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1.3 μm integrated superluminescent light source

Yang Liu *, Kun Liu, Junfeng Song, Yuchun Chang, Bonan Kang, Jingzhi Yin, Guotong Du

Electronics Engineering Department, State Key Laboratory on Integrated Optoelectronics, Jilin University, Changchun 130023, People's Republic of China

Abstract

In order to increase the optical output power of semiconductor superluminescent devices, a direct coupling method has been used to integrate, monolithically, the superluminescent diode (SLD) with a semiconductor optical amplifier (SOA). By this means, a 1.3 μm InGaAsP/InP integrated superluminescent light source was fabricated. High superluminescent output power was obtained at pulsed condition. An efficient operating scheme was discovered through the discussion of the gain, it not only increases the output power, but also stabilizes the performance of the whole device. © 2000 Elsevier Science B.V. All rights reserved.

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1. Introduction

Because of their broad spectrum and short coherent length, semiconductor superluminescent devices are widely used as the light sources of fiber-optic gyroscopes (FOG), optical time domain reflectors (OTDR), and local area networks (LANs) and so on. Meanwhile, by means of the spectrum-slicing technique, the long wavelength (1.3 or 1.5 μm) superluminescent devices may be a promising candidate light source for the wavelength–division–multiplexing (WDM) system. Spectrum-slicing is a WDM technique in which a few narrow band lights are filtered from a broad band light source [1–3]. It is potentially attractive because it avoids the need for DFB laser-arrays which have well-defined wavelengths realized by a complicated wavelength trimming technique [4]. Especially with the coming of dense WDM (DWDM), the spectral slicing light sources become more and more necessary.

However, the conventional superluminescent diodes (SLD) always have low output power, which severely restrict the performance of spectrum-sliced system. High superluminescent power is often restricted to be achieved because lasing often appears at high pumping conditions.

Goldenberg [5] and Liou [6] suggested a scheme, in which the semiconductor optical amplifier (SOA) was employed, to increase the superluminescent power. The SLD and SOA are linked with the optical fiber or lenses. Although the relative high power was obtained, the efficiency of the SOA is lower, because of the inefficient coupling and gain spectrum mismatching between SLD and SOA. According to the mentioned view, we used

* Corresponding author.
E-mail address: laserlab@mail.jlu.edu.cn (Y. Liu).

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the direct coupling method to integrate the SOA and SLD monolithically, which could conduce to raising the efficiency of SOA and increasing superluminescent power. In this paper, we focused on the long wavelength material InGaAsP/InP, and made initial progress.

2. Structure and fabrication

The integrated superluminescent light source was fabricated on an InGaAsP multiple quantum wells (MQW) wafer, which was grown by metal-organic vapor-phase epitaxy (MOVPE) on InP substrate. The integrated device posseses the gain-guide-oxide-stripe structure and it consists of two regions, the SLD region and the flared SOA region (as shown in Fig. 1). The two regions can be pumped separately. The 3 μm wide current injection stripe of SLD was aligned with the 3 μm wide input aperture of flared SOA current injection region. The SOA is 1.3–1.5 mm long and its current injection region expands linearly from 3 μm wide at input end to the 130 μm wide at output end.

The processing steps of the integrated devices are mainly as follows. 200 nm thick SiO_2 film was deposited on InGaAsP MQW wafer by electron beam evaporation technique. The whole current injection regions were delineated on the silica film by photolithographic and etching procedures. The segmented electrodes are formed by masking with 15 μm diameter tungsten filament when evaporating the Au–Zn upper electrode. After thinning substrate and evaporating the back electrode, the wafer was cleaved. The AR coating was not deposited on the output facet in the initial researching stage, because the flared geometry of SOA is not suitable for lasing.

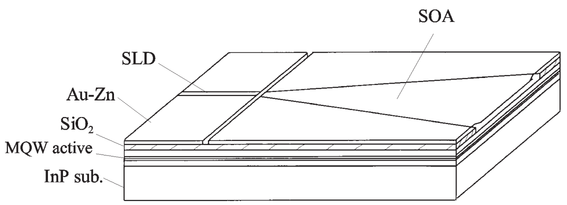

Fig. 1. Schematic structure of the integrated superluminescent light source.

3. Results and discussion

The performances of the integrated superluminescent devices were measured under pulse condition (1 μs pulse width, 0.1% duty cycle). Fig. 2 shows the output power vs current for SOA (I_A) at different pumped conditions for SLD region (I_S). The relative low power was obtained when SOA region was pumped only (when $I_S = 0$ A), the light was mainly contributed to the spontaneous emission in the SOA region. The output power increased notably after the light incidence from the narrow end of SOA (when $I_S > 0$ A), and increased continuously with the raising incident light. The net increased power was the result of amplifying of the SOA. When $I_S = 300$ mA, $I_A = 4$ A, the output power (P_{out}) 34 mW is obtained, compared with the status of $P_{out} = 16$ mW when $I_S = 0$ A, $I_A = 4$ A, the net increased power (ΔP_{ourt}) is 18 mW.

In order to determine the amplifying ability of SOA, we pumped the SLD section only, the *L–I* characteristic curve was obtained at the end of SLD section, and was shown in the inset of Fig. 2. Obviously, the SLD is operated in the superluminescent mode because the flared SOA worked as an absorber in this case. It is assumed that these values equal to the incident power (P_{in}) of SOA

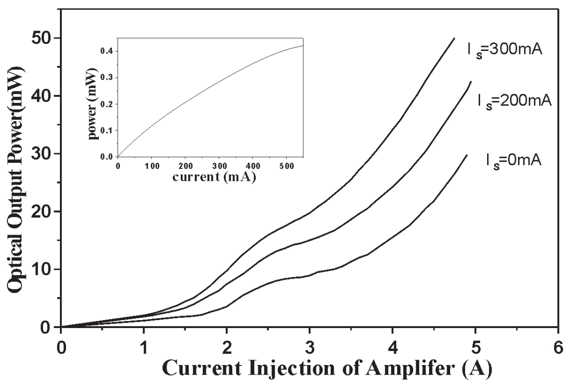

Fig. 2. The optical output power of the device vs current injection of SOA at different SLD current injection.

approximately. Compared with the case of $I_S = 0$ A, the gain of SOA (when $I_A = 4$ A) acquired by calculation is 18 dB when $P_{in} = 0.284$ mW at the condition of $I_S = 300$ mA.

To depict the operating state of the SOA clearly, the curve (Fig. 3) of gain vs the current for SOA was obtained by means of the above calculation. Since the low output power of SLD region (~100 μW) is not enough to saturate the SOA [7], it presents the small signal gain characteristics, gain increased with raising incident light. Also it can be seen that the gain of SOA had the tendency to saturate at the high current injection. The saturation is contributed to the thermal effect, to some extent, because in this case, the rise of temperature in active layer increased the non-radiative Auger recombination [8]; which is dependent to the temperature notably in the narrow band-gap materials, thereby, radiative recombination efficiency is decreased. According to the above discussion, increasing the incident power and decreasing the injection current of SOA properly, is an efficient scheme to raise the superluminescent power and stabilize the performance of the integrated devices.

The spectrum curve (Fig. 4) of the integrated device is achieved when $I_S = 300$ mA, $I_A = 4$ A. The spectral full width at half maximum (FWHM) is 28.9 nm. The central wavelength is 1.294 μm. It can be seen that the emission was the amplified spontaneous one (ASE), the integrated device worked in the mode of superluminescence. The maximum output power, which was achieved at a higher pumped level under the same pulsed condition, is 120 mW as shown in Fig. 5. To a certain extent, it predicts that the integrated device possesses much higher power potential.

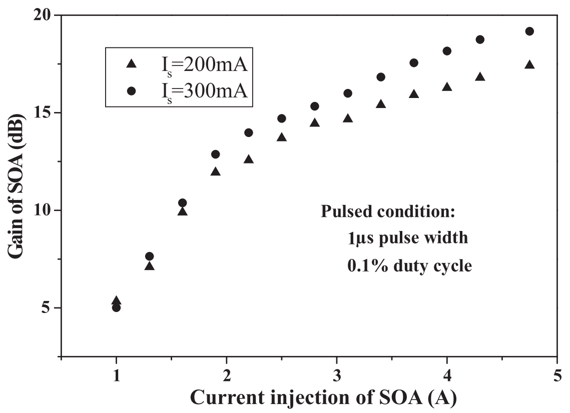

Fig. 3. Gain of SOA vs its current injection at different current injections of SLD.

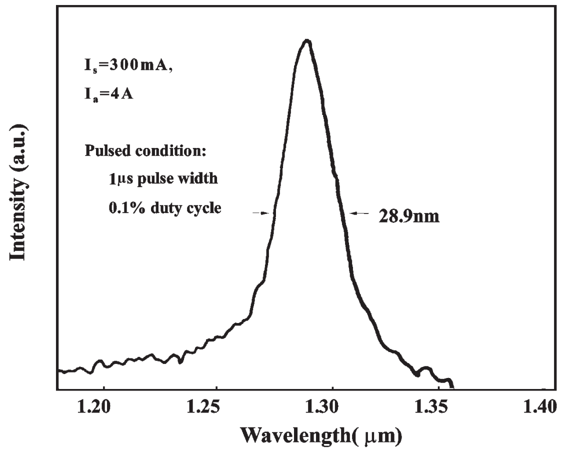

Fig. 4. The emission spectrum of integrated superluminescent light source.

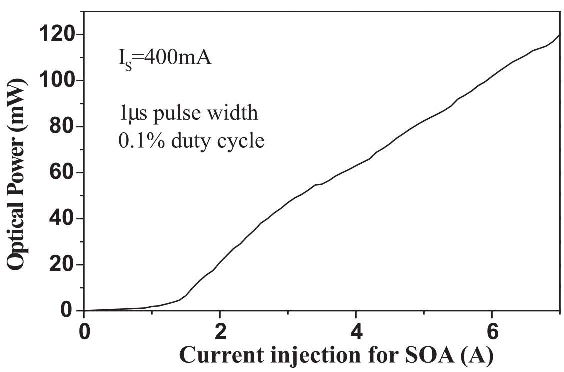

Fig. 5. The output power of the superluminescent integrated light source at pulsed condition, where the SLD region was pumped at 400 mA.

4. Conclusion

We have demonstrated the 1.3 μm superluminescent light source by monolithically integrating the SLD with SOA. Under the pulsed condition, much high power was obtained, which the conventional SLD could not reach. An efficient operating scheme was discovered through the discussion of the gain curve, it cannot only increase the output power, but also stabilize the performance of the whole device. Meanwhile, high performance devices are expected in the future by improving the structure of SLD region, which can increase the incident photon density.

Acknowledgements

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