VERTICAL CAVITY SURFACE-EMITTING LASER WITH AN AlGaAs/AlAs BRAGG REFLECTOR

Indexing terms: Semiconductor lasers, Semiconductor growth, Integrated optics

The letter elucidates the room temperature pulsed operation of a vertical cavity surface-emitting (SE) laser with an electrically conductive AlGaAs/AlAs distributed Bragg reflector (DBR). The maximum reflectivity of a DBR grown by MOCVD was 96% at 0·88 μm wavelength. The threshold current of 30 μm diameter devices was 200 mA under room temperature pulsed condition, which is the lowest value for such a broad area structure.

A vertical cavity surface emitting (SE) laser[1] is attractive for lightwave communications and parallel optical processing, taking advantage of two-dimensional array configurations. So far, Fabry–Perot resonators have been formed from two surfaces of epitaxial layers by removing the substrate, and an Au coated mirror or dielectric multilayer reflector has been used as a laser reflector.[2,3] Attempts were made to form a laser cavity with the help of semiconductor multilayers for distributed feedback (DFB)[4] or distributed Bragg reflector (DBR)[5] surface-emitting lasers. These structures may open up new three-dimensional integrated optics by using a stacked configuration.

In this letter, we report on a DBR surface-emitting laser with an electrically conductive AlGaAs/AlAs distributed Bragg reflector. As a preliminary experiment, a simple mesa cap structure[2] with a 3 μm thick and 30 μm diameter active layer is fabricated. Room temperature pulsed operation with a threshold current density of 30 kA/cm^2 and an output power exceeding 12 mW have been achieved.

The schematic structure of the AlGaAs/AlAs DBR surface-emitting laser is shown in Fig. 1. An AlGaAs/GaAs DH wafer having a 20 pair $Al_{0\cdot1}Ga_{0\cdot9}As$/AlAs multilayer is grown by atmospheric pressure metalorganic chemical vapour deposition (MOCVD). The AlGaAs/AlAs DBR consists of quarter-wavelength layers of $Al_{0\cdot1}Ga_{0\cdot9}As$ (625 Å) and AlAs (741 Å), which is used as an emitting side reflector, intentionally doped (5×10^{17} cm^{-3}) for current injection. The values of refractive indices used were $n(Al_{0\cdot1}Ga_{0\cdot9}As) = 3{\cdot}52$ and $n(AlAs) = 2{\cdot}97$. The maximum reflectivity is 96% at a wavelength of 0·88 μm. We evaluated the wafer quality by making stripe lasers. The nominal threshold current density is 4 kA/cm^2 μm, which is comparable to that of conventional DH wafers with a thick active layer. We found that carriers can be injected into the active layer through the doped DBR, and the injected carriers are also well confined by the DBR.

A simple mesa cap surface emitting laser structure with a diameter of 30 μm was fabricated. The fabrication process is similar to that described in Reference 2. First, Zn diffusion was carried to the *p*-side surface of the grown wafer. An SiO_2 circular etching mask of 30 μm diameter was formed to create round mesas. Then, an SiO_2 ring window, whose inner and outer diameter were 10 and 20 μm, respectively, was formed on the mesa. Next, the *n*-side substrate was thinned down to 100 μm and the GaAs substrate removed to eliminate the absorption. An Au/SiO_2 mirror was used as a *p*-side reflector.

Fig. 2 shows a light output/current characteristic and a typical lasing spectrum of a fabricated DBR surface-emitting laser device. The longitudinal mode separation is 154 Å (A–B), indicating that the modes are well defined by the effective length of the DBR.[6] Room temperature pulsed operation has been realised with a threshold $I_{th} = 200$ mA, which is the lowest value for such a broad area structure. The threshold current density was 30 kA/cm^2. The maximum peak output power from fabricated DBR laser devices was 12 mW. These results indicate that the doped multilayer reflector works as a highly reflective mirror with low absorption loss. The threshold could be reduced to several mA by introducing a buried heterostructure.[3]

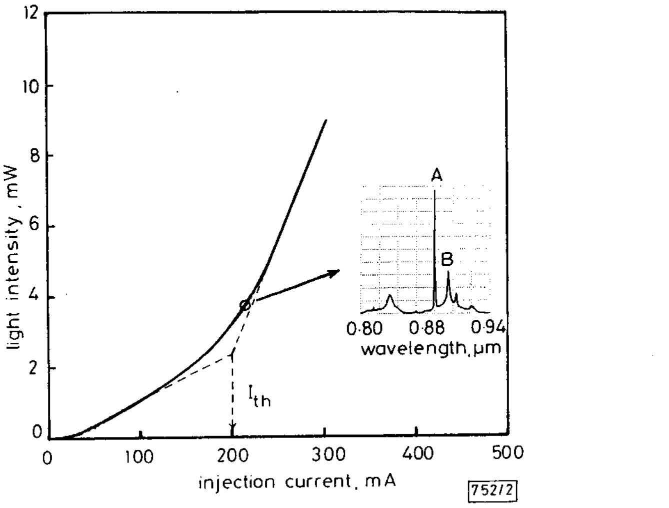

Fig. 2 *Light output/current characteristic of DBR surface-emitting laser*

Wide spectral widths (> 10 Å) are sometimes observed from surface-emitting devices.[4] From our lasers with a short cavity ($L < 10$ μm), on the other hand, a relatively narrow spectral width has always been observed even below the threshold. For the purpose of obtaining a more exact criterion for oscillation of SE lasers, we paid attention to spectra below and above the threshold, which are shown in Fig. 3. Even below the threshold, the spectral width was less than 1 Å, which is limited by the resolution of the spectrometer used. A spectral width of > 10 Å which was sometimes observed in SE laser devices[4] may indicate that the device is operating far below the threshold. The small peaks observed near the main peak (*a*, *b*, *c* in Fig. 3) are higher-order transversal modes, which can be eliminated by reducing the active region diameter.[3]

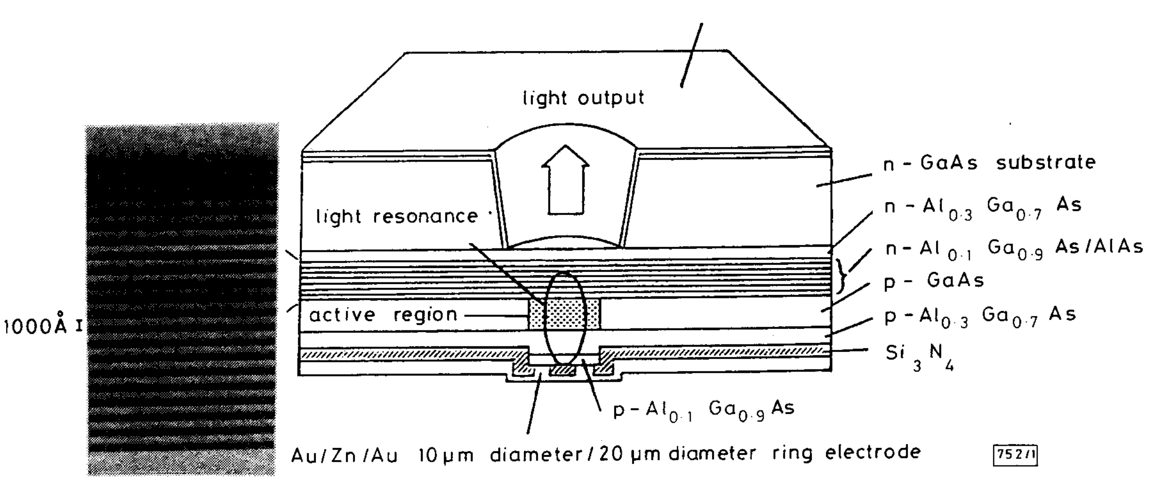

Fig. 1 *Schematic diagram of structure of AlGaAs/AlAs DBR surface-emitting laser with 3 μm-thick active layer and a 20-pair DBR*

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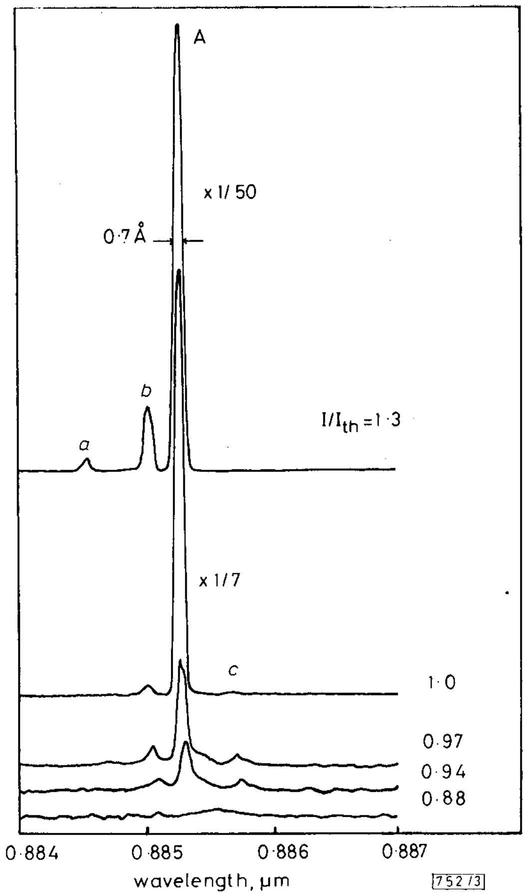

Fig. 3 *Lasing spectra of DBR surface-emitting laser with various injection levels*

Spectral resolution is 0·5 Å; spectral width is less than 1 Å, even below threshold

The DBR structure which has been demonstrated will be effective for monolithic integration with any other functional devices such as modulators and switches, which can be monolithically stacked onto an SE laser. Its advantages will be a high coupling efficiency and possibility of dense 2D array, which is not the case for the stripe laser geometry. We are trying to integrate a multiquantum well (MQW) modulator which is grown by MOCVD.

We believe that a semiconductor multilayer DBR is effective for reducing the threshold and stacking other optical functional devices on the surface emitting laser as mentioned above.

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