Phased Locked Laser Diode by Using Passive Array of Multi-Mode Interference Couplers

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Abstract: We report a phase locked laser diode based on a passive array of 1×2 multi-mode interference couplers and quantum well intermixing techniques which shows stable and clear coherence far field patters from both active and passive side up to at least 9 times threshold current.

OCIS Codes: (140.2020) Laser diode; (260.3160) Interference; (130.0130) Integrated optics.

Introduction

There is an urgent demand for cost-effective high power, quasi-single-spatial-mode semiconductor lasers operating at wavelengths around 1.55 μm [1]. Recently techniques have been developed based on seeding arrays of semiconductor optical amplifiers (SOAs) from a single laser, to generate output beams that can be combined coherently [2]. However, the coherent beam combination (CBC) diodes reported before have shortcomings, such as overall system size and cost, and require complex optical architectures. For the first time we demonstrate a simple, scalable monolithically integrated approach that couples the light from conventional ridge waveguide amplifiers coherently through staggered passive 1x2 multi-mode interference couplers (MMIs) couplers to deliver a high quality beam with a clear coherent interference far-field pattern (FFP). As the phase relationship between the input and output of a 1×2 MMI is fixed, and each output port experiences similar environmental perturbations, the relative phase of the output light remains nearly constant, which results in a spatially coherent FFP.

Compared with conventional techniques used to define passive waveguides, such as selective etching and re-growth, our technique of post-growth processing based on quantum-well intermixing (QWI) offers a simple, flexible, and low-cost alternative.

Device structure and fabrication

The epitaxial structure and fabrication process used for the device are similar to those described in [3, 4]. A schematic of the fabricated device showing its dimensions is shown in Fig. 1(a). The active components involved are four ridge waveguides with a separation of 24 μm between two adjacent outputs. The passive section includes two staggered 1×2 MMI arrays and each MMI is 16 μm wide and 308 μm long. The passive sections are bandgap widened using the QWI technique to provide a 100 nm blue-shift [4]. The ridge waveguide width throughout the device is 2.5 μm. For simplicity, the p-contacts of the four active ridge waveguides were connected in parallel.

Measurement results

The chip was mounted on a heatsink and measured at room temperature. Fig. 2(a) shows the measured *I-P* curves from the passive and the active section sides. The threshold current is 200 mA and the maximum output power (84.3 mW) from the passive side is nearly 2.5 times of that from the active side (33.9 mW) at I = 1.9 A. The output power is not saturating at this drive current. Fig. 2(b) shows the optical spectra from the passive side at I = 300, 400, 500 mA. Due to the heating, the peak wavelength was redshifted by ~13 nm when increasing the current from 300 to 500 mA, corresponding to a temperature rise of ~26 °C. Owing to the beams from the five output ports being phase locked, the optical spectra show obvious quasi-single longitudinal mode characteristics. Fig. 3 shows the measured FFP from active and passive side respectively at I = 0.5, 1.0, and 1.8 A. Both FFPs show coherent interference patterns with the main lobe remaining fixed and the relative side lobe intensities and positions changing only marginally when increasing the injection current. The smallest FWHMs of the FFP from the passive and active sides are 3.2° and 20° respectively.

In conclusion, we have demonstrated highly stable FFPs from an array of semiconductor lasers coupled coherently through staggered MMIs. While it is anticipated that more effective heat-sinking combined with an improved temperature control feedback system will improve the performance in terms of output power, wavelength stability, and degree of coherence of spatial beam combining, the FFPs are stable over a wide range of currents, up to at least 9×threshold. The approach is scalable, can be applied to lasers at any wavelength, and improved thermal control is expected to enable operation at multi-Watt levels.

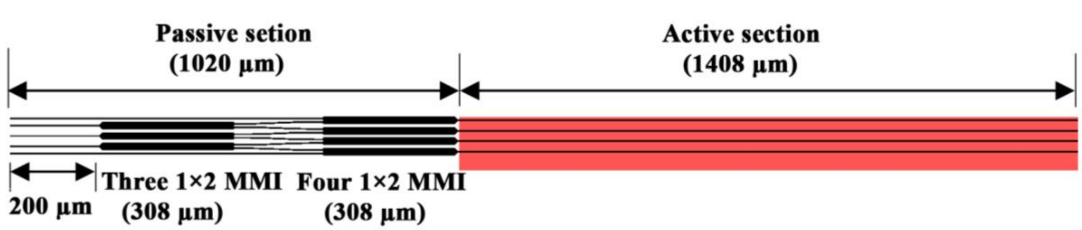

Fig. 1. Schematic of the fabricated devices

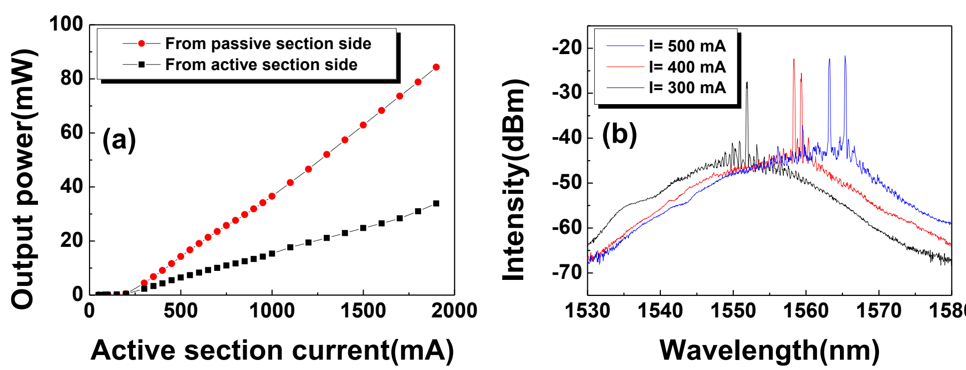

Fig. 2. (a) Measured output powers from active and passive sections respectively; (b) measured optical spectrum from passive section side.

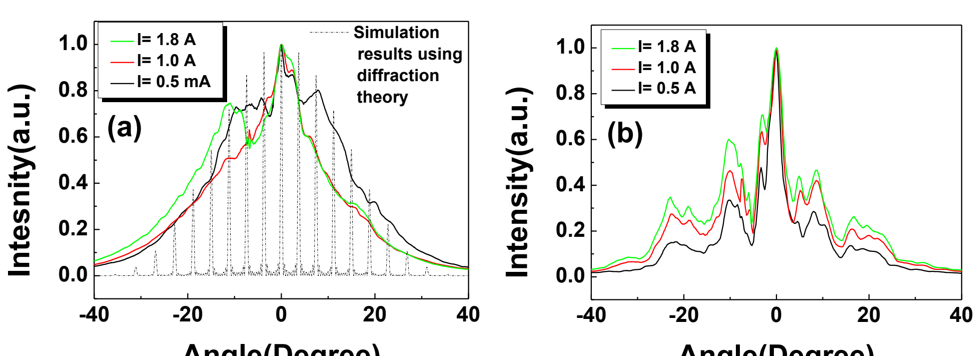

Fig. 3. Measured FFP from active (a) and passive (b) section side when $I = 0.5$, 1.0, 1.8 A.

References

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