4. The substitution of neon for helium as the fer gas resulted in a decrease (by nearly an er of magnitude) in the intensity of the emission spectral lines from the 9p, 8d, 6f, and 6g levels he case of C II (or the 6p, 5d, and 4f levels he case of Zn II), which can be populated as a lt of a charge-exchange reaction involving He$^+$ It was shown that the time evolution of the sion changes for these lines. In the case of neon, e was no prolonged afterglow following the cutof the current, as is typical of experiments in h He was used as the buffer gas. In the neon we observed only a brief recombination flash.

The experimental data show directly that the ation of the metal ions is a consequence of charge ange of metal atoms with ions of the buffer gas. umably other plasma-chemical reactions could occur.

5. It was found that the optimum length of the laser pulse was $\tau_p \sim 3$ µs. The plasma expanvelocity v_{pl} was $\sim 4 \cdot 10^5$ cm/s at $I_p = 100$ A and buffer-gas pressure $P \sim 3$ torr. Over the time e plasma expands to ~10-15 mm, and after the nt cutoff, the plasma begins to cooloff. Under conditions, estimates of the cooling rate show the cooling due to elastic collisions is at least der of magnitude more effective than the coolue to the expansion.

On the basis of the experimental results pred above, we can propose the following mechanism e formation of active media in lasers with a nted plasma source of metal vapor.

During the application of the high-voltage pulse to the outer electrodes of the active element of the laser, a plasma consisting of the metal vapor and the buffer gas is produced in each gap between plates. The plasma expands into the preionized buffer gas. Metal ions are formed as a result of a charge exchange with He$^+$ or Ne$^+$ ions. After the current ends, the plasma cools off in collisions with the buffer gas.

The mechanism responsible for the formation of the population inversion must be examined separately for each specific chemical element and spectral transition.

In summary, this study has shown that the following physical processes are observed during the formation of the active medium of an SPER laser: a) preionization of the buffer gas; b) spreading of the current through the volume of expanding plasma; c) mixing of the metal vapor and the buffer gas as the plasma expands; d) plasma-chemical reactions in the expanding plasma; e) a predominately collisional mechanism for the cooling of the plasma.

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nAsSb/GaAlAsSb avalanche photodiode with separate orption and multiplication regions

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reliminary results of our study of the avalmultiplication of the photocurrent in heteroures based on multicomponent GaInAsSb/Sb solid solutions were reported in Ref. 1. shown that these substance hold promise for velopment of avalanche photodiodes for the l interval 1.6-2.5 µm, which is of interest ample) for third-generation optical-fiber comtions.[2]

was shown in Ref. 1 that the ratio of the electron ionization coefficients in GaInAsSb lutions is $\beta/\alpha \approx 5$-10. Multiplication factors 20 at room temperature and 50-100 at liquid- temperature were achieved. However, the rk current in n-GaInAsSb–p-GaAlAsSb hettures in the prebreakdown region, which mined by impurity and interband tunneling arrow-gap substance, hinders the developefficient avalanche photodiodes for operaroom temperature.

a et al.[3] have suggested a structure with absorption and multiplication regions, in a narrow-gap substances. The construction was first implemented in an InGaAs/InP avalanche photodiode for the spectral interval 1-1.6 µm (Refs. 3 and 4).

The placement of the multiplication region with the p–n junction in a wide-gap substance makes it possible to reduce the electric field at the heterojunction with the narrow-gap region and to avoid significant tunneling currents in this region when avalanche breakdown is reached in the multiplication region. As was shown in Ref. 5, the carrier concentrations in the layers and the layer thicknesses must meet some strict requirements.

The construction proposed by Susa et al.[3] was used in the present study to degvelop an avalanche photodiode on the basis of GaInAsSb/GaAlAsSb solid solutions. A narrow-gap absorption region was made from an n-GaInAsSb solid solution ($E_g = 0.52$ eV), while the wide-gap n–p junction was in GaAlAsSb of indirect-gap composition ($E_g = 1.2$ eV), separated from the heterojunction by 0.3 µm. The structures were fabricated by liquid-phase epitaxy on a n-type

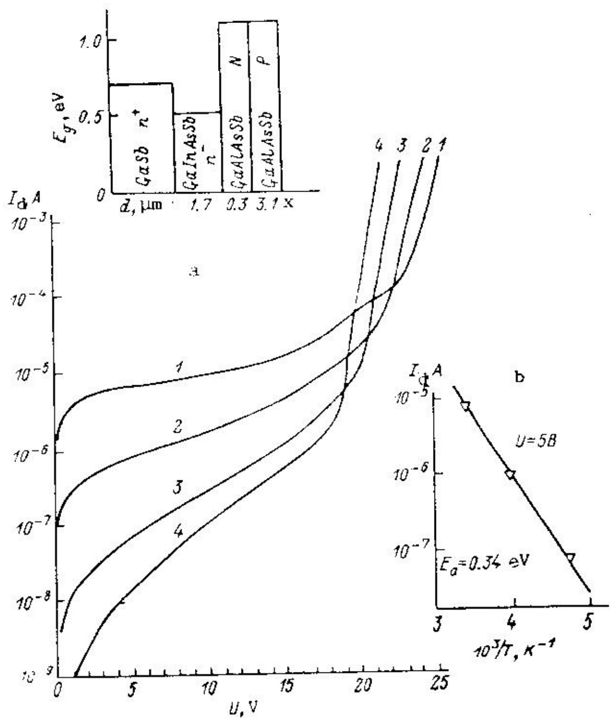

FIG. 1. Reverse branch of the current-voltage characteristic of an avalanche photodiode made from GaInAsSb/GaAlAsSb with separate absorption and multipication regions, at various temperatures T (K): 1) 296; 2) 253; 3) 213; 4) 173. Inset a: Distribution of the width of the bandgap along the coordinate in the avalanche-photodiode structure. b: Temperature dependence of the reverse dark current at U_{rev} = 5 V.

GaSb substrate. The avalanche photodiodes were fabricated as mesa diodes with a sensitive area having a diameter Φ ≈ 280 μm. The carrier concentration in the narrow-gap region was $(5\text{-}7)\cdot 10^{15}$ cm^{-3}; that in the narrow-gap region was $7\cdot 10^{16}$ cm^{-3}; and the p^+ layer of GaAlAsSb was doped with Ge to a concentration of $5\cdot 10^{18}$ cm^{-3}. The layer thicknesses are shown in Fig. 1.

A study of the current–voltage characteristics of the idodes over the temperature range 296-78 K showed that the temperature coefficient of the breakdown voltage was positive: $\gamma = (\Delta U_B/U_B)(1/\Delta T) > 0$; $\gamma = 2\cdot 10^{-3}$ K^{-1}. That is, the breakdown was of an avalanche nature (Fig. 1). The breakdown voltage was determined by the wide-gap substance and was 21-24 V at T = 296 K and 18-20 V at 78 K. The dark current density at $U = 0.5\ U_B$ was $j \approx 1\text{-}2\cdot 10^{-2}$ A/cm^2, which is lower by a factor of two or three than that in avalanche-photodiode structures of the ordinary type, whcih we described in Ref. 1.

The dark current in the voltage interval 5-12 V was determined by generation and recombination in the layer of narrow-gap material. The activation energy in this interval was E_α = 0.34 eV, according to the temperature dependence of the reverse current (Fig. 1b). The electric field in the space-charge region of the wide-gap n–p junction was E = $3.5\cdot 10^5$ V/cm, and it fell off to $8\cdot 10^4$ V/cm at the boundary with the narrow-gap layer. The field penetrated into the narrow-gap layer when the voltage across the structure was about 4-5 V, as is quite evident from the step on the reverse branch of the current–voltage characteristic with illumination. A significant multiplication of the photocurrent was observed even at V ≥ 6 V. According to estimates, the field required for the beginning of significant tunneling in the wide-gap substance was E ~ 10^6 V/cm, while that in the narrow-gap substance was above $2.5\cdot 10^5$ V/cm.

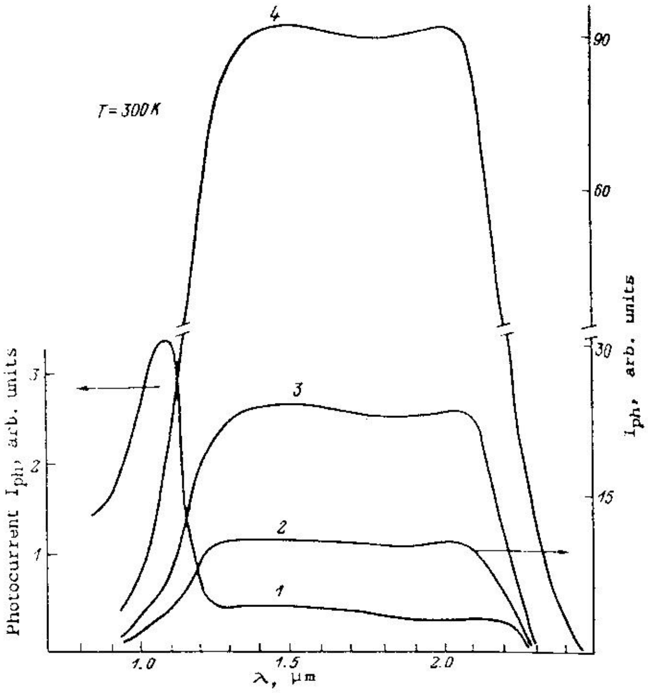

FIG. 2. Photocurrent spectrum in a GaInAsSb/GaAlAsSb avalanche photodiode at various several voltages (T = 296 K). U (V): 1) 0; 2) 5; 3) 10; 4) 20.

Figure 2 shows the photosensitivity spectrum at various voltages. Since the diode was illuminated through the wide-gap p-type layer, the photosensitivity at zero bias as determined primarily by the GaAlAsSb (curve 1). When the voltage was raised above 4 V, and the electric field penetrated into the narrow-gap layer, the photosensitivity spectrum assumed a shape characteristic of a heterostructure. The falloff at the long wavelength and short wavelength ends corresponded to the band-gap widths of the wide-gap and narrow-gap materials. A significant increase in the photosensitivity was observed corresponding to multiplication coefficints of 30-50 at room temperature. At T = 78 K, the coefficients were M = 200-500 in the high-voltage region.

The results found for the lowering of the tunneling component of the reverse current in the prebreakdown region and the realization of a avalanche breakdown in our structures are related to not only the separation of the absorption and multiplication regions but also the use of the indirect-gap material GaAlAsSb in the multiplication region. This approach made it possible to reduce the tunneling probability to a level substantially lower than that in a direct-gap substance having a band gap of the same width, as a result of the participation of phonons in the process.[6] Under this condition, the requirement on the carrier concentration in the multiplication region may be less stringent than that in Ref. 3 and 5. Further evidence for this conclusion comes from a study of the current–voltage characteristics of GaAlAsSb diode structures of the same composition which we fabricated specifically for use as reference structures.

Improving these avalanche photodiodes further require optimizing several parameters of the ucture, including the carrier concentration in the de-gap layer and the layer thicknesses, which de- mine the electric field at the heterojunction. It important to reduce the field to $E \lesssim 6\cdot10^4$ V/cm order to avoid an additional multiplication in the orption layer. Furthermore, "resonant" or quasi- onant compositions of the wide-gap GaAlAsSb solid ution (with $E_g \approx \Delta_0$) could be used to make the ltiplication region, in order to reduce the excess- se coefficient. The ue of these compositions would mit higher values of the hole and electron ioniza- coefficients.[7]

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equency conversion in single and series-connected end-type osephson junctions

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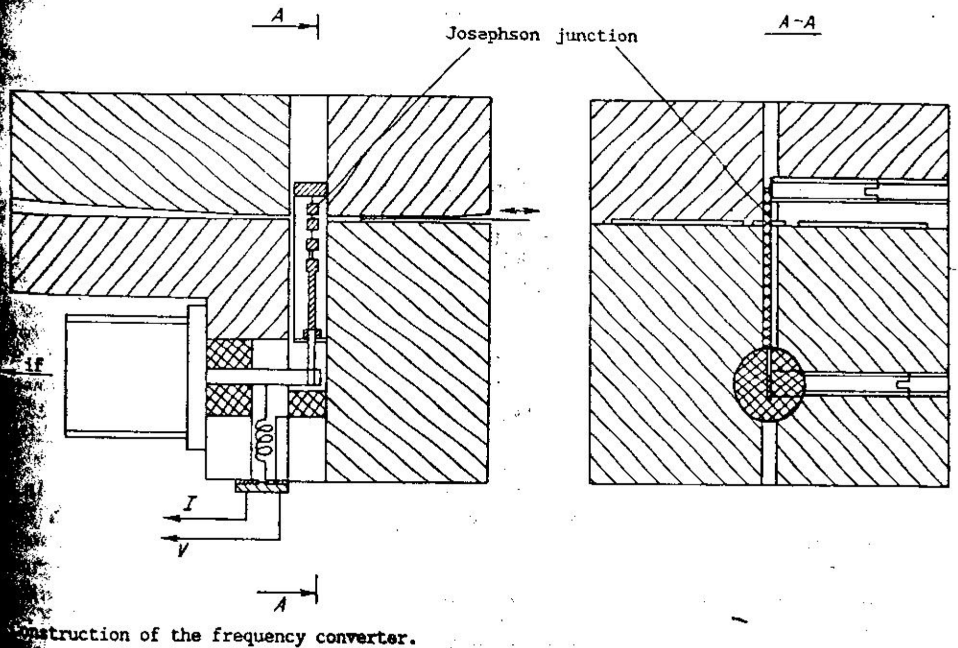
1. Cooled frequency converters are used in eter-submillimeter-range superheterodyne re- ers in order to raise the sensitivity.[1] Josephson- on converters with an external heterodyne are ble in principle of amplifying a signal carried at ntermediate frequency if the intrinsic single noise temperature is about 20T, where T is hysical temperture of the Josephson junctions 2, 3). The use of chains of identical series- cted Josephson junctions expands the dynamic of a receiver. In the present letter we re- study of an external-heterodyne frequency rter for the 2.2 mm range, consisting of end-type Josephson junctions and chains of such junctions, made of refractory materials. Josephson junctions and chains of this type have been used previously[4,5] in a detector receiver for the 4-8-mm range. We know of no previous work on external-heterodyne frequency converters made from end-type Josephson junctions.

2. End-type Nb/α−Si/Nb Josephson junctions with a direct conductivity and an area S ≲ 1 μm and chains 0.2 mm long consisting of 11 identical junctions were fabricated on silicon wafers with a thickness t = 0.4 mm by the procedure described



nstruction of the frequency converter.