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RESEARCH NOTE

HIGH-SPEED PHOTOCONDUCTIVITY OF GaP LIGHT-EMITTING DIODES AT LIQUID-NITROGEN TEMPERATURE

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Abstract—In GaP : N (Zn,Te) light-emitting diodes, extrinsic photoconductivity was excited by mode-locked TEA CO_2 laser pulses at liquid-nitrogen temperature, showing a current sensitivity of $2 \cdot 10^{-5}$ A/W and a response time of the order of 0.5 ns.

GaP : N light-emitting diodes (LEDs) may be applied as IR photoconductors and as IR to visible upconverters.[1] Experimental investigations have been performed at liquid-helium temperature where almost all carriers are bound to donors and acceptors in the n- and p-regions of the diode, respectively. IR radiation of wavelengths up to about 20 μm ionizes shallow impurities and, thus, induces a photocurrent through the diode leading to visible electroluminescence.[2] By short laser pulse excitation a response time of less than 0.5 ns has been observed which was attributed to rapid capture of holes by ionized acceptors in the highly compensated p-region of the diode and to free-hole to bound-donor radiative recombination[3] The major disadvantage of this quite simple IR detection device is the necessity of liquid-helium cooling. At the temperature of liquid nitrogen, which is undoubtedly much more convenient for practical purposes, a substantial fraction of shallow impurities is thermally ionized leading to a strong increase in the dark current and consequently to an intolerable reduction of the upconversion contrast. However, as shown by the present investigations, GaP : N LEDs are still useful IR detectors at this temperature.

The measurements were performed in the same way as described in Ref. (3). GaP : N (Zn,Te) diodes without plastic covers were immersed in a Dewar containing liquid nitrogen and irradiated by the pulse train of a self-mode-locked TEA CO_2 laser. The signal of single laser shots measured across a 50 Ω load resistor was recorded by a Tektronix R 7912 transient digitizer. Photoconductivity became clearly measurable at 2.4 V forward bias voltage. The highest responsivity was observed at 4.5 V yielding a short-circuit current sensitivity of $2 \cdot 10^{-5}$ A/W at 10.6 μm wavelength.†

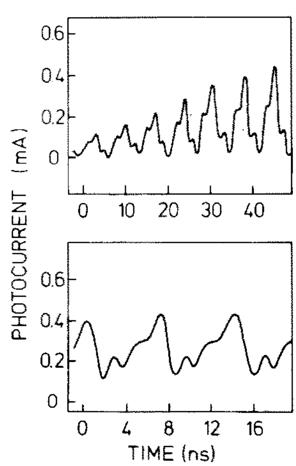

Fig. 1. Part of a pulse train from a TEA CO_2 laser detected by a GaP LED at 77 K.

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†The corresponding sensitivity at 4.2 K is 10^{-3} A/W. In Ref. (3) the IR power was overestimated giving too small a value for the sensitivity.

Above 4.5 V strong dark current noise reduced the signal-to-noise ratio to an unpractical low magnitude. Under reversed bias conditions the sensitivity was less than 10^{-7} A/W up to about 55 V where Zener breakdown occurred.

Typical recordings of CO_2 laser pulses are displayed in Fig. 1. From the fast modulation of the signal 0.5 ns was deduced as an upper limit of the response time, which corresponds to the time resolution of the digitizer. Thus the true time constant may even be shorter.

In conclusion, GaP LEDs at liquid-nitrogen temperature represent very cheap and fast photoconductors applicable for detection of short high-power IR laser pulses. They are comparable to more expensive devices like, for example, photon drag detectors or hot hole detectors.

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