High output power DBR laser for FMCW LiDAR system

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Abstract: We demonstrated a DBR laser with the output power reaching 96 mW. The linear frequency sweep of 24 GHz has been achieved with nonlinearity of 0.021% and 0.02% in the up and down ramps, respectively.

1. Introduction

Light detecting and ranging (LiDAR) technology has been widely used in many areas [1-2]. Among different kinds of LiDAR, frequency-modulated continuous-wave (FMCW) technology has advantages of high resolution and sensitivity due to coherent detection [3]. Besides, FMCW LiDAR can also simultaneously get position and velocity information of the target in a single measurement.

There are various types of lasers which can be used to achieve frequency scan linearization: distributed feedback (DFB) lasers [4], vertical-cavity surface-emitting lasers (VCSELs) [4], sampled-grating distributed-Bragg-reflector (SG-DBR) lasers [5], and external cavity lasers (ECLs) [6]. DBR lasers have the advantage of fast tuning rate due to electro-optical tuning. Moreover, DBR lasers can potentially achieve narrower linewidth. In this paper, we demonstrated a high output power DBR laser for FMCW LiDAR system. To obtain high output power, the front mirror of the DBR laser is a short section of uniform grating without current injection which has higher transmissivity comparing with the traditional SG-DBR laser. Here, the laser shows an output power of 96 mW when the gain and SOA currents are 200 mA and 400 mA, respectively. Besides, free spectrum range (FSR) of 0.29 nm with narrow Lorentzian linewidth about 310 kHz is achieved. By using method mentioned in Ref. [4], we have realized linear frequency sweep of 24 GHz with residual nonlinearity of 0.021% and 0.02% in the up and down ramps, separately.

2. Design and performance

Figure 1 shows the microscope image of the high output power DBR laser, including an SOA region for optical amplification, a gain region for optical gain, a front mirror region and a back mirror region for mode selection, a phase region for frequency sweeping, and a photodetector (PD) region for monitoring the output power. A square waveguide to diverge the beam is integrated at the end of the laser to eliminate any reflection. To acquire higher power, 500-μm long gain region is tapered from 3 μm to 4.5 μm at each end (totally 100 μm). Furthermore, the SOA region is titled by 7° and the front cleaved facet is antireflection (AR) coated to reduce the reflection. Five compressive strained InGaAlAs MQWs are used to reduce the linewidth of the laser. And the front mirror is a section of 38 μm long uniform grating whereas the back mirror uses sample grating which is about 980 μm long with 31 burst periods.

Fig. 1. Microscope image of high output power DBR laser.

The chip is mounted onto an AlN carrier and then placed onto a cooper heat sink for further test. A thermal electrical cooler (TEC) controls the temperature of the chip at 25 °C, constantly. Figure 2(a) shows the LIV curve of the device. LI curve was measured by only injection current into the gain region and the SOA was reversely biased as a photodetector to detect the power. The result shows that the threshold current of the laser is 23.5 mA with 6 Ω series resistance. And the output power of the device is detected by a large area Ge detector when the current injecting into the gain region keeps at 200 mA. Figure 2(b) shows the output power versus current injected into the SOA region. The output power of the device achieves 96 mW when the gain current and SOA current are 200 mA and 400 mA, respectively.

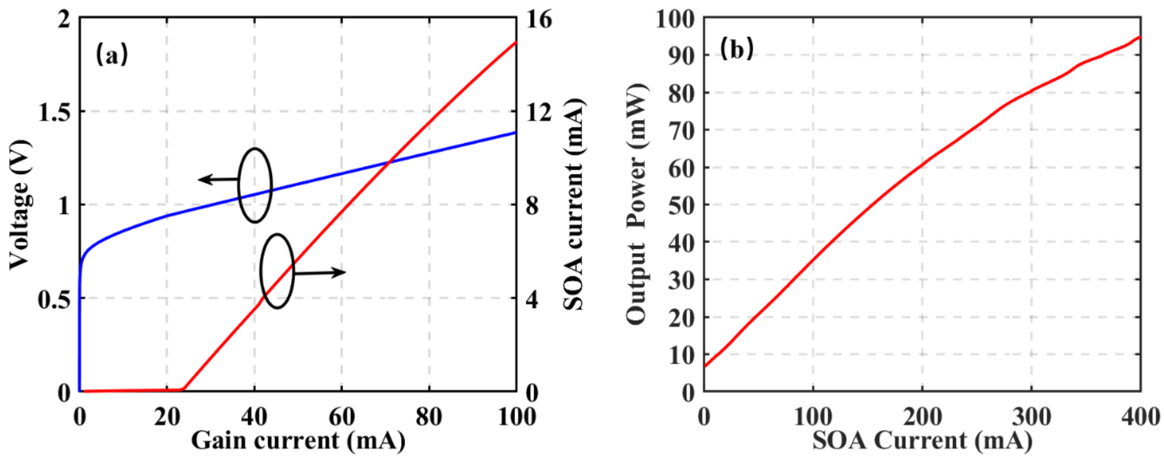

Fig. 2. (a) The LIV curve of the DBR laser; (b) The LI curve when the gain current is 200 mA.

The fine tuning capability and the Lorentzian linewidth of the DBR laser was measured by biasing the gain and SOA region both at 100 mA. Figure 3(a) shows that the free spectrum range (FSR) is 0.29 nm which could satisfy the need for frequency sweeping range of 30 GHz. The Lorentzian linewidth of the laser is tested by using the self-homodyne optical receiver method [7]. The FM noise spectrum is shown in Figure 3(b) and the Lorentzian linewidth of the DBR laser is about 310 kHz.

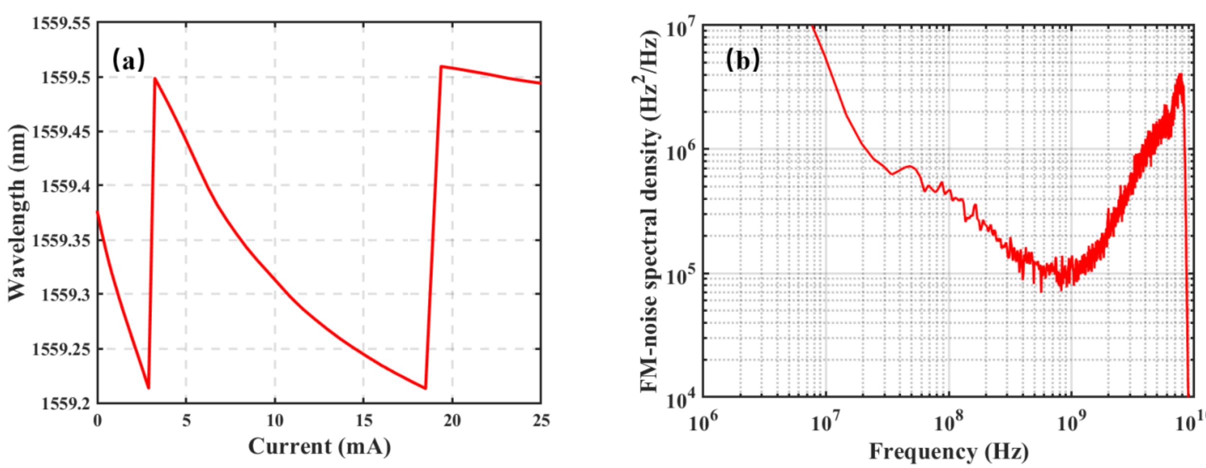

Fig. 3. (a) Wavelength tuning characteristics of the DBR laser when current is injected into the phase region; (b) FM noise spectrum of the DBR laser.

Finally, to obtain the linearization of frequency sweep, we use the method mentioned in Ref. [4]. We use a 14 pin butterfly packaged laser for testing to reduce the influence of noise and for better temperature control. The current injected into the gain and SOA regions are both 100 mA during the test. A modulated signal is applied in the phase region. The original and required signal are both triangular waveforms with frequency of 10 kHz (up and down ramps are both 50 μs). A 40 μs region of interest (ROI) (80% of each ramp) is used for evaluating the linearity of the frequency sweep. Figure 4(a) shows the root mean square (RMS) of the frequency sweep nonlinearity versus the times of iteration. As shown in Figure 4(b)~(c), the initial RMS of the up and down ramps are 806.22 MHz and 738.61 MHz, respectively. After iterating 136 times, the RMS of the up ramp reduces to 5.06 MHz, leaving the residual nonlinearity of 0.021%, and the RMS of the down ramp reduces to 4.83 MHz, leaving the residual nonlinearity of 0.02%. The results are revealed shown in Figure 4(d)~(e).

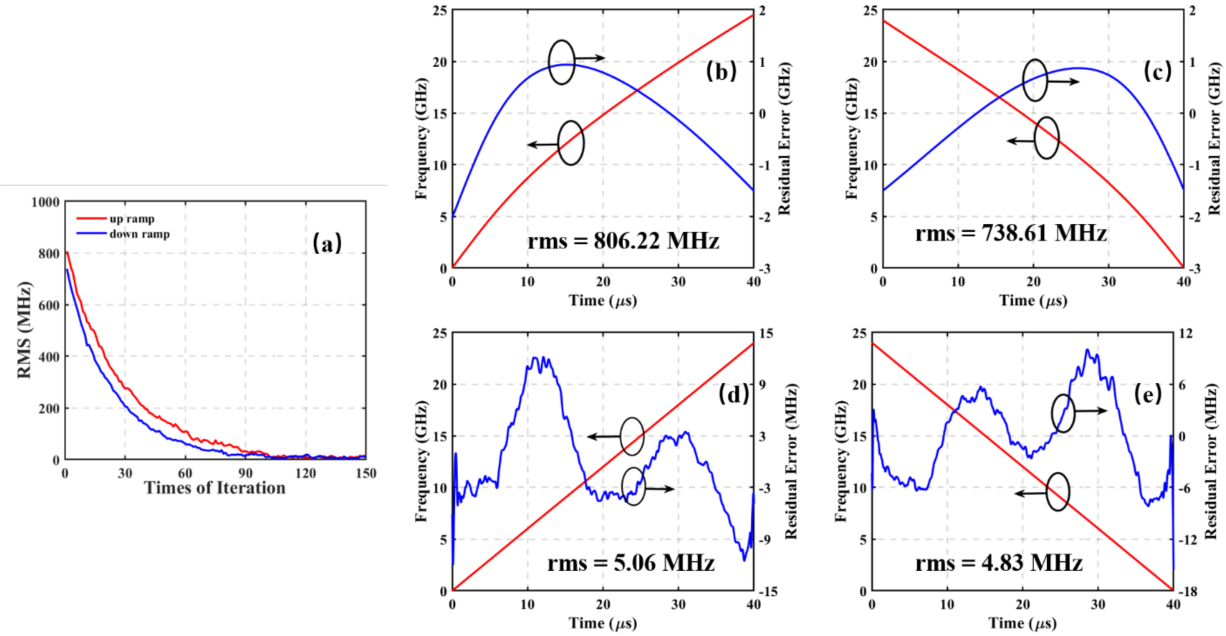

Fig. 4. (a) RMS of the up and down ramps versus the times of iteration; the up- and down- ramp of the laser frequency sweeps and residual error (b)~(c): the initial; (d)~(e): after 136 times of iteration.

3. Conclusion

In summary, we demonstrated a high output power DBR laser for FMCW LiDAR system. The laser shows an output power of 96 mW when the gain and SOA currents are 200 mA and 400 mA, respectively. A free spectrum range of 0.29 nm with narrow Lorentzian linewidth about 310 kHz is achieved. Finally, the iterative learning pre-distortion method is used for further studying the linearization of the frequency sweep. After 136 times of iteration, we have achieved a residual nonlinearity of 0.021% and 0.02% of the frequency excursion in the up and down ramps, respectively. The high output power and narrow linewidth DBR laser we demonstrated is an attractive candidate for the FMCW LiDAR system.

4. Funding
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5. References

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