Modeling of Surface Grating-loaded VCSEL with Slowing Light

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1. Introduction

In contrast to DFB lasers and DBR lasers [1, 2] with guided modes, we proposed and demonstrated surface grating VCSEL [3] where light travels as 'Zigzag' format in lateral direction, leading to slow-wave. As a result, the group index and phase index largely change [3]. In this paper, a surface grating-loaded VCSEL structure is analyzed for high-power and single-mode VCSELs by using coupled-mode theory. The reflection spectrum of grating loaded VCSELs, numerical results on lasing modes, and threshold gain for quarter phase-shift grating-loaded VCSEL are presented.

2. Grating loaded VCSEL

The schematic of the grating loaded VCSEL is shown in Fig. 1, where the grating is formed on the surface of the VCSEL. The device length is L. A grating is formed on the surface of a conventional VCSEL with 19 pairs of top DBR, 30 pairs of bottom DBR. The 1-st order grating pitch Λ is as large as 500nm. Also, the depth is as small as 10 nm. These device parameters make fabrication process easier. Since the light travels in VCSEL as a slow-wave, the output light radiates through the surface.

3. Results

The phase refractive index of the high index and low index region are simulated by the film mode matching method as shown in Fig.2. It is noted that the phase refractive index of a slow light is below unity thanks to a large waveguide dispersion, thus the 1st-order grating pitch is as large as 500 nm at 850 nm.

Figure 3 shows the comparison of reflection spectra for the slow-wave and conventional guided-wave with a coupling constant κL of 2. As shown in Fig.3, in comparison with the guided wave DBR with 3dB reflection bandwidth of 13nm, the slow-wave DBR shows much smaller 3dB reflection bandwidth of 0.099nm. It is because the group index is as large as 18.8. A shallow surface grating provides a strong optical feedback in the grating and narrow stopband can be seen. These unique features come from slowing light.

Figure 4 shows the threshold gain against wavelength with different coupling constant κL=1, 1.5 and 2 where device length L=666, 1000 and 1333µm, respectively. In this structure, single-mode lasing could be achieved. The mode spacing is 0.06nm and the threshold modal gain difference is 30cm^{-1} for κL=1.5, which is large enough for single-mode operations.

4. Conclusion

The reflection spectra and lasing condition of the grating-loaded VCSEL have been presented. Thanks to its large waveguide dispersion, the much narrower stopband of a surface grating loaded VCSEL is predicted. For quarter phase-shift grating-loaded VCSELs, a single-mode operation with low threshold can be expected for mm-long cavities. We could expect unique features such as no facet damages, well-established VCSEL manufacturing, easy grating fabrication processes for high-power and single-mode VCSELs.

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References

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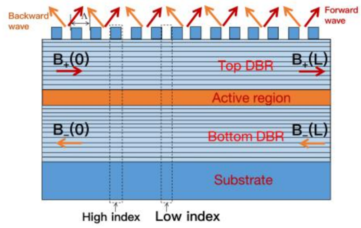

Fig. 1. Schematic structure of grating loaded VCSEL.

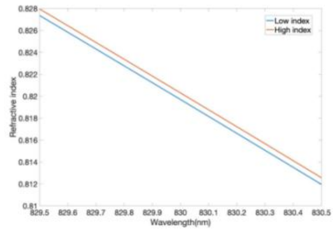

Fig. 2. Refractive index versus wavelength of grating loaded VCSEL.

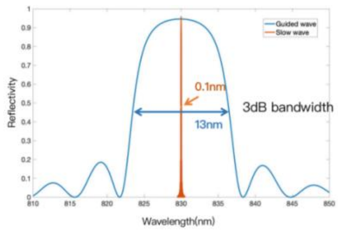

Fig. 3. Reflectivity versus wavelength of guided-wave and slow-wave.

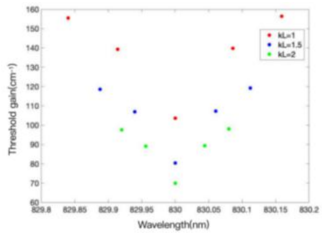

Fig. 4. Threshold gain against wavelength for quarter phase-shifted grating.