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GaInAsP/InP Surface Emitting Laser Grown by CBE and Wavelength Tuning Employing External Reflector

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We demonstrated the lasing operation of GaInAsP/InP vertical cavity surface emitting lasers grown by a chemical beam epitaxy. The lowest threshold current was 2.7mA at 77K CW for 30μmϕ devices. By changing the cavity length employing an external reflector, continuous tuning of 40Å was achieved for the first time. Our result indicates that a short cavity structure can provide a continuous wavelength tuning by taking the advantage of its wide longitudinal mode spacing.

1. INTRODUCTION

The GaInAsP/InP surface emitting (SE) laser is expected to play an important role in the large capacity parallel light wave communication systems. Chemical beam epitaxy (CBE) which uses gas-sources for both group III and V is one of suitable growth techniques for the GaInAsP/InP systems.

Large longitudinal mode spacing in SE lasers due to very short cavity structure is attractive for a pure continuous wavelength tuning without mode hopping. For this purpose, an electrical intra-cavity tuner using the quantum confined Stark effect (QCSE) has been theoretically investigated[1]. A thermoelectric (Peltier) effect in a DBR section was used to tune the wavelength[2,3], and wavelength shift of 12Å was observed. Employing an external reflector, this tuning scheme can be easily realized and we can verify the stability of the SE laser under tuning. An experimental demonstration of an external reflector to control wavelength of the SE laser was reported, but the tuning was discrete[4].

2. EXPERIMENTAL

2.1 GaInAsP/InP SE LASER BY CBE

The CBE system used in this experiment is a modified RIBER CBE-32. As group III sources, tryethylgallium (TEGa) and trymethylindium (TMIn) with H_2 carrier gas were used. Pure arsine (AsH_3) and phosphine (PH_3) were utilized for group V sources which were precracked at 1000°C by a cracking cell custom designed for this machine. The device structure is shown in Fig. 1. The band gap wavelength and the thickness of the GaInAsP active layer is 1.55μm (at 300K) and 1.0μm, respectively. The composition of p^+-GaInAsP contact layer is

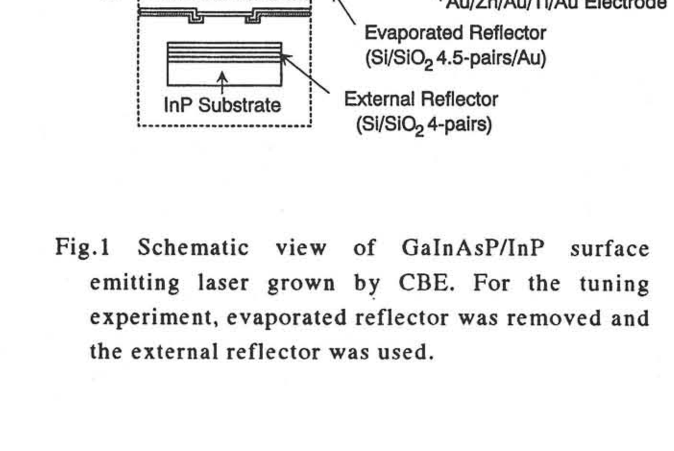

Fig.1 Schematic view of GaInAsP/InP surface emitting laser grown by CBE. For the tuning experiment, evaporated reflector was removed and the external reflector was used.

1.3μm. The diameter of round-low mesa and the outer/inner diameter of the ring electrode on the *p*-side is 30μm and 20μm/10μm, respectively. The Si/SiO_2 multilayer reflectors were evaporated on both light output and rear sides by electron beam (EB) deposition method with an *in-situ* optical thickness monitoring[5]. Figure 2 shows a current-light output characteristic and lasing spectrum under CW operation at 77K. The lowest threshold current and current density are 2.7mA and 455A/cm^2, respectively. These are the lowest value for GaInAsP/InP SE laser at 77K ever reported. The lasing wavelength was 1.43μm. We can improve the laser threshold by optimizing the structure. We have to take the relative large absorption (α~400cm^{-1}) measured for highly *p*-doped GaInAsP contact layer[6] into consideration.

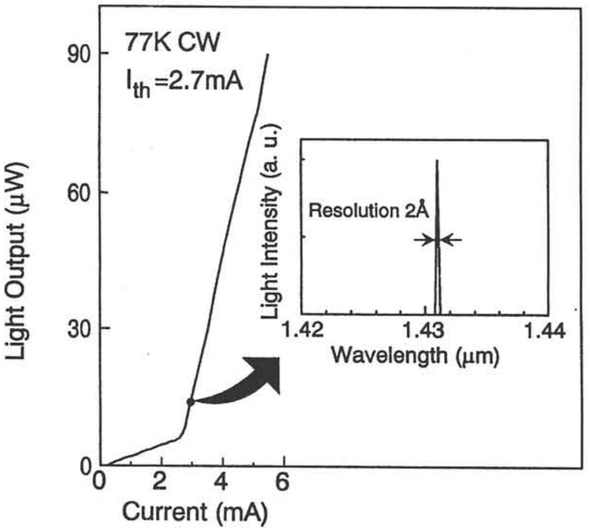

Fig. 2 A current-light output characteristic and lasing spectrum of SE laser with evaporated reflector at 77K.

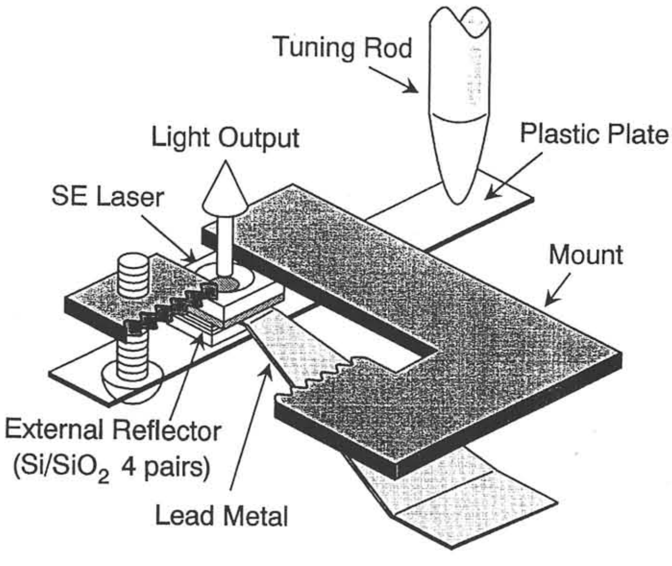

Fig. 3 Experimental arrangement for wavelength tuning of SE laser by employing external reflector.

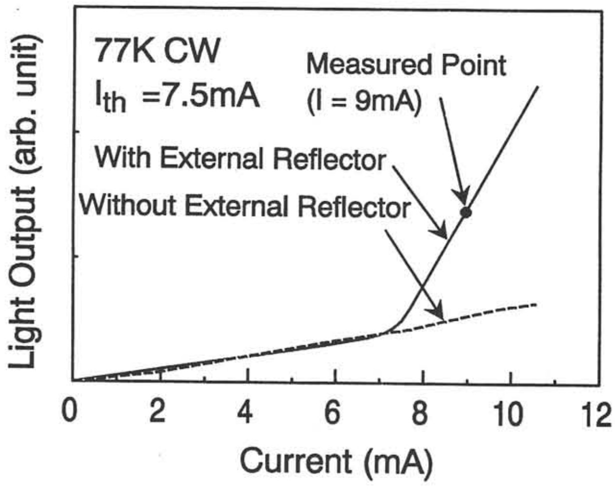

Fig. 4 A current-light output characteristic using external reflector. Lasing operation was obtained only with the external reflector.

2.2 WAVELENGTH TUNING BY AN EXTERNAL REFLECTOR

To control the cavity length by employing an external reflector, the rear side reflector was removed and the semiconductor surface was exposed to the air (see insertion of Fig. 1). No anti-reflection (AR) coating was introduced on the surface. Another 4-pairs Si/SiO_2 reflector was deposited on another InP substrate used as an external reflector. The experimental arrangement is shown in Fig. 3. The SE laser device was mounted on a heatsink. The external reflector was put on the chip and fixed by a plastic plate. At the initial state, the reflector was set in contact with the chip surface. The cavity length was slightly changed mechanically by controlling the gap between the chip and the external reflector.

The tuning experiment was carried out under CW condition at 77K. A typical current-light output characteristic is shown in Fig. 4. The threshold current of the SE laser with an external reflector is 7.5mA, while without the reflector, lasing operation was not obtained. This indicates that the external reflector exhibits almost the same effective reflectivity as the evaporated reflector, since SE lasers with evaporated reflectors made from the same wafer exhibited the threshold current of 3~10mA at 77K. In the tuning experiment, injection current was fixed at 9mA. Obtained tuning characteristic is shown in Fig. 5. The lasing wavelength shifted with the tuning rod position from 1.4439μm to 1.4479μm (Δλ=40Å). Further separating the reflector, lasing operation stopped due to misalignment between the reflector and the device. In this situation, a spontaneous emission peak can be seen instead of lasing wavelength. Including this emission peak shift, one longitudinal mode moved up to 1.4525μm (Δλ=86Å) continuously.

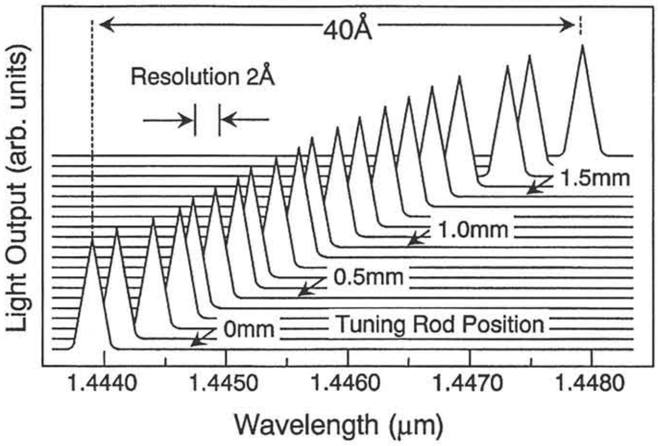

Fig. 5 Measured lasing spectra under tuning. The maximum wavelength shift of 40Å was obtained.

3. CONCLUSIONS

We obtained the first lasing operation of CBE grown GaInAsP/InP SE lasers with I_{th}=2.7mA at 77K. Device performance can be improved by optimizing the structure, for example, by introducing combined reflector consisting of semiconductor DBR and dielectric multilayers. We demonstrated the largest continuous wavelength tuning ever reported by using the cavity length control scheme. More precise alignment of the external reflector, much wider continuous tuning can be realized. Some electrical tuner using QCSE in semiconductor quantum structures is under investigation theoretically and experimentally. Our result also indicates that the external reflector can be used in short cavity SE laser, which is useful for a phase-locked 2-dimensional SE laser array[7].

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