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A New InGaAsP/InP Heterobipolar Laser Transistor

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Recently, optoelectronic integrated circuits (OEIC's) are actively studied[1,2]. In order to realize a highly multi-functional OEIC, new devices with functions of light emission and electrical switching are desired to be realized. A double-heterobipolar transisitor (D-HBT), which consists of semiconductor compounds with direct energy gaps, is considered to be one of promissing devices for this purpose because of its capability of confining the photons in a layer[3]. In this study, we have developed a new structure HBT which produces a stimulated emission from the base region. We report the fundamental characteristics of this device.

Figure 1 shows the schematic structure of the device. The wafer grown by LPE consists of four layers: n-InP (collector, 5μm), p-InGaAsP (base, active layer, λg=1.3um, 0.2μm), n-InP (emitter, 4μm) and n^+-InP (cap, 1μm). After a mesa structure was formed by chemical etching, the mesa was buried with p^+-InP LPE layers. Au/Zn and Au/Sn were selectively deposited to give ohmic electrodes on p and n regions, respectively. This structure constructs a npn double-heterojunction bipolar transistor with p^+-InP graft base layers.

When it operates in the saturation state of the transistor operation, holes are transversely injected into the p-quarternary base region from the graft base and a lot of electrons are vertically injected from the emitter into the collector through the base. Since the base region has a narrower band gap than that of InP, most of the holes and a part of the electrons are confined in the region and then recombine to generate photons. The photons are also confined in this region because the region has a higher refractive index than that of InP. Thus, laser oscillation occures when the both types of carriers are injected sufficiently. In cut-off state, however, since holes are not injected, the collector current is very small and light emission does not occur.

Figure 2 shows the current-voltage characteristics of the fabricated device. The h_{FE} is higher than 300, and the collector resistance is less than 10Ω. Figure 3 shows the dependence of light output power on base current under no bias voltage. Laser operation was observed when the base current is larger than 20mA. The external differential quantum efficiency is found to be about 15 percent per facet. Figure 4 shows the response properties of the optical output and the collector voltage to the driving base current, here, the collector was reversely biased through 30Ω series resistor.

In summary, we have demonstrated a new switching heterobipolar device - a laser transistor, which is able to control both optical emission and electrical current.

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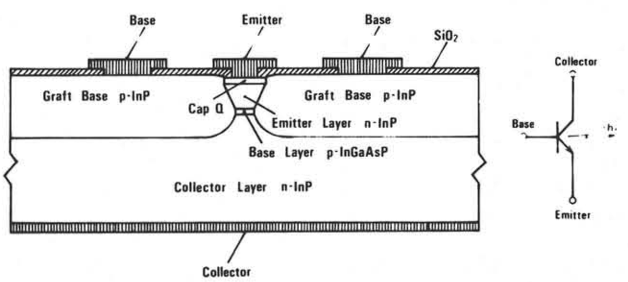

Fig.1. Schematic cross-sectional view of the new device and the equivalent circuit

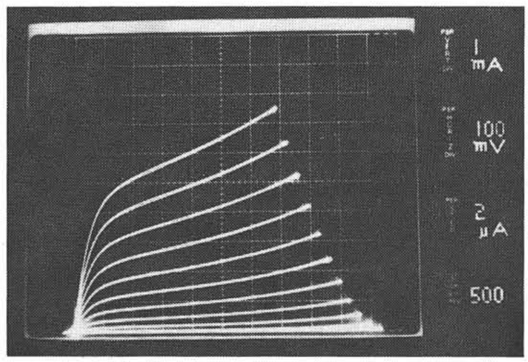

Fig.2. Current-voltage characteristics

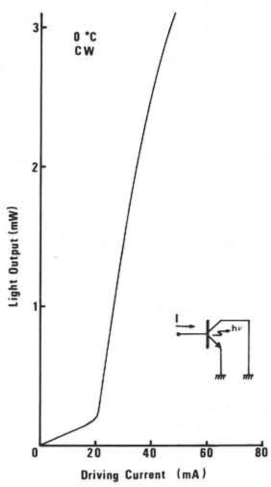

Fig.3. Light output vs. base current characteristic at no bias

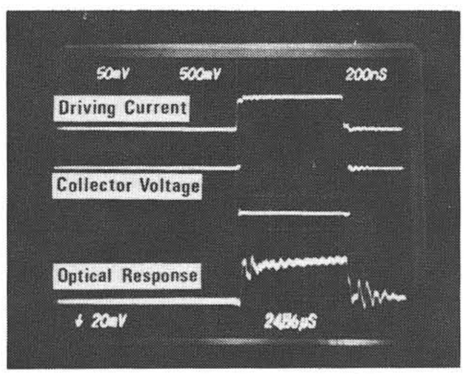

Fig.4. Response characteristics of the collector voltage and the light output