Narrow-Linewidth DBR Laser Using Open-Access High-Precision Grating in InP PIC Generic Foundry Platform

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ABSTRACT

In this paper, we present DBR lasers using DUV lithography in a generic InP-based photonic integration platform. The DBR lasers exhibit SMSR over 45 dB and laser linewidths below 100 kHz.

Keywords: Bragg gratings, Photonic integrated circuits, Semiconductor lasers.

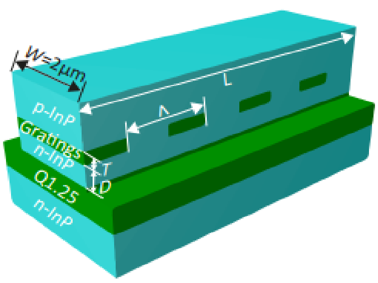
1 INTRODUCTION

Continuous wave (CW) semiconductor lasers in photonic integrated circuits (PIC) with narrow linewidth and high side-mode-suppression ratio (SMSR) have become increasingly important for coherent transmission. In the last few years monolithically integrated distributed Bragg reflector (DBR) lasers have also made considerable advances. Digital supermode (DG) DBR lasers with InGaAlAs multi-quantum well material showed linewidths <200 kHz and SMSR of 40 dB [1]. Sampled-grading (SG) DBR lasers showed 300-kHz spectral linewidths and 40-dB SMSR [2]. Recently, a more complicated SGDBR laser demonstrated 70-kHz spectral linewidth and 50-dB SMSR utilizing intra-cavity spectral filter and SOA [3].

In this paper, we demonstrate the simplest three- and four-section DBR lasers without any additional intra-cavity filter. Moreover, the reported DBR lasers are developed in an open-access generic foundry offering monolithic InP photonic integration technology platform [4]. The DBR gratings are defined by a deep-ultraviolet (DUV) scanner with precise control of small features down to 100 nm which has been widely used in Silicon but is new for InP. The DBR lasers comprising the high-precision DBR gratings achieve single mode emission with SMSR >45 dB and <100-kHz linewidths.

2 DEVICE DESCRIPTION

Fig. 1(Left) shows the DBR grating structure patterned by the DUV scanner. The surface flatness of the InP has been improved and the illumination condition has been optimized by using polishing process to meet the required depth of focus (DOF) of DUV scanner, that features the advantages of both e-beam and holographic lithography. There are two DUV lithography steps involved in DBR fabrication, for writing the gratings and defining the waveguide width, respectively [5]. Such a DBR grating can be integrated with other active and passive building blocks in the platform to create a DBR laser. Fig. 1(Right) depicts the two simple DBR laser (DBRL) designs reported in this paper and these testing DBRLs are arranged as shown in Fig. 2(Left). The lengths of the sections of the five devices under test are summarized in table 2(Right). DBRL1-4 are composed



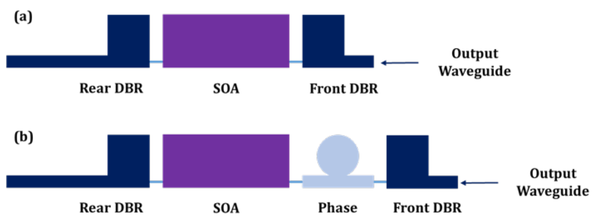
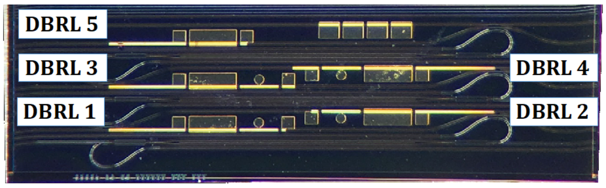


Figure 1: (Left) Schematic of DBR grating in the platform (not to scale) [5]. (Right)(a) Schematic of DBR laser with three sections: Front DBR, Gain (SOA), and Rear DBR. (b) DBR laser with four sections: Front DBR, Phase, Gain, Rear DBR.



	DBRL1	DBRL2	DBRL3	DBRL4	DBRL5
Front DBR	30	50	100	200	50
Rear DBR	600	600	600	600	600
Grating Pitch	237	237	237	237	237
SOA (gain)	370	370	370	370	370
EOPM (phase)	300	300	300	300	-
DBRL Length	1.39	1.41	1.46	1.56	1.08

Figure 2: (Left) Photo of DBR lasers (DBRL) in PIC (4.6 mm x 1.6 mm). DBRL 1 - 4 are four-section lasers while DBRL 5 is three-section laser. Table(Right) The corresponding lengths of each section of DBRL 1 - 5 are in µm. The DBRL Lengths are in mm.

of four sections, namely Front grating, from which the optical output is collected whose lengths are varied from 50 µm to 200 µm, Gain section of 370 µm, Phase section of 300 µm, and Rear grating of 600 µm for all the samples. DBRL5 does not include the phase section.

3 CHARACTERIZATION RESULTS

The optical output of each DBRL was collected from the front DBR grating, using a lensed fiber. The DBRLs were operated under a fixed temperature 16°C. Fig. 3(a) shows the L-I curves, in which the current injected into the gain section (SOA) was swept from 0 mA up to 100 mA. The front and rear DBR gratings were also contacted but no currents were applied. The maximum fiber-coupled optical output powers lie within the range of 1 - 2 mW for 100-mA bias current. The threshold currents are 14 - 22 mA. As seen in Fig. 3(b), for the bias current above the threshold current, the SMSR of DBRL4 stays in the range between 40 and 50 dB. However, the other four DBR lasers mostly operate in single mode but unexpectedly switch to multimode or mode hopping. The peak wavelengths were recorded with the bias currents swept from 0 to 100 mA as shown in Fig. 3(c). DBRL4 shows a smooth dependency of wavelength from 1549.8 nm up to 1550.6 nm on the bias current. In Fig. 3(d), DBRL4's optical spectra for bias current of 20 – 100 mA are presented. The wavelength tuning covers the range between 1549.8 nm to 1550.6 nm from bias current of 20 mA to 100 mA, corresponding to the tuning efficiency of 0.0091 nm/mA. The laser coherence and signal purity of DBRL4 is investigated beyond the resolution of the optical spectrum analyzer. As shown in Fig. 4(a), the laser linewidth

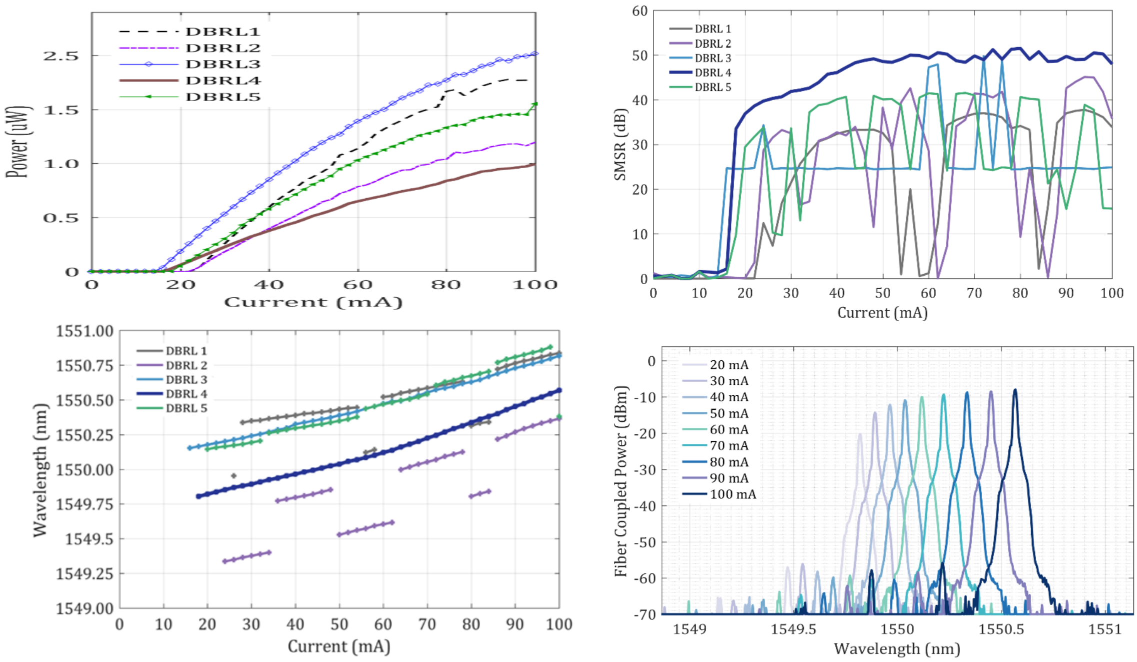


Figure 3: (a) L-I curves for the five DBRL cavities. (b) SMSR vs. gain current for the five DBRL cavities. (c) Peak wavelength vs. gain current for the five DBRL cavities. (d) Optical spectrum for gain current from 20 to 100 mA for DBRL4.

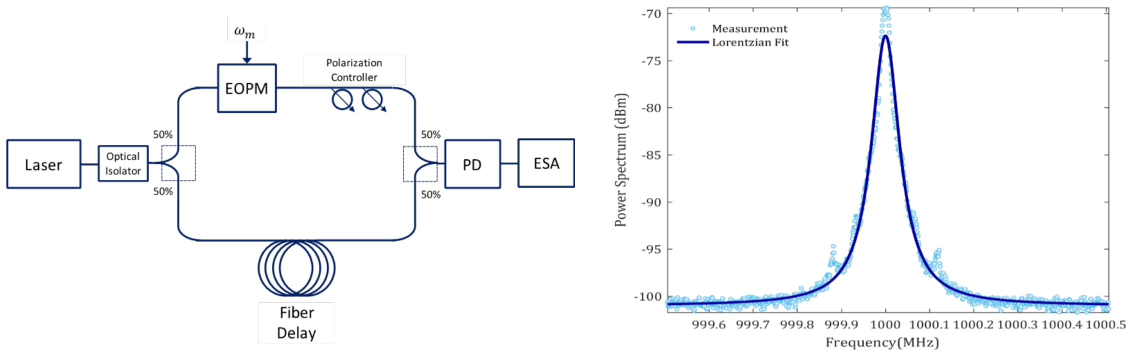


Figure 4: (a) Delayed self-heterodyne setup for measuring the optical linewidth. (b) Lineshape measured using the delayed self-heterodyne method.

was measured using the delayed self-heterodyne method. A 6.8-km optical fiber was used as optical delay line and the other output after the 3-dB fiber coupler was sent to a phase modulator to shift the detection frequency to 11 GHz. The optical delay line produced a 35-μs time delay, corresponding to a 10-kHz resolution on electrical spectrum for the mode beating of the two combined optical tones. For the DBRL4 is biased at 100 mA, the SMSR is 48.53 dB and the wavelength is 1550.6 nm. As shown in Fig. 4(b), the measurement was fit to a Lorentzian profile with a full width at half maximum (FWHM) linewidth of 200 kHz, which corresponds to an optical FWHM Lorentzian linewidth of 100 kHz.

4 CONCLUSIONS

We have demonstrated the simple DBR lasers using DUV-defined DBR gratings in generic foundry approach. One of the DBR lasers shows a SMSR over 45 dB and laser linewidth below 100 kHz. Its insufficient output power, tuning range and the measurements for other DBRLs suggest there is considerable room to improve. Nevertheless, this DBR grating has revealed the potential for creating higher performance lasers by engineering the cavity design. Furthermore, this open-access technology enables the monolithic integration of DBR, SOA, and passive components for forming composite lasers. Wider tuning range, narrower linewidth and higher SMSR are thus expectable by incorporating intra-cavity filters such as Mach-Zehnder interferometer [6] and micro-ring resonator [7].

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