to produce in the resonator a sequence of local radiating inhomogeneities with a pitch $\Delta L < L_s$, and then add the radiation coherently outside the resonator.

The experimental SL of GaAs (Figs. 1 and 2) had the form of a zigzag mesa structure with diffuse p-n junction lying in the plane of the figure. The ends of the zigzag strip, 100 μ wide, were terminated with total-internal-reflection prisms [6]. On the vertices of the zigzag, the strip is bounded by reflecting surfaces comprising to cleaved 011 planes of the single crystal. As the light flux propagates in the zigzag along the injected junction, it strikes angle $\theta \simeq 10°30'$ seven semitransparent mirrors with reflection coefficients $R_s(\theta) \simeq 0.4$ and $R_p(\theta) \simeq 0.2$ (for the two polarizations). The mirrors attenuate the extraction, with effective coefficients $\alpha = -(1/I)\cos\theta \ln R(\theta)$ equal to $\alpha_s \simeq 10$ cm^{-1} and $\alpha_p \simeq 18.5$ cm^{-1} ($\Delta L = \ell/\cos\theta$, $\ell \simeq 800$ μ is the distance between the cleavage planes).

Relative to the outer space, the mirrors form in the plane of the p-n junction two radiating lattices with a period $d = 2\ell \tan\theta \simeq 300$ μ, the four principal radiation maxima of which lie at angles $\phi_k = \pm\phi_0 + \pi k$ to the normal (k = 0 and 1), where $\phi_0 = \sin^{-1}(n \sin\theta) \simeq 40°30'$ ($n \simeq 3.58$ is the refractive index of gallium arsenide).

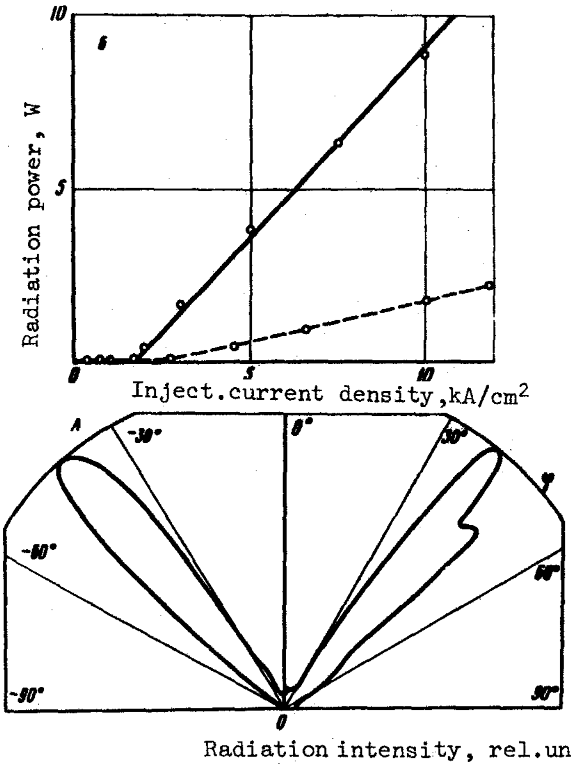

Fig. 3

Figure 3a shows the polar radiation diagram of the SL obtained at liquid-nitrogen temperatures; the half-width of each lobe about 6°. As is well known, even an SL with an ordinary Fabry-Perot resonator produces a diffraction pattern that is far from regular, and its divergence in the junction plane greatly exceeds the diffraction limits. Therefore, recognizing that in this experiment the inhomogeneities of the material and injection, the lack of manufacturing precision, etc., can introduce appreciable phase distortions, we could hardly expect to obtain a distinct interference pattern with a number of maxima corresponding to the number of lattice periods. Nonetheless, there is obviously a noticeable narrowing of the directivity pattern compared with control SL having the ordinary configuration, produced in the same technological cycle from the same GaAs plate.

It should be noted that it is possible, by elementary means, to guide all four laser beams to a single point. It is also possible to produce a reflecting coating with R = 1 on one of the cleaved surfaces of the SL.

The dependence of the radiation intensity on the injection-current density (Fig. 3b) has a clearly pronounced threshold character and is analogous to the same dependence for the control laser (dashed). The total radiation power in all four lobes exceeds the radiation power of the control SL at equal injection-current density by more than the ratio of the injection junction areas (in this case by approximately five times). The largest registered power exceeded 10 W in the pulse, which undoubtedly is not the limit.

The total length of the resonator between the terminal prisms is L ≈ 6000 μ and is sufficient to transform the discrete spectrum of the longitudinal modes into a continuous one by virtue of the condition

$$L > [2n(\alpha_0 + \alpha)]^{-1} \approx \frac{\pi}{2n\alpha}.$$

Therefore the emission spectrum does not have the usual mode structure, and the central frequency of the line is determined by the position of the maximum of negative-absorption coefficient, as in a laser with nonresonant feedback [7]. The half-width of the emission line, measured with a DFS-12 spectrophotometer at a current density 4000 A/cm², is about 5 Å. The spectra of all the radiating areas are identical.

The distributed character of the extraction of the radiation from the resonator uncovers possibilities for further increasing the number of periods of the radiating grating and a corresponding increase of the power of the coherent radiation, reduction of its spectral width and reduction of the width of the directivity pattern without increasing the injection current density, and also reduction of the thermal and radiation stresses in the crystal. At the present time these possibilities are subject only to technological rather than physical limitations.

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INCREASE OF RADIATION BRIGHTNESS IN A BRILLOUIN LASER

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One of the most important characteristics of radiation is its brightness B (W/cm^{2}sr). It can be increased by stimulated scattering in a resonator [1]. Stimulated Mandel'shtam-Brillouin scattering in a resonator (the Brillouin laser) was investigated by a number of authors, but there are still no reports of the increase of the brightness of such a system. We report here for the first time the increase of the brightness in a Brillouin laser[1].

We investigated the generation of a carbon-disulfide[2] Brillouin laser with transverse pumping (Fig. 1). The resonator was made up of two dielectric mirrors M_1 and M_2, spaced $\ell = 1.7$ m apart and having reflection coefficients $r_1 = 98\%$ and $r_2 = 80\%$. A rectangular diaphragm measuring 0.9 × 0.9 cm was placed in the resonator. The CS_2 filled a glass cell 24 cm long, 1 cm wide, and 2 cm high. The windows through which the generated radiation passed were placed at an angle 94° to the side walls and were made nonreflecting. A system of 17 glass total-internal-reflection prisms ensured multiple passage of the pump light perpendicular to the resonator axis. A thin layer of glycerine was located between the prisms and the cell. The exciting-radiation losses were determined mainly by the absorption in the glass and did not exceed 50%. The pumping was by means of a ruby laser, whose pulse entering the cell had a duration $T = 0.8$ μsec, an energy $E = 0.3$ J, a cross section $S = 0.9$ cm^2, a divergence $\phi = 4.5 \times 10^{-3}$ rad, and a spectral width $\Delta\nu = 40$ MHz.

The use of a pulse in the microsecond range was dictated by the fact that to increase the brightness it is necessary to develop a near-diffraction directivity pattern during the operating time of the Brillouin laser. To this end, the generated radiation must cover a path L determined from the condition $d/L \sim \lambda/d$, where d and λ are respectively the beam diameter and the generation wavelength. The time needed to traverse this path is $\tau \equiv L/c \sim d^2/c\lambda$. Substituting the numerical values, we obtain $\tau \sim 0.5$ μsec for $d = 1$ cm.

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[1] For more details see [3].

[2] In CS_2 the gain is $g \simeq 0.17$ cm/MW and the gain line width is $\delta\nu \simeq 40$ MHz. These values can be easily obtained for the case of transverse pumping from the results of [4].