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High Power CW Operation of GaAs Injection Lasers at 77° K

Continuous-wave operation of GaAs injection lasers depends critically upon the junction temperature^{1,2} which, in turn, depends critically upon the heat flow from the laser body.^{3,4} There are two instances in the literature in which continuous operation at 77° K was achieved at very low output power levels. In one, both mirror-ends of a Fabry-Perot structure were partly silvered;⁵ in the other, stimulated emission was observed from a unit with four cleaved sides.⁶ The purpose of this communication is to report that continuous-wave operation at 8400 Å of unsilvered GaAs lasers at 77° K has been consistently achieved at power levels near 0.65 watt and to describe the heat sink structure which has afforded the necessary thermal transfer characteristics.

Figure 1 shows the current generated in a Si solar cell as a function of the direct current through a heat-sink-mounted GaAs laser positioned near the solar cell and with both immersed in liquid nitrogen. The solar-cell current represents the output from one end of the unsilvered laser (the end exposed at the near edges of the mount) shown in Fig. 2. It is seen that at 3.7 amperes of direct current through the laser, the solar-cell current is 300 mA. Making the reasonable assumption that the solar cell has 70% efficiency,⁷ the continuous power output from the exposed end of the laser is calculated to be 640 mW. The output from the unexposed end of the laser is nearly completely lost because of its confinement between the overhanging heat-sink plates. The width of this laser was 0.125 mm, the length was 0.4 mm, the pulsed threshold current was 0.45 amperes (100 nsec pulses, 100 pulses/sec), and the continuous-wave threshold was 0.50 amperes at 77° K. Continuous-wave operation has been observed in similar units with threshold current densities at 77° K ranging from 800 to 2800 A/cm². Measurements have not yet been made for lasers silvered

Figure 1 Solar-cell current due to radiation from one end of an unsilvered laser as a function of the direct current through the laser at 77°K.

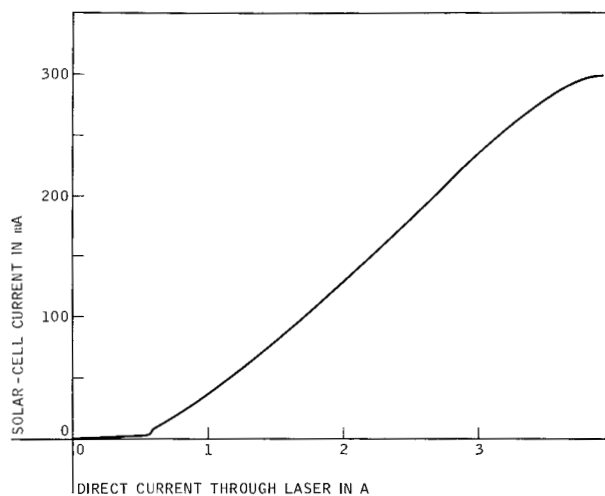
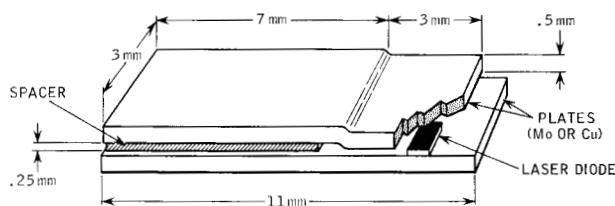


Figure 2 Configuration and dimensions of the heat-sink mount. A typical laser diode is 0.085 mm thick, 0.125 mm wide, and 0.40 mm long.



on the ends recessed between the plates of the mount.

The GaAs wafer from which the lasers are made is lapped to a total thickness of 0.075 to 0.100 mm following the Zn diffusion. A thin film of Au and a thin film of Sn is electrolessly plated on the wafer. In a nonoxidizing atmosphere, the wafer is heated for several seconds at about 400° C to "alloy" in the Au:Sn plate. A layer of In about 15 microns thick is then electroplated upon both faces of the wafer and the wafer is cleaved and sawed into lasers.

The plates for the heat-sink mount are fashioned from ordinary Cu or Mo annealed stock that is not of exceptionally high purity; thicknesses of 0.020 in. and 0.025 in. have been used. (The mount to which Fig. 1 applies used copper plates). The insulating spacer has been fabricated from various materials, such as semi-insulating GaAs, Pyrex glass, and ceramic BeO (for this last case molybdenum plates were bonded to the BeO by the Coors Porcelain Company, Golden, Colorado). After fabrication the free ends of the metal plates are then electroplated with about 15 microns of In.

In the assembled device, Figs. 2 and 3, the spring action of the free ends of the metal plates provides firm pressure contacts on the laser, which is positioned some distance away from the bend of the upper plate so as to minimize the effect of any differential expansion between the spacer and the laser. The effect of pressure^{8,9} has not yet been investigated thoroughly in this work, but it has been roughly estimated that the uniaxial pressure on the laser is in some cases as much as 1000 atmospheres. The series electrical resistance of the pressure contact is usually between 0.1 and 0.2 Ω , measured between 1 and 2 amperes at room temperature.

There is no heating of the assembled device subsequent to the mounting of the laser as is usually done to bond the laser to its contacts, for it has been found that heating is detrimental to the performance of the laser and does not decrease appreciably the series electrical resistance. The good thermal transfer between the laser and the mount is believed to be due, at least in part, to the metallurgical simplicity of the system.

Acknowledgments

The collaboration of many persons was vital to the development of this mounting scheme and their contributions are gratefully acknowledged. Particularly, I must note the collaboration of Miss A. R. Benoric and that of P. Fiore, E. W. Harden, K. L. Konnerth, R. C. McGibbon, R. F. Rutz, and J. C. Topalian, and the contributions of J. W. Crowe and W. E. Ahearn of the IBM Federal Systems Division, who made many of the measurements and contributed advice benefitting the design.

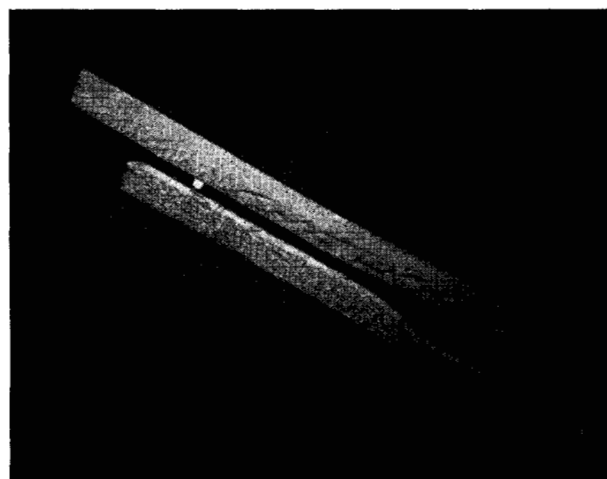


Figure 3 A photograph of the heat-sink mount. Dimensions are as shown in Figure 2.

References

1. W. E. Howard *et al*, "CW Operation of a GaAs Injection Laser," *IBM Journal* 7, 74-75 (1963).
2. M. F. LaMorte *et al*, "CW Operation of GaAs Injection Lasers," *Proc. IEEE* 52, 1257-1258 (1964).
3. S. Mayburg, "Temperature Limitation of Continuous Operation of GaAs Lasers," *J. Appl. Phys.* 34, 3417-3418 (1963).
4. W. E. Engeler and M. Garfinkel, "Characteristics of a Continuous High-Power GaAs Injection Laser," *J. Appl. Physics* 35, 6 (1964).
5. G. Burns *et al*, "The Effect of Temperature on the Properties of GaAs Lasers," *Proc. IRE* 51, 947-948 (1963).
6. M. Pilkuhn *et al*, "Continuous Stimulated Emission from GaAs Diodes at 77° K," *Proc. IEEE* 51, 1243 (1963).
7. G. Cheroff *et al*, "Apparatus for Light Efficiency Measurement," *Rev. Sci. Instr.* 34, 1138-1141 (1963).
8. M. J. Stevenson *et al*, "Line Widths and Pressure Shifts in Mode Structure of Stimulated Emission from GaAs Junctions," *IBM Journal* 7, 155-156 (1963).
9. F. M. Ryan and R. C. Miller, "The Effect of Uniaxial Strain on Threshold Current and Output of GaAs Lasers," *Appl. Phys. Lett.* 3, 162-163 (1963).

Received October 30, 1964.

Note added in proof

R. F. Rutz and K. L. Konnerth of this laboratory have quite recently measured a number of unsilvered units having c.w. output powers between 0.650 and 1.00 watt. One unit produced 500 milliamperes of solar cell current, which corresponds to a power output of 1.07 watt. A group of similar units were c.w.-operated at 90°K; one of these produced 450 mW of c.w. output power.