Semiconductor Membrane Distributed-reflector (DR) Laser

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Recent advance in the LSI performance is attractive for processing the large amount of data. However, some problems such as signal delay or large power dissipation has occurred in the global wiring inside LSI as the scaling advances. In order to solve these problems, an introduction of optical interconnects to LSI was proposed and various studies have been reported [1]. Toward realization of optical data link inside the LSI, we proposed and demonstrated semiconductor membrane DFB lasers for low power consumption and high speed operation [2]. Even though a sub-mA threshold current operation of the membrane DFB laser was realized in our previous work [3], an enhancement of light output to one direction is very important to build an optical link with low-power consumption. For this purpose, we realized, for the first time, a membrane distributed-reflector (DR) laser which consists of 30-μm long DFB section and 90-μm long passive DBR section, and demonstrated a low-threshold current (250 μA) operation as well as its asymmetric output power ratio (output power from the front side to that from the rear side) of 6.7 under a room-temperature continuous-wave (RT-CW) condition.

Figure 1 shows the schematic structure of the membrane DR laser which consists of an active DFB section with GaInAsP strain-compensated 5 quantum-wells (SC-5QWs: 6-nm wells and 15-nm barriers) and passive DBR section with GaInAsP butt-jointed built-in (BJB) waveguide (λ_g = 1.22 μm), where gratings for DFB/DBR sections were formed on the surface of the top InP layer, and the device was cleaved at around 200-μm apart from the DFB/DBR grating edge. The cross sectional view of the device is shown in Fig. 2, where the grating period in the DFB section Λ_{DFB} and that in the DBR section Λ_{DBR} were set to 298 nm and 296 nm, respectively, so as to match the lasing wavelength and center wavelength of the DBR. For fabrication of membrane DR laser, the initial wafer with core layer thickness d_{core} = 270 nm including SC-5QWs was prepared. Firstly, the active layer was embedded by GaInAsP (λ_g = 1.22 μm) and the BJB structure was formed. Next, the lateral-current-injection (LCI) structure was formed by two-step regrowth of n-InP and p-InP side claddings. After depositing 1-μm thick SiO_2 film, the wafer was bonded upside down on Si host substrate, and InP substrate side and etch stop layers were removed by polishing and wet chemical etching. By using the contact layer except *p* region was removed and evaporated Ti/Au for electrodes. Finally, the surface grating including was formed by electron beam lithography and wet chemical etching.

Figure 3 shows light output-current characteristics of a DR laser with a stripe width W_s of 0.7 μm. The DFB section length L_{DFB} and the DBR section length L_{DBR} were 30 μm and 90 μm, respectively. A threshold current I_{th} of 250 μA, which corresponds to the threshold current density J_{th} of 1.2 kA/cm^2, was obtained. An external differential quantum efficiency from the front facet η_{df} of 11% and that from the rear facet η_{dr} of 1.6%, which correspond to asymmetric light output ratio of 6.7, were obtained. Figure 4 shows its lasing spectrum at a bias current of $2I_{th}$, where the lasing wavelength of 1545 nm and the sub-mode suppression-ratio (SMSR) of 22 dB were observed, and the index-coupling coefficient of the DFB grating was estimated to be 1300 cm^{-1} from the stopband width of 29 nm. Figures 5 and 6 show light output-current characteristics and lasing spectrum, respectively, of 50-μm long membrane DFB laser fabricated on the same wafer for comparison. Since the passive DBR suffers from a residual optical loss for the DR laser shown in Fig. 3, slightly lower I_{th} of 210 μA (and J_{th} = 600 A/cm^2) was obtained with the membrane DFB laser.

References

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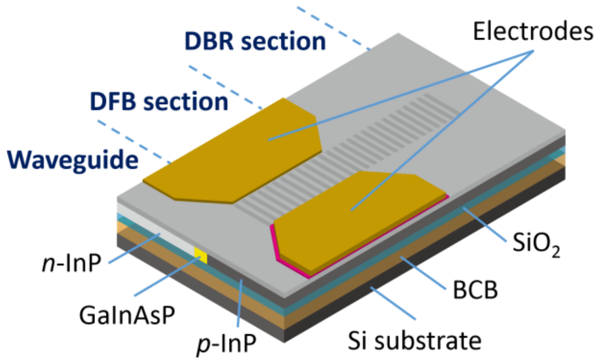

Fig. 1. Schematic structure of membrane DR laser.

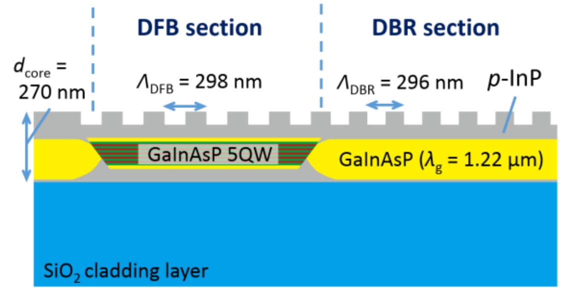

Fig. 2. Cross sectional view of the fabricated membrane DR laser along cavity direction.

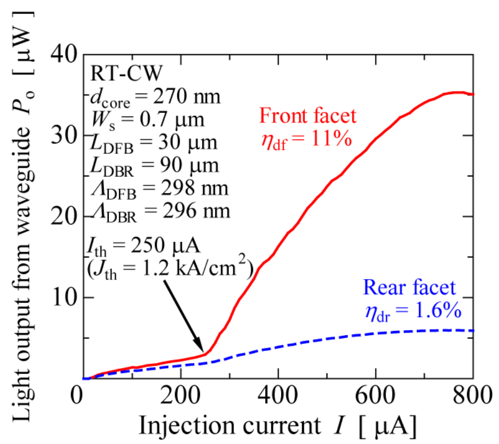

Fig. 3. Light output-current characteristic of membrane DR laser.

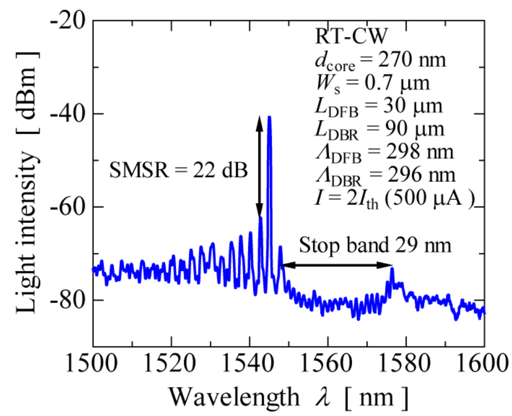

Fig. 4. Lasing spectrum of membrane DR laser.

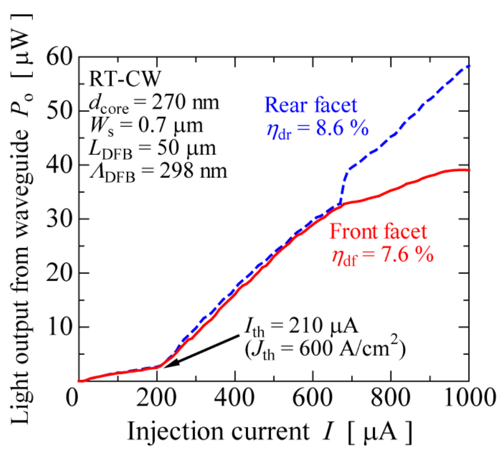

Fig. 5. Light output-current characteristic of membrane DFB laser fabricated on the same wafer.

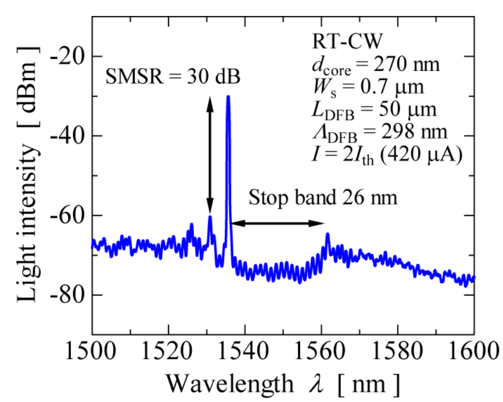

Fig. 6. Lasing spectrum of membrane DFB laser fabricated on the same wafer.