Monolithic integration of widely tunable sampled grating DBR laser with tilted semiconductor optical amplifier*

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Abstract: High output powers and wide range tuning have been achieved in a sampled grating distributed Bragg reflector laser with an integrated semiconductor optical amplifier. Tilted amplifier and anti-reflection facet coating are used to suppress reflection. We have demonstrated sampled grating DBR laser with a tuning range over 38 nm, good wavelength coverage and peak output powers of more than 9 mW for all wavelengths.

Key words: sampled grating; DBR lasers; integration; SOA
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1. Introduction

Widely tunable lasers are promising wavelength-agile sources for use in dense wavelength-division-multiplexed (DWDM) fiber-optic networks, wavelength-routing and switching architectures[1]. A number of different tunable laser technological approaches are proposed, such as the superstructure grating distribute Bragg reflector (SSG-DBR)[2], sampled grating DBR (SG-DBR)[3], vertical grating assisted codirectional coupler (GCSR)[4] and digital supermode distributed Bragg reflector (DS-DBR)[5], but none offer the simplicity of the SGDBR platform for integration with modulators, amplifiers or other components[1].

In some cases, a tunable laser with output powers as high as +10 dBm and tuning range as wide as 40 nm is desired, however, it is difficult to achieve simultaneously for a single SG-DBR laser. For a fixed laser gain current, the output power can vary 6 dB over the tuning range[1]. So an integrated semiconductor optical amplifier (SOA) is needed to compensate for increased absorption loss in the mirrors at high tuning currents and increase the output power from the device.

In this paper, we present the widely tunable SG-DBR lasers monolithically integrated with curved SOA. A tuning range of over 38 nm with good wavelength covering and peak output powers greater than 9 mW for all wavelengths is achieved.

2. Device fabrication and performance

The device structure was grown on an S-doped n-type InP (100)-oriented substrate by metal organic chemical vapor deposition (MOCVD), shown in Fig. 1. The epitaxial structure consists of eight pairs of compressively strained InGaAsP MQW sandwiched between separated confinement heterojunction (SCH) with 1.3Q InGaAsP of 120 nm, then followed by an InP layer used for grating mask, a 1.3Q stop etch layer and a final InP buffer layer for P^+ ion implantation. The bandgap wavelength shift was carried by quantum well intermixing (QWI). First of all, gain section and SOA section were masked with a thermal silicon oxide layer, and then P^+ ion implantation and a rapid thermal annealing (RTA) were carried out. The sample was characterized by a spatially resolved microphotoluminescence (μ-PL) at room temperature before and after the QWI process. After the QWI process, the peak wavelength of the mirror and phase section implanted by P^+ ions shifts from 1563 to 1424 nm, and the peak wavelength of the gain region and SOA section shifts to 1523 nm, as shown in Fig. 2 . After wet etching off the top buffer InP layer and 1.3Q stop layer, the sampled gratings were defined holographically on the grating region of the upper SCH layer. Finally, a p-type cladding InP layer and p^+-InGaAs contact layer were regrown by MOCVD. A 2 μm wide ridge waveguide was formed by

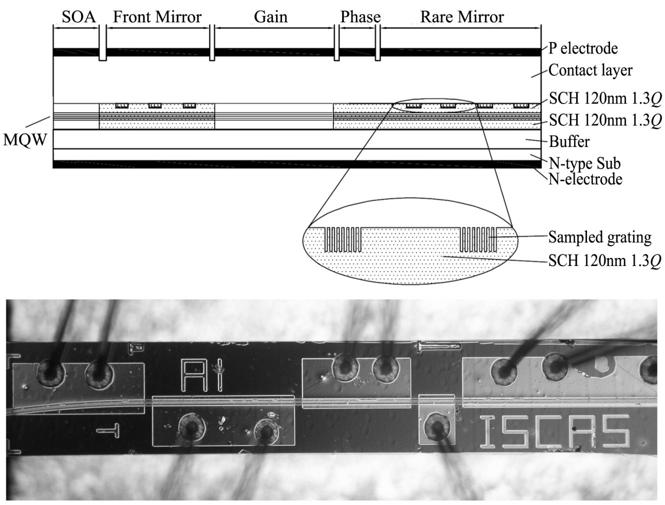

Fig. 1. SGDBR laser with integrated SOA, side-view schematic and micrograph.

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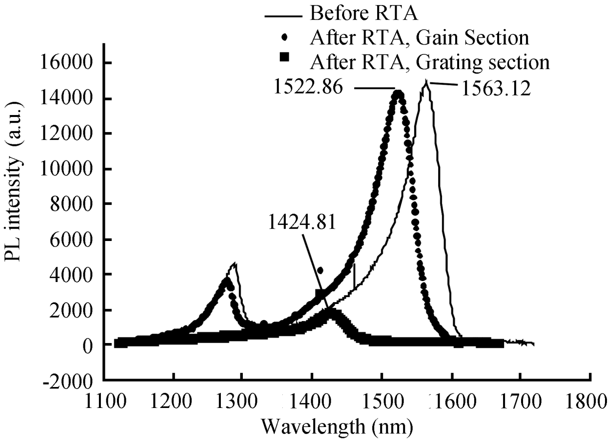

Fig. 2. Normalized room temperature PL spectra of individual functional sections before and after quantum-well intermixing.

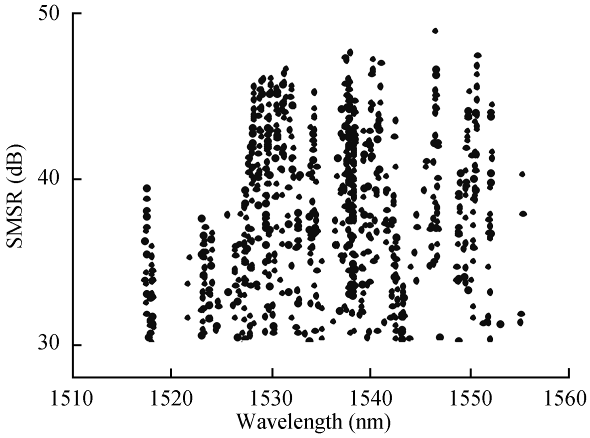

Fig. 3. Tuning range of our device, tuning range from 1517.2 to 1555.3 nm with SMSR > 30 dB.

a combination of dry and wet etching. The isolation sections were accomplished by etching p^+-InGaAs and He^+ implantation. A Ti–Au metal layer was sputtered and a p-electrode was formed. Finally the substrate was thinned and Au–Ge–Ni metal was evaporated on the backside, after it was alloyed, the n contact was formed. The sample chip was cleaved and both front and back output facet are anti-reflection (AR) coated. The micrograph of the chip is shown in Fig. 1.

The device is comprised of five sections: a SOA section (350 μm), a front SG-DBR mirror (390 μm), a gain section (300 μm), a phase section (100 μm), and a rear SG-DBR mirror (608 μm). The isolation trench is 20 μm and the total device length is 1828 μm. The output guide was tilted 7° to reduce the reflection. The front mirrors contain six 65 μm sampling periods with 5 μm grating bursts, and the back mirrors have eight 76 μm periods with 6μm burst length and the device was designed with mirror peak spacings of 5 and 4.4 nm, respectively.

The tuning range of the device when tuning current only applied on front and rear DBR sections is shown in Fig. 3. When the front mirror and rear mirror current is increased from 0 to 70 mA and 80 mA, respectively, the tuning range with sidemode suppression ratio (SMSR) greater than 30 dB is from 1517.2 to 1555.3 nm with well wavelength coverage. The tuning curves for the front and back mirror are shown in Fig. 4; eight peaks with a nominal spacing of 4.9 nm were used in the front mirror, and nine peaks with a nominal spacing of 4.2 nm were used in the back mirror, which is closed to our design. The spectrum superposing is shown in Fig. 5.

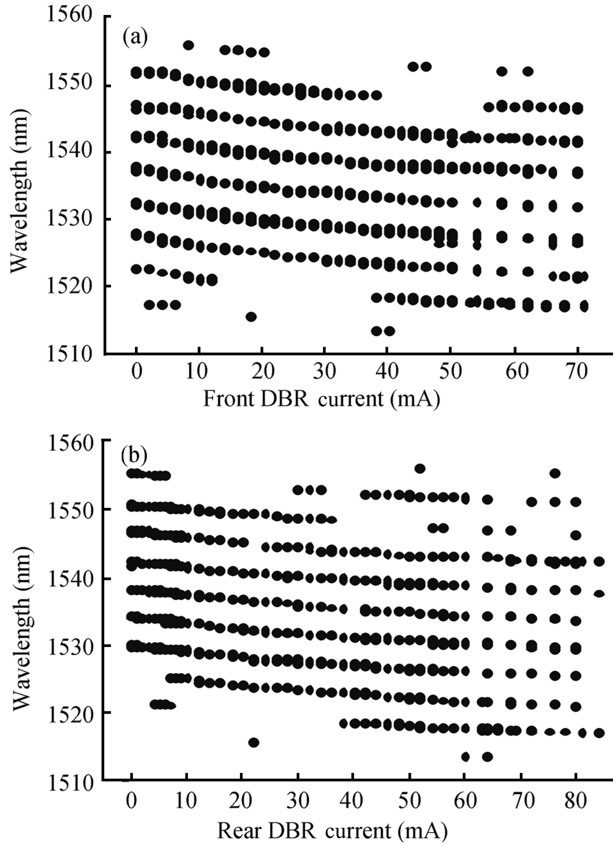

Fig. 4. Tuning curves for the (a) front and (b) back mirror.

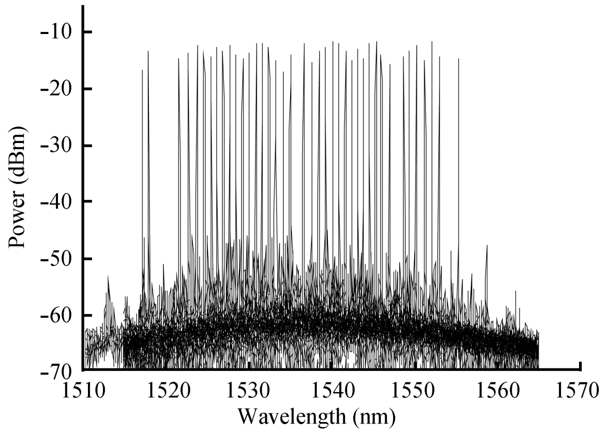

Fig. 5. Tunable wavelengths from 1517.2 to 1555.3 nm under different tuning conditions.

When the gain current is fixed at 120 mA, SOA current increases to 100 mA and both mirror currents are 0 mA, the output power is as high as 14 mW. Even when both mirror currents reach 80 mA, the output power can also get 9 mW, as shown in Fig. 6. When the SOA current changes from 60 to 120 mA, the SMSR and the wavelength change slightly, which stands for the SMSR and the wavelength are almost indepen-

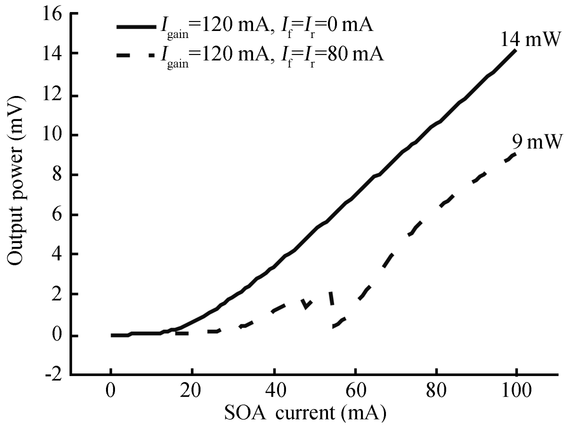

Fig. 6. Output power versus SOA current at different gains and mirror currents.

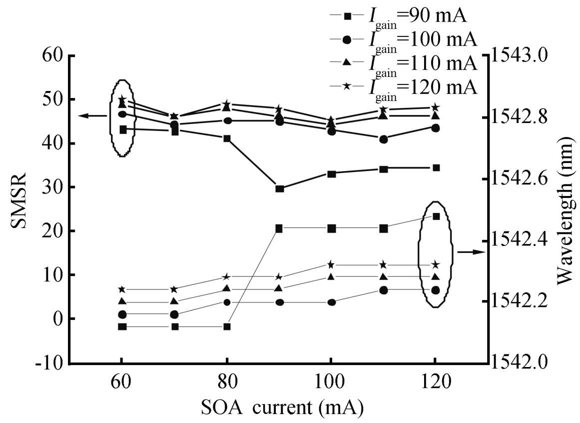

Fig. 7. SMSR and wavelength versus SOA current at different gain currents.

dent on the SOA current, as shown in Fig. 7. However, a twist still appears when the SOA injection current comes to 55 mA in Fig. 6, dash line, which means that although tilted amplifier and anti-reflection facet coating are used, the reflection still can not be suppressed thoroughly.

3. Conclusion

In summary, high output powers and wide range tuning have been achieved in a sampled grating distributed Bragg reflector laser with an integrated semiconductor optical amplifier. Tilted amplifier and anti-reflection facet coating are used to suppress reflection. We have demonstrated sampled grating DBR laser with a tuning range over 38 nm, good wavelength coverage and peak output powers of more than 9 mW for all wavelengths.

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