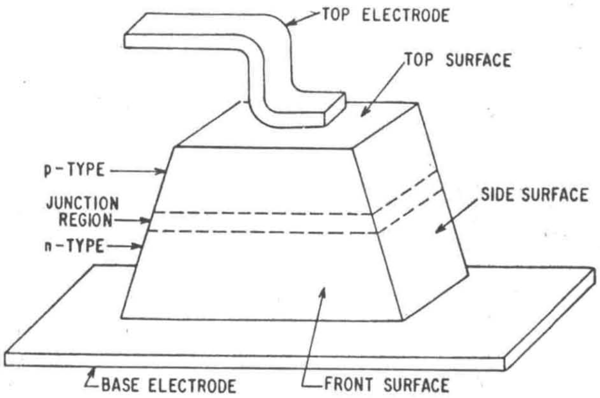

FIG. 1. Laser diode geometry.

mentally determined pressure shifts of similar levels in Si[1] are in agreement with this estimate. While this expected change does fall outside of our experimental uncertainty, the pressure shift of the band gap itself is not known nearly well enough to show up differences of that magnitude. Even if the shift were known more accurately, the concept of a discrete level would be inconsistent with the large impurity concentrations found in our diodes. For these reasons it seems highly improbable that the results of our measurements could be used to identify one of the possible recombination processes.

Unlike some lasers, the crystal itself forms the optical resonator in the junction laser. In our experiments two opposite faces of the crystal are polished parallel to one another as shown in Fig. 1. Because of the large stimulated emission per unit length of active region (region with inverted population) and the large dielectric constant of GaAs, no external reflecting surfaces are required.

The frequencies of the normal modes set up between two parallel reflecting surfaces are given by

$$\nu_{\mathrm{res}} = c/n\lambda_{\mathrm{res}} = cs/2ln, \tag{1}$$

where c is the velocity of light, l the distance between surfaces, n index of refraction, and s the mode number (an integer in the order of 2000).

The application of pressure on a resonator supporting these modes leads to a change in its physical size due to the compressibility of the solid as well as to a change in the dielectric constant.

EXPERIMENTAL DETAILS

The diodes used in our experiments are nearly cubic structures (Fig. 1) with the parallel planes separated by about 4×10^{-3} cm. The junctions are formed by diffusing Zn into n-type wafers with donor concentrations of about 1.5×10^{18} per cc. The acceptor concentrations are several times 10^{19} per cc. The diodes were mounted in an optical pressure cell and the output was measured through a Jarrell–Ash monochrometer with a resolution of 0.3 Å and an accuracy of about 1 Å. The detector was a cooled photomultiplier with a S 1 photoemissive surface.

The pressure fluid used was n-pentane and the cell was cooled by dry ice. The diode temperature was monitored by a cupron copper thermocouple. The shift of the peak of the incoherent emission was found by operating at current levels just below threshold. In order to get an accurate picture of the mode shift of the coherent radiation the diode was operated just at threshold so that several modes were visible. A typical recorder pattern is shown in Fig. 2. Since there is an appreciable amount of thermal tuning during the current pulse, especially at these high current densities (30 000 A/cm^2), the photomultiplier output was sampled using the gate of a Tektronix sampling scope.

In order to follow each mode unambiguously the pressure increments were made as small as possible: typically a few atmospheres. Because a temperature change of 1°K shifts the modes as much as a pressure change of about 50 atm, the measurements in small pressure increments were used only to identify modes, bracket the errors and watch for unexpected developments. Even then a particular mode could be followed for only 250–300 atm, so that the temperature of the sample had to be kept constant to about $\frac{1}{10}$°K to keep errors within reasonable limits. The maximum pressure applied to the diodes was 2000 atm. The pressure was measured with a gauge from American Instrument Company with an accuracy of $\frac{1}{2}$°.

RESULTS

For the peak of the incoherent radiation we find a shift of

$$\Delta\lambda/p\lambda = -7.6\times10^{-6}\ \mathrm{atm}^{-1}$$

giving for the emitted radiation

$$h\nu(\mathrm{eV}) = 1.43 + (1.09\pm0.04)\times10^{-5}\ p(\mathrm{atm}).$$

The evaluation of the data for the coherent radiation was somewhat complicated by the fact that the diode structure is not ideal and that therefore the mode separation is not the same for all modes. Also, differential strains exist in the crystal which are modified under the application of pressure. A least-square analysis of the pressure dependence of about 40 different modes leads to an average mode shift of[2]

$$\Delta\lambda_{\mathrm{res}}/p\lambda_{\mathrm{res}} = (-2.07\pm0.05)\times10^{-6}\ (\mathrm{atm})^{-1}$$

or in terms of energy

$$\Delta h\nu/\Delta p = 2.96\times10^{-6}\ \mathrm{eV/atm}$$

[1] M. G. Holland and W. Paul, Phys. Rev. 128, 30 (1962).

[2] This is in general agreement with measurements reported in Refs. 3 and 4.

[3] J. Feinleib, S. Groves, W. Paul, and R. Zallen, Bull. Am. Phys. Soc. 8, 201 (1963).

[4] M. J. Stevenson, J. D. Axe, and J. R. Lankard, Bull. Am. Phys. Soc. 8, 310 (1963).