Letters to the Editor

CADMIUM SULFIDE LASER EXCITED BY FAST ELECTRONS

N. G. BASOV, O. V. BOGDANKEVICH, and A. G. DEVYATKOV

P. N. Lebedev Physics Institute, Academy of Sciences, U.S.S.R.

Submitted to JETP editor February 8, 1964

J. Exptl. Theoret Phys. (U.S.S.R.) 47, 1588-1590 (October, 1964)

As reported earlier [1,2] excitation of free carriers in the bands of semiconductors by irradiating them with a beam of fast electrons is one method for obtaining optical masers in the visible and infrared regions. The first experiments in this direction were reported in [3]. However the limited beam power and insufficiently high quality semiconductor materials available then prevented the achievement of negative temperature states in those experiments.

Recombination radiation from CdTe excited by an electron beam from a Van-der-Graaf generator has also been observed by V. S. Vavilov, Egorov, Nolle, and Vintovkin [4].

The present paper reports further experiments using electron pumping to obtain stimulated emission and laser action in semiconductors.

A single crystal of CdS of dimension $3 \times 2 \times 1.5$ mm, prepared by E. A. Konorov, was soldered with Woods metal to a copper cold finger in the vacuum space of a cryostat containing liquid helium. The end faces of the crystal (2×1.5 mm) were made parallel and carefully polished. A beam from an electron gun, having a pulse length of 2.5 μsec and a frequency of several tens of cycles, entered a cylindrical cavity in which an E_{010} standing wave was excited. The electron beam was bunched in phase and accelerated to an energy of the order of 200 keV by the electric field in the cavity. The energy of the electrons was limited to the above value in order not to cause significant radiation damage in the crystal lattice [5]. After acceleration in the resonator the electron beam went through a window covered with a 15 μ aluminum foil into the cryostat and impinged on a 2×3 mm face of the crystal. The electron current density was measured by a Faraday cylinder in separate experiments and could be varied from 0 to 1 A/cm^2 by varying the heater current of the injector. An optical system was used to image one of the end faces of the crystal onto the slit of an ISP-51 spectrograph. The emission spectrum of the sample due to its irradiation was recorded on film.

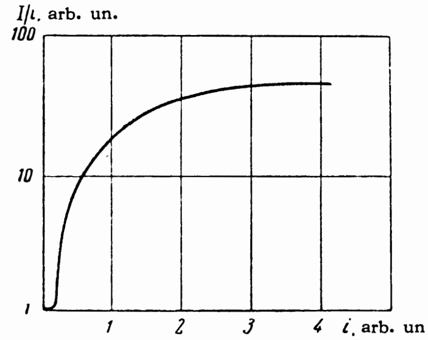


FIG. 1. Dependence of the relative line intensity at 4966 Å on the electron beam current density. The ordinate is the logarithm of the ratio of the line intensity to the current density.

The recombination radiation spectrum consisted of a series of broad bands with transition energies lying within the forbidden gap. For large electron beam current densities the emission spectrum exhibited three sharp lines with wavelengths of 5035, 4966 and 4891 Å.

The initial half-width of the 4966 Å line was measured with a DFS-12 spectrometer to be 35 Å. As the beam current density was increased the intensity of this line increased linearly at first and then jumped suddenly by two orders of magnitude (see Fig. 1). The threshold current depended strongly on the quality of the crystal. Simultaneous with the increase in the intensity, a decrease in the half-width of the line from 35 to 7 Å was observed (Fig. 2). The magnitude of the threshold current depended strongly on the quality of the crystal.

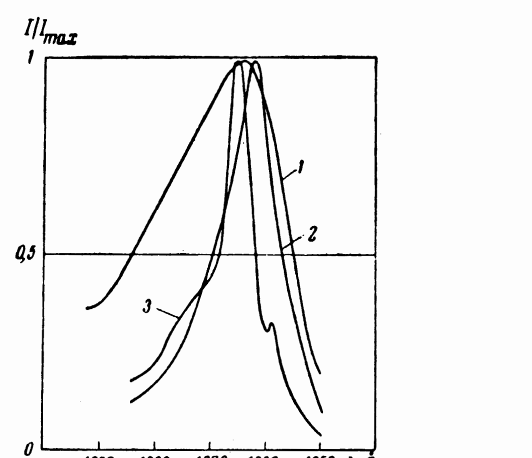


FIG. 2. Variation in the line width of the emission at 4966 Å as a function of the electron beam current density: curve 1, i = 0.1; 2, i = 0.2; 3, i = 0.6 (arbitrary units).

For larger current densities the intensity of the line continued to grow but its width increased somewhat. For small current densities the emission intensity, after the excitation was switched off, fell exponentially with a time constant of about 2 μsec. At higher beam currents the time of the afterglow decreased and the light pulse coincided exactly with the current flux.

In order to estimate the relative intensity of the line, the pulse amplitude was measured with an FÉU-19 photomultiplier, first using an interference filter (4960 ± 35 Å) and then without the filter. The amplitude of the pulse without the filter increased linearly with increasing current. For small currents the emission was totally absorbed by the filter. It was estimated that the intensity of the stimulated emission at the maximum current density was comparable with the total spontaneous emission intensity.

In conclusion the authors consider it a pleasant duty to express their thanks to V. S. Vavilov for a number of useful suggestions and for constant interest in this work, and to Yu.M. Popov and O. M. Krokhin for constant and fruitful discussions concerning the preparation and execution of these experiments and also to A. N. Mestvirishvili and N. P. Lantsov for competent help with the accelerator.

[1] N. G. Basov, Advances in Quantum Electronics, Columbia University Press, 1961, p. 506.

[2] Yu.M. Popov, Doctoral Dissertation, FIAN, 1963.

[3] N. G. Basov and O. V. Bogdankevich, JETP **44**, 1115 (1963), Soviet Phys. JETP **17**, 751 (1963).

[4] Vavilov, Egorov, Nolle, and Vintovkin, FTT **6**, 1406 (1964), Soviet Phys. Solid State **6**, 1099 (1964).

[5] R. Bäuerlein, Z. Physik **176**, 498 (1963).

Translated by J. A. Armstrong
221

PULSED LASER ACTION IN MOLECULAR HYDROGEN

P. A. BAZHULIN, I. N. KNYAZEV, and G. G. PETRASH

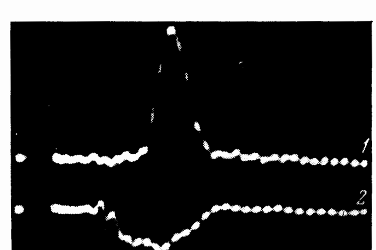
P. N. Lebedev Physics Institute, Academy of Sciences, U.S.S.R.

Submitted to JETP editor June 9, 1964

J. Exptl. Theoret. Phys. (U.S.S.R.) 47, 1590-1591 (October, 1964)

A great deal of attention has recently been given to the problems of obtaining coherent emission in the optical region of the spectrum, to the discovery of new materials for laser action, and to the investigation of the physical mechanisms leading to population inversion. We have observed pulsed laser action in an active medium consisting of a plasma discharge in hydrogen. The laser discharge tube, which had Brewster angle windows, was 145 cm. long and had an inside diameter of 15 mm. External confocal mirrors with a separation of 2 m were used. Both multilayer dielectric mirrors and silver coated mirrors were used. The discharge was excited with a voltage of up to 35 kV. The pulse repetition rate was usually 20 cps. The output radiation was studied with a grating monochromator constructed in our laboratory. An FÉU-22 photomultiplier was used as a detector. The laser pulses and the current pulses were recorded on a DESO-1 oscilloscope.

Laser action was observed as a short emission pulse of approximately triangular form. The length of this pulse between half-power points was about 0.2 μsec. The laser action occurred during the current pulse. In the figure we show: 1- the laser pulse, and 2- the oscilloscope trace of the current pulse. Laser action was observed on six lines; their wavelengths and wave numbers are given in the table. The wavelengths of these lines are measured to an accuracy of about ±5 Å. The error for the line at 13,100 Å may be somewhat larger. The use of different mirrors might make



1 – laser pulse; 2 – current pulse in the discharge. The time markers are 0.05 μsec. apart.