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Abstract

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An Optical Quantum Generator Based on Cadmium Telluride with Electron Excitation

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It is known that excitation by fast electrons is an effective method for generating nonequilibrium carriers in semiconductors, and that the average energy for formation of a pair is approximately equal to three times the width of the forbidden band (1−3).

In previous work carried out at the Physics Institute of the Academy of Sciences of the USSR, the spectrum of recombination radiation of cadmium telluride under electron excitation was investigated (4); it was established that the energy yield of radiation at temperatures below 100°K can reach $10 \div 12\%$ (5), and narrowing of the emission line at λ7800 Å was observed, indicating the attainment of inverse population of energy levels in the crystal (6).

The aim of the present work was to obtain induced emission of light from CdTe in the near infrared region under excitation by electron pulses. The duration of the excitation pulses was 0.4 μsec at a repetition frequency of 10 Hz and electron energy of 150 keV. The samples, in the form of cubes approximately $0.4 \times 0.4 \times 0.4$ mm in size, were cut from a cadmium telluride crystal with hole conductivity and a hole concentration of approximately 10^{14} cm^{-3} at room temperature*. Two opposite faces of the sample were plane-parallel and polished; the front face of the sample was also polished, while by its rear face the sample was glued to the cold finger of a helium cryostat. The temperature of the cold finger was $10 \div 15$°K. The electron beam fell on the front face of the sample, and the radiation was recorded with a ZMR-3 spectrometer from the lateral plane-parallel faces, which formed a resonator for infrared oscillations. When the radiation was recorded through the lateral faces, the short-wavelength spectral line (4,5) was shifted by $20 \div 30$ Å toward the long-wavelength side in comparison with the radiation recorded from the front face irradiated by electrons. When the current density was increased from 0.3 to 1 A/cm^2, a sharp increase in the intensity of this line by approximately two orders of magnitude was observed (Fig. 1), with a simultaneous decrease in the linewidth at half-height from 25 Å to a value not exceeding 3 Å (Fig. 2). (In calculating the linewidth at half-height, the width of the spectrometer slit was taken into account.) It was not possible to resolve a finer structure of the line at an electron current density of about 1 A/cm^2 because of the insufficient resolution of the spectrometer.

Fig. 1. Dependence of the radiation intensity I (relative units) on the electron-current density j

Figure 1: Fig. 1. Dependence of the radiation intensity I (relative units) on the electron-current density j

Fig. 2. Dependence of the width of the radiation line on the electron-current density. 1—$j = 0.31$ A/cm^2; 2—$j = 0.54$; 3—$j = 1.1$ A/cm^2

Figure 2: Fig. 2. Dependence of the width of the radiation line on the electron-current density. 1—$j = 0.31$ A/cm^2; 2—$j = 0.54$; 3—$j = 1.1$ A/cm^2

At a current density of 1 A/cm^2, the divergence of the radiation (the angle between directions corresponding to radiation intensities equal to one-half the maximum value) was approximately 15° in the horizontal plane, perpendicular to the irradiated face. In this case the radiation power within a solid angle equal to 15° was not less than 0.3 W, with a power of the exciting electrons of 300 W. A further increase in the efficiency of generation will apparently require an increase in the excitation current density and an improvement in the quality of the resonator. The narrowing of the spectral emission line to a value

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* The CdTe crystals were grown by S. N. Maksimovskii.

less than kT, the sharp increase in intensity, and the appearance of directionality of the radiation at a threshold current density of the exciting electrons of about 1 A/cm^2, in our opinion, testify to the generation of stimulated radiation in cadmium telluride.

In work [4] we assumed that the short-wavelength band of CdTe recombination radiation is associated with vertical interband transitions. However, studies of the radiation spectrum of cadmium telluride at a higher excitation level, at which the short-wavelength line predominates in the radiation spectrum, showed that the width at half-height of this line at room temperature is less than kT. Therefore the short-wavelength radiation line cannot be attributed to interband transitions. The short-wavelength radiation line coincides with the region of intrinsic exciton absorption, determined experimentally and theoretically in work [7]. In this connection, the stimulated radiation of cadmium telluride that we have achieved is apparently associated with exciton transitions. Induced radiation of cadmium sulfide, close in its properties to cadmium telluride, and of semiconductors of the $A_{\mathrm{III}}B_{\mathrm{V}}$ type–InAs and InSb–as well as GaSe under excitation by fast electrons was observed by the authors of works [8–10].

Fig. 1. Dependence of the radiation intensity I (relative units) on the electron-current density j.

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CITED LITERATURE

[1] V. S. Vavilov, L. S. Smirnov, V. M. Patskevich, DAN, **112**, 1020 (1957).
[2] V. M. Patskevich, V. S. Vavilov, L. S. Smirnov, ZhETF, **33**, 804 (1957).
[3] V. S. Vavilov, UFN, **75**, 263 (1961).
[4] V. S. Vavilov, E. L. Nolle, V. D. Egorov, S. I. Vintovkin, Fiz. tverd. tela, **6**, 1406 (1964).
[5] V. S. Vavilov, E. L. Nolle, S. N. Maksimovskii, Fiz. tverd. tela, **7**, 1558 (1965).
[6] V. S. Vavilov, E. L. Nolle, V. D. Egorov, Fiz. tverd. tela, **7**, 934 (1965).
[7] D. T. F. Marple, B. Segal, Bull. Am. Phys. Soc., **9**, 223(A) (1964).
[8] N. G. Basov, O. V. Bogdankevich, A. G. Devyatkov, DAN, **155**, 783 (1964).
[9] N. Ehrenreich, Proc. VII Intern. Conf. Physics of Semiconductors, Paris, Dukdod. 1964, p. 1301.
[10] N. G. Basov, O. V. Bogdankevich et al., DAN, **161**, 1059 (1965).

Note: Figure translations are in progress. See original paper for figures.