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Compact Multiwavelength Laser Source Based on Cascaded InP-Microdisks Coupled to One SOI Waveguide

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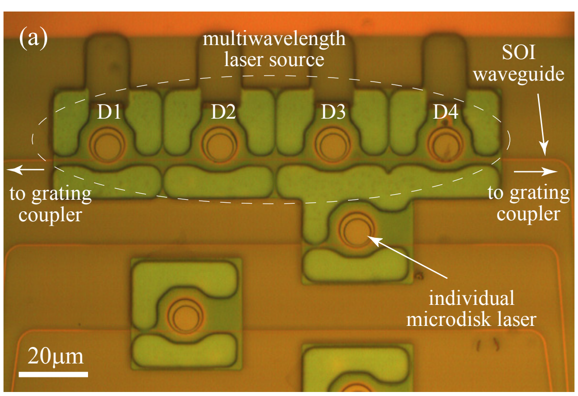
Abstract: A compact multiwavelength laser source, which consists of four cascaded InP-microdisks coupled to one SOI waveguide, is introduced for WDM purposes. Equally distributed laser peaks and low crosstalk were obtained with the proposed structure.

OCIS codes: (130.3120) Integrated optics devices; (140.5960) Semiconductor lasers

1. Introduction

In recent years, silicon-on-insulator (SOI) has been proposed as a promising platform for passive photonic components [1]. However, creating a silicon-based laser source – to achieve full photonic functionality on this platform – is strongly hampered by the indirect bandgap of silicon. We recently presented electrically injected InP-microdisk lasers coupled to a sub-micron SOI waveguide [2]. In this device, the dominant laser mode is the whispering-gallery-mode (WGM) confined at the edge of the microdisks. Low threshold and continuous-wave (CW) operation were obtained. To fully exploit the bandwidth capacity of the SOI photonic integrated circuit, compact multiwavelength laser (MWL) sources are needed. Typically, an integrated MWL is realized by employing semiconductor lasers with desired wavelengths and combining them with a power combiner [3] or arrayed-waveguide-grating (AWG) multiplexer [4]. An alternative approach is to put the AWG directly inside the laser cavity as a wavelength-selective element [5]. However, the incorporation of an AWG multiplexer increases the footprint of such devices to at least several square millimeters.

In this paper, we present a compact MWL source by cascading our InP-microdisk lasers on a single bus SOI waveguide. The intrinsic evanescent-out-coupling configuration of the laser structure favors this easy and dense integration scheme without employing an additional multiplexer [6]. The performance of the proposed MWL, including the lasing spectrum and crosstalk, is studied under static conditions.



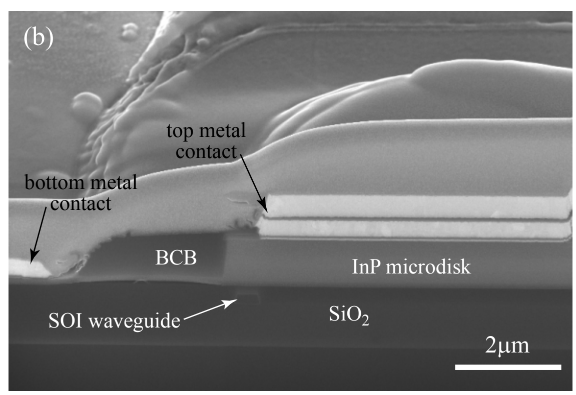


Fig. 1. (a) Top view of the sample (before metallization); (b) FIB cross-sectional picture of a completely fabricated microdisk laser.

2. Design and structure

The microdisk laser consists of a bus SOI waveguide with dimension of 500×220nm^2 and a microdisk cavity etched into a thin InP active layer bonded on top of the SOI waveguide wafer. Metal contacts are included for electrical injection. Figure 1 shows some pictures of the fabricated microdisk laser and the multiwavelength laser source. We refer to Ref. [2] for the specific layered structures and parameters, as well as the fabrication details.

The MWL source is composed of four cascaded microdisk lasers with slightly different diameters, as shown in Fig. 1(a). Due to the small coupling efficiency between the bus SOI waveguide and the dominant WGM, as well as different emitting wavelengths, the optical crosstalk between each laser within the device is expected to be insignificant. This will be further discussed below. The microdisks were put 33μm apart from each other. Grating couplers were fabricated at the two ends of the bus SOI waveguide for measurement purpose [7]. Three groups of microdisks with diameters of 10μm, 7.5μm, and 5μm are available on this sample.

3. Individual microdisk laser

First, the performance of the individual microdisk lasers was evaluated. After a burn-in treatment (by applying a high current, i.e., tens of mA, for several minutes), all the devices exhibit CW operation. However, the laser performance is quite weak for microdisks with 5μm diameter, probably due to the misalignment of the top metal contact resulted from the contact lithography, which is more severe for the WGM on a small disk. Therefore, we will ignore this group of lasers in the following discussion. The typical light-current-voltage (LIV) curves of a 10μm and 7.5μm diameter laser are plotted in Fig. 2. The threshold current and voltage for 10μm diameter lasers are 1.0mA and 1.10V, respectively, while for 7.5μm diameter lasers, 0.9mA and 1.15V, respectively. As compared to our previous results [2], a lower driving voltage is obtained here, which is favored by the higher doping concentration of the tunnel junction in the present sample. However, increasing the doping level also increases the propagation loss of the WGM due to free-carrier-absorption (FCA). This is a possible reason for the higher threshold current obtained here. The measured laser powers from both ends of the bus SOI waveguide show similar characteristics, meaning that our microdisk lasers are actually working in a regime of bidirectional operation [8]. The long and short range oscillations of the LI curves above threshold are most likely due to the reflection feedback from the grating couplers, which is calculated to be about -22dB. An accurate model with coupled rate equations for both carrier and optical field should be analyzed for more insight [8].

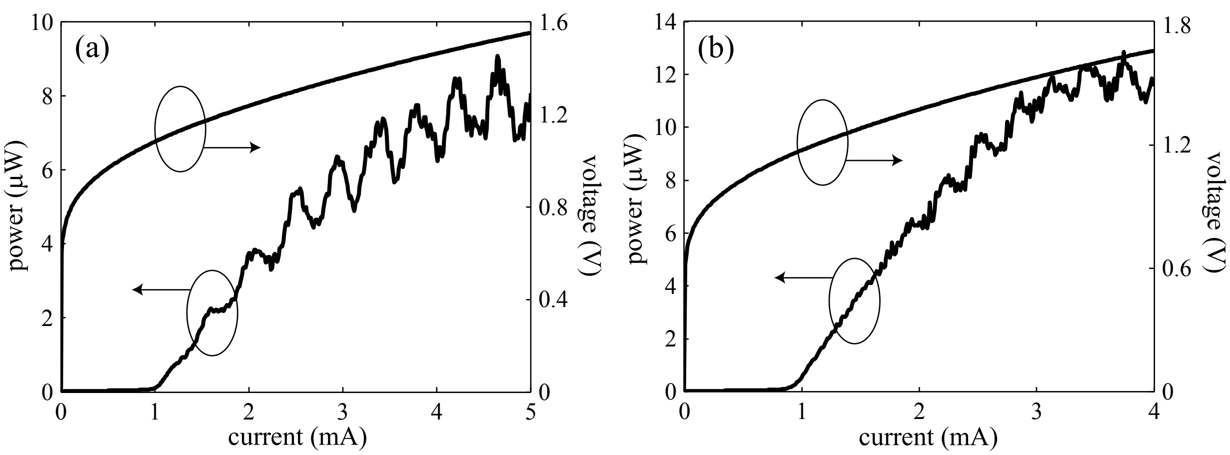


Fig. 2. LIV curves of microdisk lasers with (a) 10μm diameter and (b) 7.5μm diameter under CW. Powers were normalized by the efficiency of the grating coupler.

4. Multiwavelength laser source

The multiwavelength laser sources were then measured. Figure 3 shows the spectra recorded when the four microdisk lasers were simultaneously biased at the same current. It can be seen that the emitting wavelengths are equally distributed within one free spectral range (λ_{FSR}) of the individual microdisk lasers. This is matched by the design, where the difference in diameter between adjacent disks is 44nm, which theoretically corresponds to a laser peak shift of $\lambda_{FSR}/4$. Note that, in the measured spectra, the dominant peak powers of the lasers show ~10dB fluctuation. The microdisk laser that is closest to the grating coupler generally has a higher output power level. The numerical analysis shows that this non-uniformity is due to leakage losses to high-order modes, when light passes through the microdisks (thickness: 1μm). The thick microdisk layer supports several high-order modes, and the coupling coefficient to these modes is much larger than that to the fundamental mode since they have a larger field-overlap, and are better phase-matched with the mode in the SOI waveguide. This effect can be minimized by employing an ultrathin microdisk of about 300nm thick to ensure single mode in the vertical direction. The fabrication randomness also contributes to this non-uniformity. In principle, however, the output powers can be balanced through an external equalizer, or by applying a different bias current to each of the microdisk lasers.

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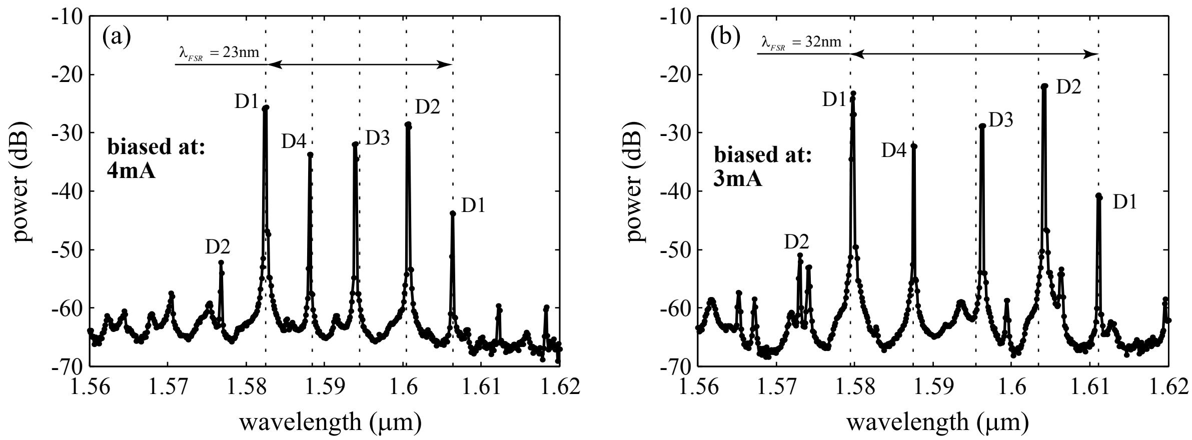

Fig. 3. Normalized spectra of the MWLs from the left end of the bus SOI waveguide when the four microdisk lasers were simultaneously biased at the same current, (a) for 10μm diameter group and (b) for 7.5μm diameter group. The dashed lines are separated by $\lambda_{FSR}/4$. The corresponding disk number is marked on each of the laser peaks (cf., Fig. 1).

By varying the bias current of one of the microdisk lasers and recording the whole spectrum, we further tested the crosstalk of the present multi-channel laser sources under static conditions. From the measured spectra (not shown here), we found that the peak positions of the other three lasers remained unchanged, and their peak power varied with less than 1.5dB. Therefore, we conclude that there is no obvious thermal and optical crosstalk between the microdisk lasers in the present design.

5. Conclusion

We have presented here a four-channel MWL source based on the SOI platform. The evanescent-out-coupling configuration of our microdisk laser favors an easy and dense integration scheme. Both the individual laser and MWL sources have been characterized under static conditions. The measured spectra show that the emitting wavelengths are equally distributed within the free spectral range of a single microdisk laser. The crosstalk between the lasers has been determined to be insignificant. Next, we will aim at improving the peak power uniformity. In addition, a dynamic transmission experiment by directly modulating each of the lasers would be a valuable demonstration.

Acknowledgement

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