Since the electrons are cooled more rapidly than the ions, owing to their larger mobility along the magnetic field, the energy density stored in the ions during the heating time may turn out to be larger than that in the electrons.

[1] M. V. Babykin, P. P. Gavrin, E. K. Zavoiskii, et al., Zh. Eksp. Teor. Fiz. 52, 643 (1967) [Sov. Phys.-JETP 25, 1421 (1967)].
[2] M. V. Babykin, P. P. Gavrin, E. K. Zavoiskii, et al., ibid. 47, 1597 (1964) [20, 1073, (1965)].
[3] M. V. Babykin, E. K. Zavoiskii, L. I. Rudakov, et al., ibid. 43, 1976 (1962) [16, 1391 (1963)].
[4] L. I. Rudakov and L. V. Korablev, ibid. 50, 220 (1966) [23, 145 (1966)].

CURRENT OSCILLATIONS IN n-Ge DOPED WITH MANGANESE

I. V. Karpova and S. G. Kalashnikov
Institute of Radio Engineering and Electronics, USSR Academy of Sciences
Submitted 7 October 1967
ZhETF Pis'ma 6, No. 11, 954-956 (1 December 1967)

By now a large number of investigators reported observation of current oscillations in germanium and silicon. In some cases these oscillations were due to the occurrence of negative volume differential conductivity and moving electric domains. These phenomena were observed at temperatures much higher than room temperature. In a number of cases the negative conductivity and the current oscillations were connected with injection through the contacts.

In the experiments described below, we observed current oscillations with large amplitude in n-type germanium doped with manganese. These oscillations are apparently not connected with injection in the contacts, are observed near room temperature and in weak fields, and it seems to us that they have an origin different than that indicated above.

The compensating impurity in our samples was antimony, whose concentration was chosen such as to make the electrons fill completely the lower level of the manganese (E_v + 0.15 eV) and fill partially the upper level (E_c - 0.37 eV). It must be noted that if the antimony concentration was made larger than twice the manganese concentration, there were no oscillations.

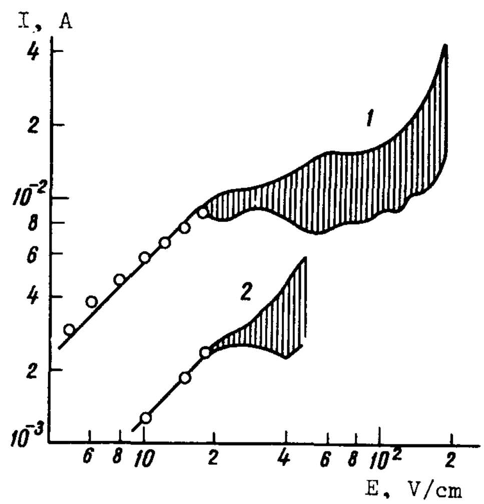

Fig. 1. Current-voltage characteristics for two samples: 1 - 5 mm long, 2 - 2.5 mm long.

Figure 1 shows the current-voltage characteristics of two samples differing in length by a factor of 2, and having approximately the same impurity concentration. The manganese concentration was $\sim 10^{14}$ cm^{-3}, and the degree of filling of the upper level of manganese by electrons was close to unity. The curves were plotted under conditions when the resistance of the sample exceeded the load resistance. The measurements were made in a pulsed mode at pulse durations from 1 msec to 10 μsec and at a repetition frequency 0.5 Hz. It is seen from the figure that in fields below a certain critical value corresponding to the start of the oscillations, the current-voltage characteristic is close to linear. The value of the field E_{cr} was 18 V/cm and did not change when the sample length was varied from 2.5 to 15 mm.

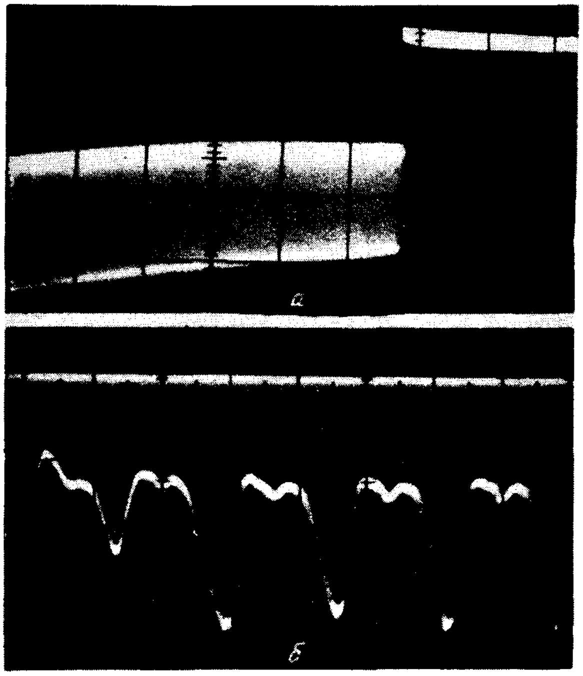

Fig. 2. Oscillogram of current pulse: a - sweep rate 0.2 msec/large div.; b - 5 msec/large div.

Figure 2 shows the current oscillogram. The variation of the current in the oscillations reached 50 - 90% of the magnitude of the pulse. The oscillation period was equal to several microseconds and remained practically constant when the length of the sample was increased sevenfold. Oscillations occurred both in darkness and with the crystal illuminated, and their occurrence did not depend on the surface finish. Oscillations with maximum amplitude were observed at temperatures 300 - 310°K. Further heating caused the oscillation amplitude to decrease. When the crystal was cooled, the period of the oscillations increased and the regular oscillations were transformed into noise.

Experiments with dumbbell-shaped samples and with specially shaped samples, in which the area of one of the electrodes was much larger than that of the other, have shown that the observed oscillations are apparently not connected with injection of carriers through the contacts.

It was shown in [1] that current oscillations in semiconductors containing impurities with deep levels may be connected with recombination waves. It was reported in [2] that oscillations were observed in compensated silicon doped with gold; in the authors' opinion these oscillations are connected with this mechanism. We propose that the oscillations observed by us are also connected with recombination waves. Favoring this assumption are the following: (i) The manganese in germanium is a suitable impurity for the observation of recombination waves; (ii) the period of the observed oscillations does not depend on the sample length; (iii) it follows from [1] that prior to the occurrence of the oscillations the current-voltage characteristic should be close to linear, as was indeed observed in our experiments; (iv) the order of magnitude of the critical field and of the oscillation period turns out to be, at the temperatures and concentrations indicated above, the same as expected theoretically. Further experiments, which are now under way, will make it possible to establish finally the nature of the described oscillations.

In conclusion, we are sincerely grateful to O. V. Konstantinov, V. I. Perel', and G. V. Tsarenkov for stimulating the present experiments, for valuable discussions, and for acquainting us with the results of their theoretical calculations.

[1] O. V. Konstantinov, V. I. Perel', and G. V. Tsarenkov, Fiz. Tverd. Tela 9, 1761 (1967) [Sov. Phys.-Solid State 9, 1381 (1967)].
[2] J. S. Moore, C. M. Penchina, N. Holonyak, Jr., M. D. Sirkis, and T. Yamada, J. Appl. Phys. 37, 2009 (1966).

STIMULATED LIGHT EMISSION OF A PLASMA-BEAM DISCHARGE

Yu. V. Tkach, Ya. B. Fainberg, L. I. Bolotin, Ya. Ya. Bessarab, N. P. Gadetskii, Yu. N. Chernen'kii, and A. K. Berezin
Physico-technical Institute, Ukrainian Academy of Sciences
Submitted 13 October 1967
ZhETF Pis'ma 6, No. 11, 956-960 (1 December 1967)

As is well known, most existing gas lasers are based on the use of different types of discharge at relatively high pressures (10^{-1} - 10 mm Hg) and correspondingly low electron temperatures (T_e = 5 - 6 eV). The electron temperature in pulsed lasers using a rapid pinch [1] reaches $T_e \sim 20$ eV, and this makes it possible to increase the emission intensity appreciably. To increase further the excitation efficiency of ion lines with large excitation potential, it is necessary to raise substantially the electron temperature, so that the plasma electron energy is close to the maximum of the excitation function, i.e., to approximately 50 - 100 eV. To obtain coherent emission in the ultraviolet region it is necessary that a high electron temperature be produced in low-pressure discharges. These two requirements (high temperature at low pressure) are satisfied to a considerable degree by the plasma-beam discharge, the investigation of which has recently been the subject of a large number of both theoretical and experimental papers [2,3]. In such a discharge, the ionization and the excitation of the atoms and of the ions of the gas is effected by the plasma electrons, the energy of which increases rapidly as a result of collective interaction between the electron beam and the plasma, leading to intense excitation of the high-frequency oscillations in whose field the plasma electrons acquire their energy.

In this case, breakdown is attained at much lower pressures than in ordinary discharges, and the plasma electron temperature greatly exceeds the temperature in other discharges, reaching tens and hundreds of kiloelectron volt. The plasma-beam discharge is a strongly unbalanced system. Furthermore, the ion temperature in such a discharge can be raised to several hundred electron volts, a fact that can be used to broaden the band of