Heterogeneously Integrated InP-based Type-II DFB Laser Array on Silicon

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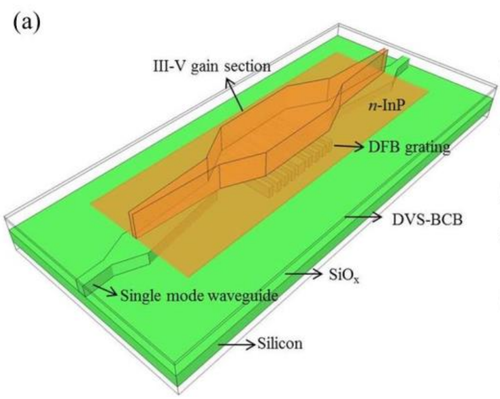
Introduction

The spectral range of 2-3 μm is of interest for spectroscopic sensing applications as many important gases have strong absorption lines in this wavelength range. Silicon photonics opens new possibilities to realize compact spectroscopic gas sensors in the 2-3 μm wavelength range. For this purpose, different active photonic devices operated in this wavelength range are heterogeneously integrated on silicon to complete the components required for on-chip spectroscopic systems [1]. Recently, 2.3 μm range heterogeneously integrated III-V-on-silicon distributed feedback (DFB) lasers using InP-based type-II quantum wells were demonstrated [2]. The heterogeneous InP-based type-II DFB lasers can provide ~2 nm tunability and have been proven to be suitable for tunable diode laser absorption spectroscopy (TDLAS) of carbon monoxide gas. The integration of 2 μm range multi-wavelength DFB laser arrays on a silicon chip enables the simultaneous detection of several gas species with a single III-V-on-silicon sensor. In this paper, a heterogeneous III-V-on-silicon DFB laser array covering a wavelength range from 2.28 μm to 2.43 μm is presented.

Design and Fabrication

Figure 1(a) shows the schematic of a heterogeneously integrated InP-based type-II DFB laser on silicon. The active region of the III-V epitaxial layer stack contains six periods of a "W"-shaped InGaAs/GaAsSb quantum well. In the central gain section, the optical mode is strongly confined in the III-V waveguide, resulting a high modal gain. The light coupling from the III-V waveguide to silicon waveguides is realized by using III-V/silicon spot size converters. The DFB grating used in this device is a quarter-wave shifted first order grating etched in the silicon waveguide layer. The III-V epitaxial layer stack is bonded to the planarized silicon-on-insulator (SOI) wafer using a 50 nm thick DVS-BCB layer. After InP substrate removal, the DFB laser is processed in the III-V membrane. Detailed information about the device design and fabrication can be found in [2].



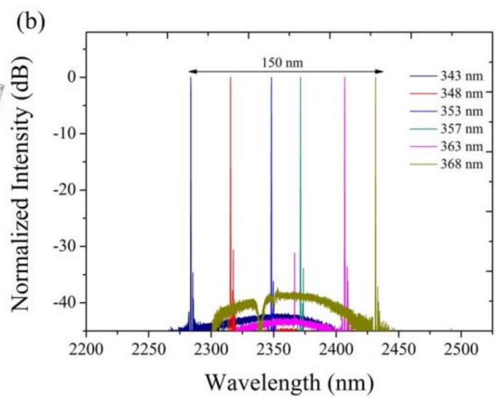


Fig. 1. (a) Schematic of the heterogeneously integrated DFB laser; (b) normalized emission spectra of six DFB lasers with different grating period in an array.

Results

The measured spectra of a six-wavelength DFB laser array are shown in Fig. 1(b). All of the lasers are characterized in a CW regime at a temperature of 5˚C, biased at 150 mA for the laser with grating period from 343 nm to 363 nm and at 220 mA for the device with grating period of 368 nm. The lasing wavelength of the DFB lasers span from 2280 nm to 2430 nm, which can cover the absorption window of several important industrial gases (e.g., CH_4, NH_3 and HF). A side mode suppression ratio (SMSR) of 30 dB is achieved for all the devices.

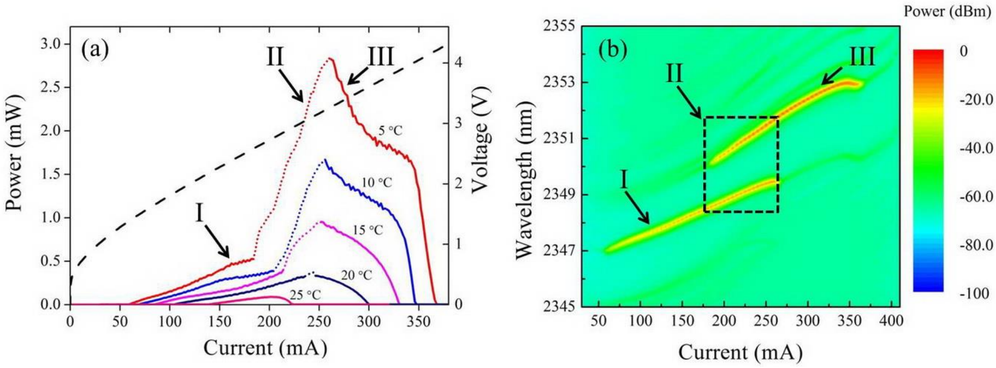


Fig. 2. (a) P-I-V curve of the DFB laser with grating period of 353 nm; (b) 2-D optical spectra of the device as a function of the injection current at 5 ˚C.

Figure 2(a) shows the power-current-voltage (P-I-V) curve of the DFB laser with grating period of 353 nm. For this 3.8 μm wide and 1000 μm long device, the threshold current is 60 mA at 5 ˚C, which increases to 110 mA at room temperature. The normalized coupling coefficient κL deduced from the emission spectra is around 7.5. This high coupling coefficient results in spatial-hole burning in the DFB laser. As the injection current increase to 185 mA, the side mode start lasing as seen in fig. 2(a) and 2(b). The transition from defect mode to side mode lasing can be seen between 185 mA to 260 mA as shown in fig. 2(b). The maximum on-chip single mode (>20dB) output power for the defect mode and side mode is 0.5 mW and 2.7 mW, respectively. A stable single mode tunability is achieved in current range I (60 mA-180 mA) and range III (270 mA-350 mA) as shown in fig. 2(b). The tuning range of the dominant mode and side mode is 1.5 nm and 1.2 nm at 5˚C, respectively.

Conclusion

A heterogeneously integrated III-V-on-silicon DFB laser array spanning from 2280 nm to 2430 nm is reported. It enables the realization of a fully integrated spectroscopic sensor that can simultaneously detect several gases.

References

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