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EXPERIMENT FOR DETERMINATION OF ELECTROLUMINESCENT DIODE/DIODE MOUNT THERMAL CHARACTERISTICS

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The development of an effective light emitting diode array source for pumping a Nd:YAG laser is critically dependent on controlling the efficiency and output spectral characteristics of the diodes. A reduction in diode efficiency or a shifting of the diode output spectrum can result in a considerable decrease in laser performance. It has been shown[1] that diode efficiency and output spectral characteristics are dependent on the diode operating temperature and drive current; therefore, it is apparent that considerable emphasis must be placed on the design of the diode configuration and the diode header (mount). Poor choice of design parameters can result in excessive heating in the diode due to non-radiative transitions, absorption, or ohmic losses[2] which cause both decreases in efficiency and shifting of the diode spectrum.

It is the purpose of this document, first, to present a practical laboratory technique for evaluating the thermal characteristics of the diode/diode header combinations in terms of the diode spectrum and efficiency; and, second, to present experimental data verifying this technique measured for a GaAlAs light emitting homojunction diode mounted on an oxygen-free high conductivity (OFHC) copper header.

EXPERIMENT DESCRIPTION

The experiment is divided into two parts. Part one consists of determining two calibration curves, efficiency versus temperature and peak wavelength versus temperature, for the diode/diode header combination when operated under constant low electrical drive power. One calibration curve is sufficient, however, the second provides a means of cross-checking experimental results. These calibration curves will later be used with the results of part two to determine the diode temperature under higher power operation. Part two consists of determining the efficiency versus drive power and peak wavelength versus drive power as the input power to the diode is increased and the diode heat sink is maintained at a constant low temperature.

During part one of the experiment, the diode/diode header combination, mounted on a temperature-controlled heat sink, is driven with a constant low electrical input power while increasing the temperature of the heat sink. Under these conditions, the experimenter can determine the efficiency and peak wavelength versus heat sink temperature curves. It is desirable to use low electrical input power to the diode in order to minimize the diode/heat sink temperature gradient. This condition can be obtained by decreasing the power into the diode while maintaining constant low heat sink temperature until the efficiency of the diode no longer increases with decreasing power input. Then it can be assumed that the power into diode does not significantly increase the temperature of the diode. The difference in temperature between the top surface of the heat sink and the diode junction can be approximated using steady state heat flow equations for the header and diode.

The output power of the diode can be measured with a calibrated thermopile or solar cell arrangement. It is preferable to collect all the light emitted from the diode so the measurement will be independent of the angular orientation of the diode. The efficiency is calculated from

$$\eta = P_0/P_i \tag{1}$$

where η is the diode efficiency, P_0 is the diode output power, and P_i is the electrical input power to the diode.

The output spectrum of the diode can be determined with a spectrometer-photodetector combination where the diode is operating under the same conditions as stated above. This part of the experiment may require that the diode be operated at power levels for which the diode temperature is considerably greater than the heat sink temperature in order to obtain acceptable signal-to-noise ratios while using small spectrometer slit widths for acceptable resolution. Under these conditions, the experimenter can still obtain the increase in diode temperature rather than the actual diode operating temperature as a function of power input.

EXPERIMENTAL RESULTS

Results of the two experiments performed for a GaAlAs light emitting homojunction LPE grown diode, PbSn soldered to an OFHC copper header are shown in Figure 1. The diode with Te as an n-type dopant and Zn as a p-type dopant was approximately 3.81×10^{-4} cm^2. It was driven with a 2 KHz, 50% duty cycle square wave (450 mamps average current) while the heat sink was varied at approximately 3C° intervals over a 10-50°C range. The relative efficiency versus temperature data points are normalized to the efficiency at 10.3°C. Spectral measurements were taken using a 75 cm Spex Spectrometer, a cooled Electro-optics PM101 photodetector and a Clevite/Brush 220 Chart Recorder. The temperature of the heat sink was monitored with a copper constantan thermocouple. The system was calibrated using a National Bureau of Standards calibrated Quartz-Iodine Lamp. The transfer function of the system was found flat to within 1.1 db over the wavelength range considered so that the peak wavelength data is uncorrected. The diode output power was measured using a calibrated Eppley Thermopile.

Power and spectral measurements are now made while the input power to the diode is increased and the temperature of the heat sink is held constant at some low value. Under these conditions, it is assumed that the increased power dissipated in the diode will result in an increase in the diode temperature. Figure 2 shows the diode efficiency and peak wavelength as a function of average input drive power. The temperature of the heat sink was maintained at 10.3°C while the 2 KHz, 50% duty cycle drive power was increased. The combined use of Figures 1 and 2 enable the experimenter to determine the increase in diode temperature with power input. For example, a diode driven at 1.4 watts average input power has peak wavelength 8078 ± 1.5Å and relative efficiency 0.91 ± 0.01 corresponding to an increase in temperature (over the calibration power condition) of 10.8 ± 0.5°C and 10.7 ± 1.0°C respectively. The accuracy in temperature of the peak wavelength experiment was limited by the 1.5Å resolution of the spectrometer and can be improved by reverting to a shorter system or more sensitive detector. For the efficiency measurements the limiting factor is the inability to repeat successive measurements to better than 1% of the average reading of the detector. These fluctuations can be caused simply by laboratory thermal instabilities. For this reason, the peak wavelength calibration technique is preferred when sufficient resolution is attainable.

Thus, the spectrum and efficiency calibration techniques are both effective methods for determining the diode/diode header thermal characteristics under high power operation, and the use of either is determined only by output power of the diode or sensity of the detector system.

The author gratefully acknowledges the experimental assistance of J. C. Owen in this work.

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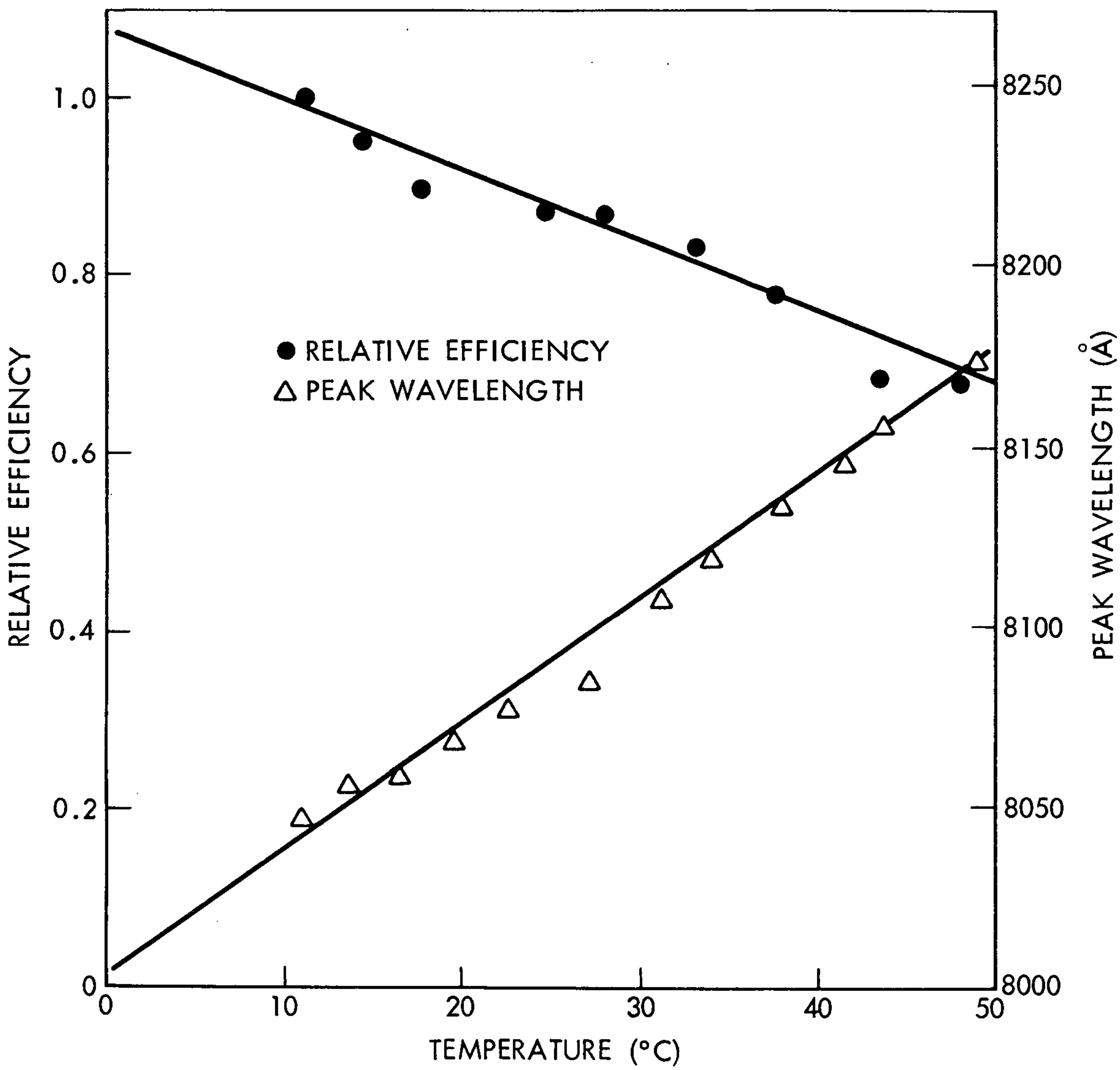

Figure 1. Relative efficiency and peak wavelength of a GaAlAs diode as a function of heat sink temperature.

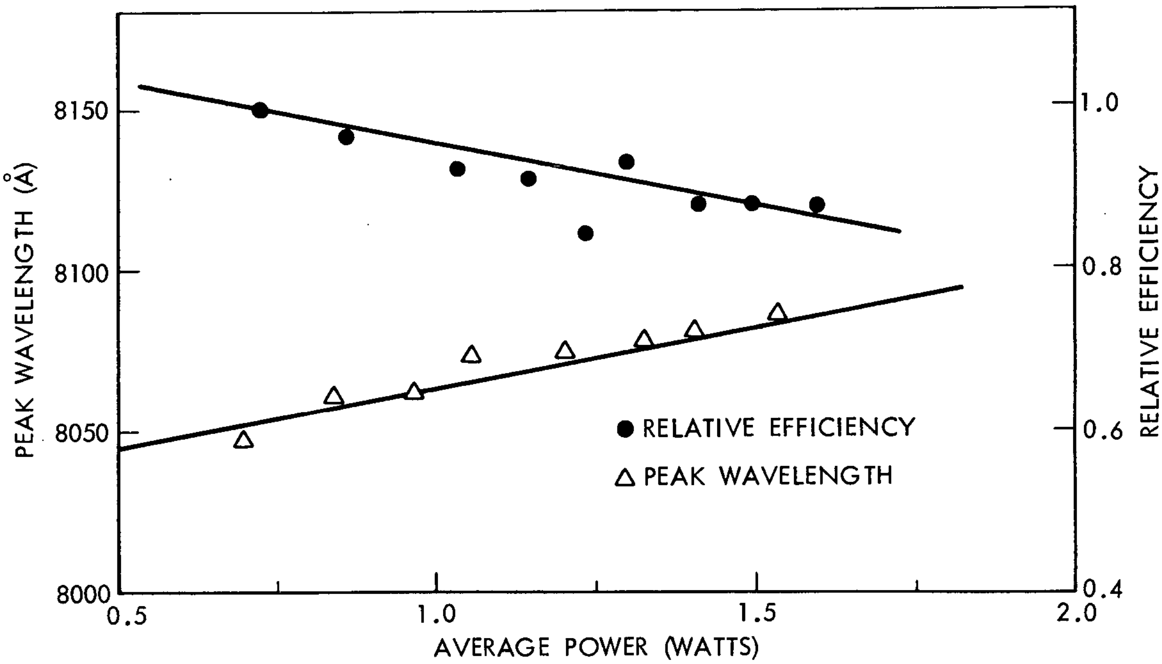

Figure 2. Relative efficiency and peak wavelength of a GaAlAs diode as a function of average drive power.

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