Micro-cavity GaAlAs/GaAs Surface Emitting Laser with $I_{th}=6\,\text{mA}$

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This is a first demonstration of a micro-cavity GaAlAs/GaAs surface emitting (SE) laser with $I_{th}=4.5\,\text{mA}$ (77 $K$, CW) and 6 $\text{mA}$ (300 $K$, pulsed). The structure of the CBH-SE micro-cavity laser by the selective meltback [1] is shown in Fig. 1. A micro-cavity of 7 $\mu\text{m}$ long and 6 $\mu\text{m}$ in diam. has been realized.

A circular buried heterostructure (CBH) [2] [3] and a highly reflective TiO$_2$/SiO$_2$ multilayer Bragg reflector [4] have been introduced.

Figure 1 also shows a fabrication process. The most important process is to make a small diameter active layer. This is performed by selectively melting back the GaAs active layer to make a constricted mesa in a LPE furnace for 20 seconds under the following conditions: the meltback starting temperature is 800 $^\circ\text{C}$ and employed cooling rate is 0.5 $^\circ\text{C}/\text{min}$. The degree of undersaturation for Ga and As in the solution is taken to be 4 $^\circ\text{C}$, which is the temperature drop from that for saturation. During this process the n-GaAlAs cladding layer is hardly melted back.

The present SE laser was mostly tested under pulsed condition ($1\,\mu\text{sec}$ pulse width, 6 kpps) at 20.5 $^\circ\text{C}$. The light-output/current (L-I) characteristic is shown in Fig. 2. The threshold current was 6 $\text{mA}$. Although we used rather a long pulse, decrease of light output was not observed at low level excitation. We drove the device up to 40 $\text{mA}$. The differential quantum efficiency was 9 % and more than 1 $\text{mW}$ peak power was obtained. First CW operation at 77 $K$ was achieved with $I_{th}=4.5\,\text{mA}$.

The lasing spectra at $I=20\,\text{mA}$ and 40 $\text{mA}$ are shown in Fig. 3. The SE laser ran single mode but the linewidth was broadened at $I=40\,\text{mA}$.

The near field pattern of this SE laser was a circle of $2r\approx6\,\mu\text{m}$ in diam. as shown in Fig. 3. Actually, the threshold of 6 $\text{mA}$ can be roughly understood from Fig. 4 for the diameter of 6 $\mu\text{m}$. This means that the scaling law, $I_{th}$ is proportional to $r^2$, stands without any noticeable diffraction loss. We can expect to reduce the threshold to a few mA by optimizing the micro-cavity structure.

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References
Fig. 1. Structure and fabrication of micro-cavity SE laser.

Fig. 2. Light output/current characteristic.

Fig. 3. Spectra and Near Field Pattern of micro-cavity SE laser.

Fig. 4. Threshold current vs. radius of active region characteristic.