Dual-Wavelength DFB Laser with 1.28 THz Frequency Spacing Based on Four Phase Shifted Sampling Gratings

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***Abstract*—A 1.55 µm dual-wavelength DFB laser with a frequency spacing of 1.28 THz using a four phase shifted sampled Bragg grating is demonstrated. The grating coupling coefficient is 2.83 times that of conventional sampled Bragg gratings while the frequency spacing resolution can reach 0.83 GHz.**

Keywords—dual-wavelength DFB laser, THz generation, phase shifted sampled Bragg grating

I. INTRODUCTION

Terahertz (THz) frequency sources are of considerable interest in applications such as environmental detecting, medicine, agriculture and communications [1]. An ideal method of obtaining THz signals is using photomixing with two different optical signals [2]. Dual mode distributed feedback (DFB) lasers with two-phase-shifted Sampled Bragg Gratings (SBGs) have been reported for THz generation [3]. By utilizing a four-phase-shifted section (4PS) SBG structure in the DFB laser, the lasing wavelength can be controlled precisely by changing the sampling period and a higher coupling coefficient κ can also be obtained, corresponding to 2.83 times that of conventional Sampled Bragg Gratings (CSBGs) [4]. In this paper, a 1.55 µm dual-wavelength DFB Laser with a 4PS-SBG structure is reported, with dual wavelengths set by having different gratings on either side of the ridge. The wavelength spacing is 10.37 nm, corresponding to a frequency spacing of 1.282 THz. The side-mode suppression ratio (SMSR) of the device is larger than 40 dB and the output power can reach 31.7 mW. The device operates in the +1st channel, therefore the lasing wavelengths can be controlled by changing only the sampling period [4]. Theoretically, the resolution of the wavelength spacing can be as small as 0.83 GHz, assuming the difference between the two sampling periods on each side of the ridge waveguide is 0.5 nm, i.e., the highest resolution of modern e-beam lithography (EBL) machines.

II. DEVICE STRUCTURE AND EXPERIMENTAL RESULTS

The wafer structure is the same as reported in [5] and the fabrication processes are similar to those described in [3]. The device here uses a 4PS-SBG in which three $\pi/2$-phase shifts were added in each sampling period. This structure suppresses the 0th channel and enhances the coupling coefficient, κ, of the +1st channel value to 0.9 times that of a uniform seed grating. Since CSBGs only have κ values $1/\pi$ times those of seed gratings, the κ of a 4PS-SBG is equivalent to 2.83 times that of a CSBG. Meanwhile, the lasing wavelength of each grating is controlled by the sampling period. The change of equivalent seed grating period in the +1st channel $\Delta\Lambda_{+1}$ can be expressed as:

$$\Delta\Lambda_{+1} = \frac{1}{(P/\Lambda_0+1)^2}\Delta P \qquad (1)$$

where ΔP is the difference in the sampling periods, P is the larger sampling period, and Λ_0 is the seed grating period. Due to the best resolution of EBL systems being 0.5 nm (ΔP is 0.5 nm), the minimum $\Delta\Lambda_0$ is 0.00104 nm, therefore the ultimate resolution in frequency spacing is 0.83 GHz. Figure 1(a) shows a scanning electron microscope (SEM) picture of the ridge waveguide with a width of 2.5 µm and the recess of the gratings was 0.6 µm on both sides. The device contains two 4PS-SBGs with different sampling periods on each side and a π-phase shift is inserted into the middle of the cavities to ensure each sidewall grating gives rise to operation in a single longitudinal mode. The sampling periods P_1 and P_2 were 4344 nm and 4997 nm respectively, and the seed grating period was 257 nm, so that the device operates at 1.56 μm with a frequency spacing of 1.28 THz.

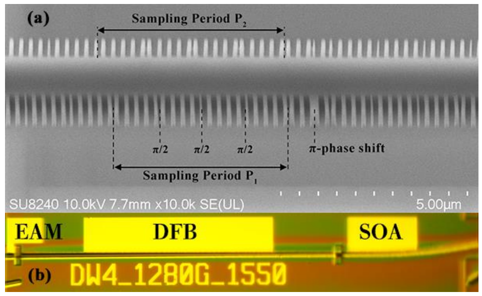

Fig. 1. (a) The SEM picture of the 4PS-SBG grating pattern, (b) The micrograph of the fabricated device.

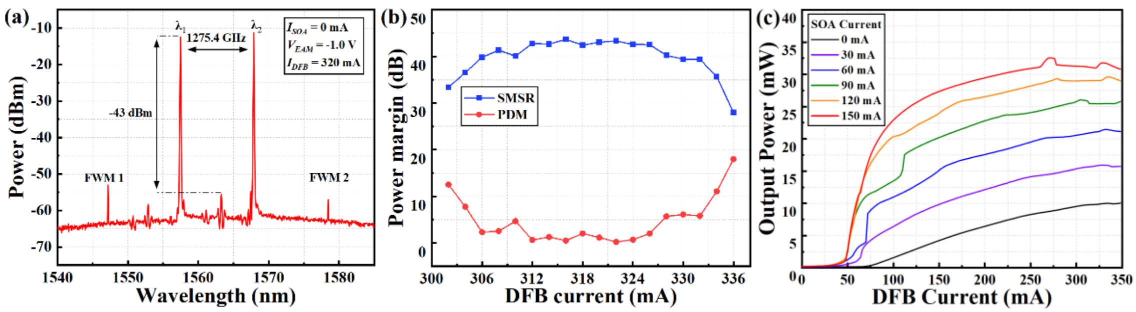

Fig. 2. (a) Measured optical spectrum at I_{DFB}=320 mA, I_{SOA}=0 mA, V_{EAM}=-1.0V, (b) SMSR and PDM versus DFB current, and (c) P-I curves from the SOA side with different SOA currents.

As shown in Fig. 1(b), the device comprises an electro-absorption modulator (EAM) (20 μm long), a DFB (1000 μm long) and an SOA (420 μm long) with the sections separated by isolation slots (20 μm wide). The SOA was used to increase the output power, and had a curved waveguide with a radius of 1720 μm and an angle of 10° at the output facet to reduce the reflection. The EAM enhances the phase relationship between the two lasing modes and stabilizes the mode beating frequency through the mechanism of four-wave mixing (FWM).

Devices were measured from the SOA side under CW conditions at 20˚C. With the DFB current I_{DFB} =320 mA, SOA current I_{SOA} = 0 mA, and EAM voltage $V_{EAM} = -1.0$ V, the device operated in two lasing modes λ_1 (1557.48 nm) and λ_2 (1567.87 nm) (to reduce the reflection (Fig. 2(a)). The wavelength spacing is 10.39 nm, corresponding to a frequency spacing of 1275.4 GHz and two FWM signals can be observed indicating a good phase relationship between the modes [6]. Fig. 2(b) shows the SMSR and power difference between two main modes (PDM) when I_{SOA} = 0 mA and V_{EAM}=−1.0 V. When I_{DFB} was changed from 306 mA to 326 mA, the device exhibited stable dual mode lasing with a SMSR >40 dB and PDM <5 dB. Fig. 2 (c) shows the power-current curves for different SOA currents. The threshold current is around 50 mA and the optical power reaches 31.7 mW when I_{SOA} = 150 mA and I_{DFB} = 330 mA.

III. Conclusion

In conclusion, a 1.55 μm dual-wavelength DFB Laser with a 1.28 THz frequency spacing and 43 dB SMSR was demonstrated based on a 4PS-SBG sidewall structure. The advantage of this structure is its high coupling coefficient and the precise control of the lasing wavelength spacing by changing the sampling period, while at the same time eliminating re-growth. The ultimate resolution in frequency spacing can be as small as 0.83 GHz. The device has the potential to be a compact optical source for THz generation.

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