Digest of Tech. Papers The 13th Conf. on Solid State Devices. Tokyo

B-4-6 Bistability and Differential Gain in Semiconductor Lasers

Hitoshi Kawaguchi

Musashino Electrical Communication Laboratory

Nippon Telegraph and Telephone Public Corporation, Musashino, Tokyo

INTRODUCTION There has been considerable interest in bistable optical devices which can be used to perform optically controlled memory and switching operations. Development of differential gain devices which have potentials for high efficient repeaters and logic elements, is also being watched with keenest interest. Such operations can be realized with a laser that has saturable optical loss in the laser resonator. More than a decade ago, bistability was examined using a GaAs laser with a so-called "double unit".[1~4] However, in those reports, direct experimental observation of bistability in the current-light output (I-L) curves are never made. This paper reports a bistable operation hysteresis characteristic and a differential gain characteristic in newly-designed inhomogeneously excited semiconductor lasers.[5]

DEVICE STRUCTURE AND FABRICATION Figure 1 shows the laser structure. An InP/InGaAsP/InP DH structure was prepared using an LPE technique. The current channel was made by planar Zn diffusion method according to designed stripe geometry. The stripe which was broken line-like, was 10 μm wide. The injection region was 20 μm long, and the non-injection region was 10 μm long. In the figure, the injection regions are shaded. Cavity length was 200 μm.

RESULTS Typical I-L curves for CW operation at different heatsink temperatures are shown in Fig.2. At 215.2K, a noticeable hysteresis loop is seen in the I-L curve (d). As the excitation level is increased from zero, the output gradually increases until it reaches point A, where it abruptly jumps to a higher output power. On the other hand, as the excitation level is decreased, the output decreases to point B, where it drops abruptly to the lower curve, completing the loop. The current range of the bistability (ΔI) markedly decreased with decreasing temperature, making direct observation of the bistability somewhat difficult. In this case, the laser's output characteristic slope abruptly changed at the threshold(curve (b)). This corresponds to differential gain. As shown by curve (a), at still lower temperature, a normal I-L curve is observed.

Switching characteristics were measured for bistable operation. Bias current I_b was set at 148 mA, which is the middle value of the current range for the bistability, as shown in Fig.3(a). Switching between the two stable states was accomplished by applying current pulses (rise time $\simeq$ fall time $\simeq$ 3.5 ns) added to the bias current. Fig.3(b) shows light output (upper trace) and trigger current (lower trace). Amplitude for both the ON and OFF current pulse was about 2.5 mA.

The light output trace shows typical characteristics of the bistable multivibrator which can be induced to make an abrupt transition from one state to the other by means of external trigger excitation. The smallest amplitude necessary for the switching mainly depends on the stability of the device temperature. If the temperature is stablized enough, operation conditions can be chosen where the ΔI is small. The switching time is limited by the response time of the saturable absorption. Fig.4 shows response for the rise (a) and the fall (b). From our experiment, light rise time was less than 0.5 ns. Fall time depended on the megnitude of the OFF pulse. We found that $T_f \propto \sqrt{I_T/I_{Tth}-1}$, where I_T is current of the OFF pulse and I_{Tth} is the smallest trigger current pulses needed for the switching, and T_f=1 ns at $I_T=4I_{Tth}$.

This device can also be switched by suitable light pulses. The I-L characteristics for the devices can also be designed by the length of injection region. Therefore, such devices will have a number of useful applications.

REFERENCES

1)G.J.Lasher,Solid-State Electron.7,707(1964).

2)Marshall I.Nathan,J.C.Marince,R.F.Rutz,A.E. Michel,and G.J.Lasher,J.Appl.Phys.36,473 (1965).

3)Yu.P.Zakharov,V.V.Nikitin,A.S.Semenov,A.V. Uspenskii,and V.A.Scheglov,Soviet Physics-Solid State 8,1660(1967).

4)N.G.Basov,IEEE J.Quantum Electron.QE-4,855 (1968).

5)H.Kawaguchi and G.Iwane,Electron.Lett.17, 167(1981).

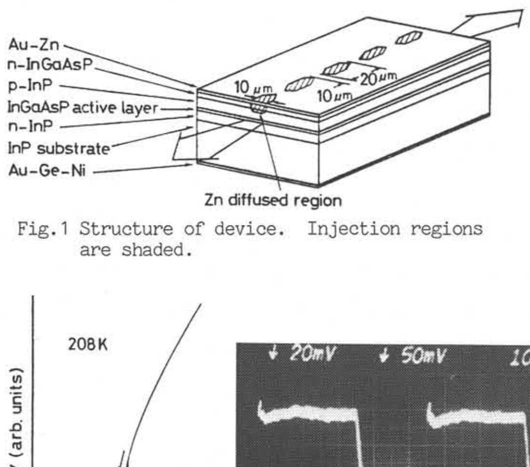


Fig.1 Structure of device. Injection regions are shaded.

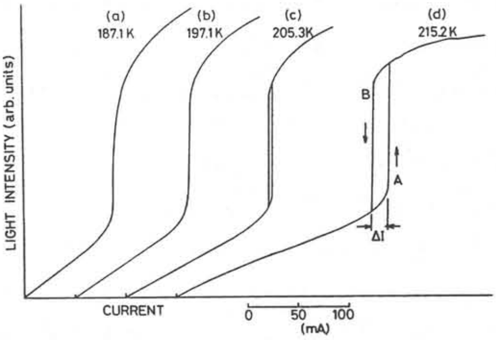
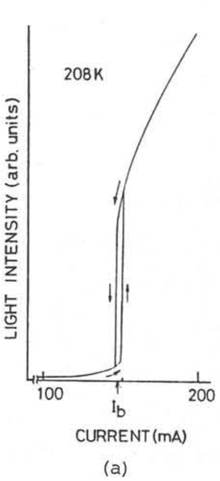
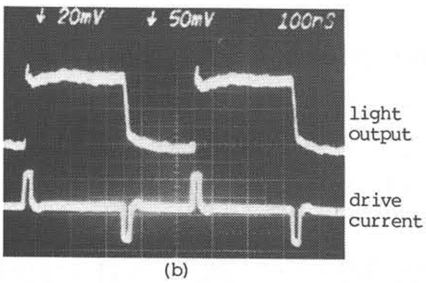


Fig.2 Typical observed I-L curves for CW operation. At 215.2K, a remarkable hysteresis loop is seen (curve d). ΔI decreased with decreasing temperature, making direct bistability observation somewhat difficult (curve b,differential gain). At still lower temperature, the normal I-L curve is observed (curve a).



(a)



(b)

Fig.3(a)Typical observed I-L curve at 208K.
(b)Sampling oscilloscope trace of the light output (upper trace) and trigger current (lower trace).

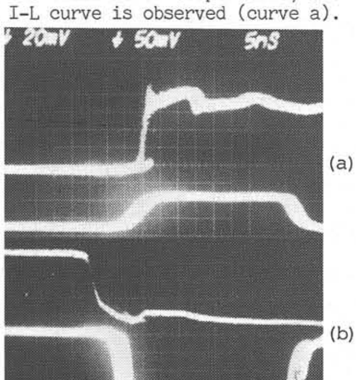


Fig.4(a) Response for the rise and (b) the fall. Trace of the light output (upper trace) and trigger current (lower trace).