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Microcavity Surface-Emitting Laser with Record Low Threshold Current of 190 μA

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Since the advent of semiconductor lasers, reduction of a threshold current [1] has been an important research theme. For this purpose, a microcavity surface-emitting laser [2),3),4)] is one of the most promising devices. Here, we demonstrate a record low threshold current of 190 μA in a microcavity surface emitting laser with a 5 μm diameter airpost.

Figure 1 shows the structure of a microcavity surface-emitting laser. This device has a *pin* structure sandwiched between p- and n-distributed Bragg reflectors (DBRs). The epilayers grown on an n-GaAs substrate by molecular beam epitaxy (MBE) for the *pin* structure are as follows: an n-$Al_{0.25}Ga_{0.75}As$ layer (0.13 μm, Si doped at 5 x 10^{16} cm^{-3}), an undoped 10 nm-thick $In_{0.2}Ga_{0.8}As$ strained single quantum well active layer sandwiched between undoped GaAs and $Al_{0.25}Ga_{0.75}As$ barriers, and a p-$Al_{0.25}Ga_{0.75}As$ layer (0.13 μm, Be doped at 5 x 10^{16} cm^{-3}). The undoped layers are p type and the background carrier concentrations are 1 x 10^{15} cm^{-3}. The DBRs consist of alternate layers of AlAs and GaAs which make quarter-wave stack. There are 28.5 periods in the bottom reflector (Si doped at 2 x 10^{18} cm^{-3}) and 24 periods in the top reflector (Be doped at 2 x 10^{19} cm^{-3}). A p-GaAs cap layer (0.16λ, Be doped at 2 x 10^{20} cm^{-3}), which also acts as a phase-matching layer, is grown on the surface of the top reflector. Reactive ion beam etching (RIBE) with Cl_2 [5] was applied to form a 5 μm diameter airpost. The scanning electron micrograph of the airpost is shown in Figure 2.

Figure 3 shows the current vs. light-output (I-L) characteristic in pulsed operation at room temperature with no heat sink. The pulse width is 0.5 μs, and the pulse repetition rate is 100 kHz. A record low threshold current of 190 μA was achieved, and the threshold voltage was only 2.4 V. It is considered that this low threshold current indicates that quality of the MBE grown wafer is high [6], the dry-etched surface is smooth enough to guide light, and the non-radiative recombination at the sidewall is low enough. Light-output above threshold was linearly polarized, and the intensity ratio between the two orthogonal lights was about 40.

In conclusion, we have achieved a record low threshold current of 190 μA in a microcavity surface-emitting laser with a 5 μm diameter airpost, in pulsed operation at room temperature.

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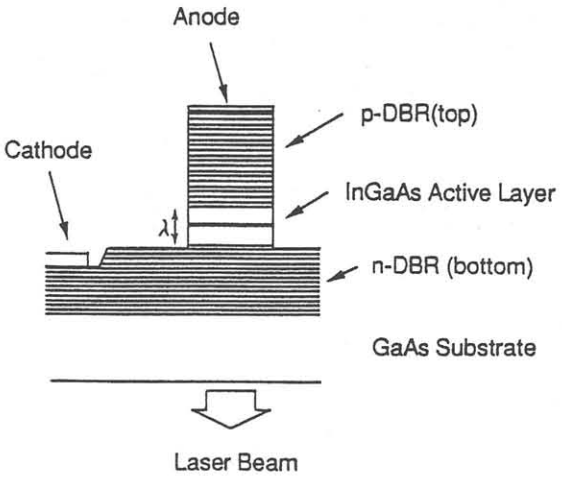

Fig. 1 Device structure of a microcavity surface-emitting laser. Airpost diameter is 5 μm.

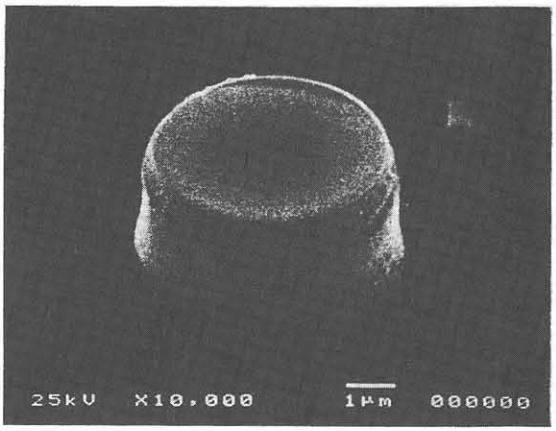

Fig. 2 Scanning electron micrograph of the airpost made by RIBE.

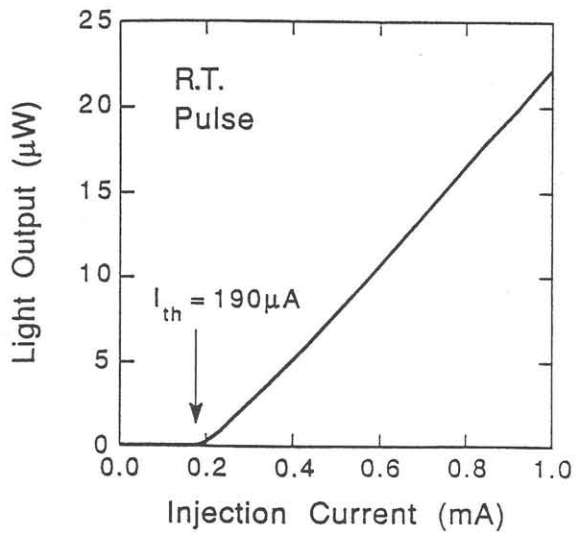

Fig. 3 Current vs. light-output characteristic for pulsed operation at room temperature. The pulse width is 0.5 μs and the pulse repetition rate is 100 kHz.