High Single-mode Output Power in VCSEL-Integrated Bragg Reflector Waveguide Amplifier

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Abstract We present a vertical-cavity surface-emitting laser-integrated Bragg reflector waveguide amplifier. A single-mode output over 10 mW is obtained by only 500 μm-long slow-light propagation and radiation.

Introduction

Enhancing the single-mode output power of a semiconductor laser has always been an ultimate task for both academic and industry. Especially in recent years, the fast development of drones, robots and autonomous cars require high-power, high-quality and low-cost sensing solutions. Vertical-cavity surface emitting laser (VCSEL) is a strong candidate for its compact size and low production cost [1]. However, its output-power for single-mode operation is still limited to a few milliwatts [2]. In this work, we obtained a single-mode power over 10 mW with high beam quality in a VCSEL-integrated Bragg reflector waveguide amplifier.

Experiment and Discussions

The device we designed has mainly two sections integrated laterally: one VCSEL on the left and a long waveguide amplifier attached on the right side. The two sections were electrically isolated via an ion implantation process. We show the top view of a fabricated device from the microscope in Fig. 1(a) and an infrared camera-captured image in Fig. 1(b). The amplifier is designed to be a few millimeters for getting higher optical gain and at the same time avoiding the reflection at the waveguide end. When some current is injected to the VCSEL section, slow-light is laterally coupled to the waveguide. It is interesting that if we inject current through the amplifier electrode, the coupled slow-light intensity will increase intensively. Especially when the amplifier is biased above its threshold condition, its vertical emission will be suppressed while a large output at the tilted angle can be obtained.

With a VCSEL current of 4.5 mA, especially clear single mode coupling and radiation are observed. The FFP profiles are illustrated in Fig. 2. Extremely sharp beam can be seen at a deflection angle of 12 degrees. Comparing with the radiation without amplifier, optical gain of 4.6dB and 15.4dB are obtained for amplifier current of 20 mA and 40 mA. The captured power with and without VCSEL input are shown in Fig.3. Deducted power between the two can be used to estimate the output power of the deflection beam. 10 mW output power in single mode is observed with 44mA amplification current.

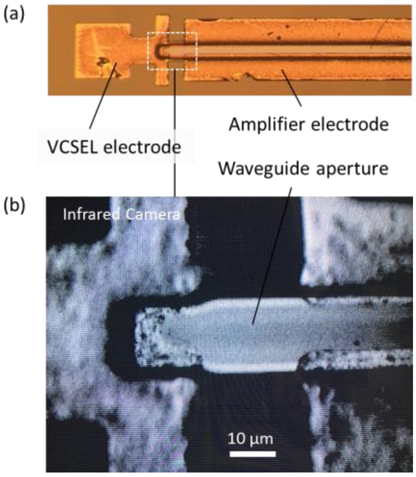

Fig. 1 Top-view of one fabricated device: (a) optical microscope, (b) infrared camera.

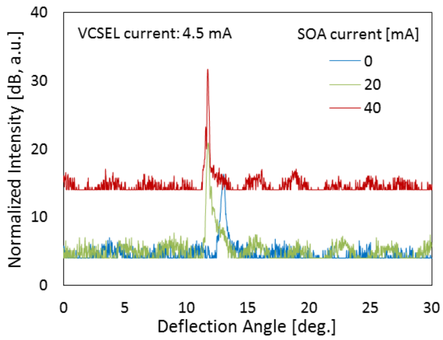

Fig. 2 Far-field pattern profiles of the measured device for typical VCSEL and amplifier currents.

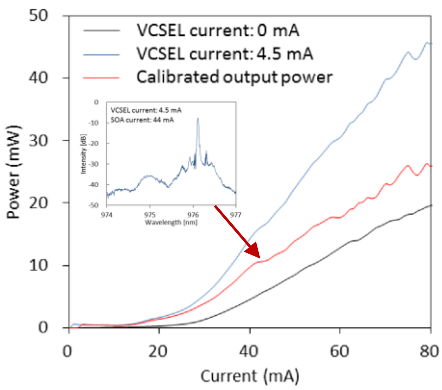

Fig. 3 Output power captured by a photo-detector above the device for different VCSEL currents.

Conclusions

We present a 10 mW-class single-mode semiconductor amplifier. By optimizing the wafer and electrodes designs, further enhancement of the single mode power to 100 mW or even Watt-class is promising. The proposed device can be a high-quality laser source for long-haul optical communication systems, Optical Coherence Tomography applications and various laser sensing systems.

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References

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