Numerical analysis of high output slow light VCSEL amplifier

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Introduction

There is always demand to find new applications of VCSELs, by using it directly or through integration into another photonic devices. VCSELs met vital requirements for many applications, because of low cost and easy fabrication in arrays. Also, VCSELs have superior performance in comparison with other semiconductor lasers, they exhibit low threshold current and high beam quality [1].

Variety of recent applications such as autonomous vehicles based on LiDAR systems, optical coherence tomography and free space communications require VCSEL with high output power. So, there are many attempts to increased output power of VCSELs to be suitable for these applications. Recently, our group proposed new scheme to boost output power of VCSEL based on slowing down light in Bragg reflector waveguide [2].

The structure in the vertical direction is as same as a conventional 980 nm one-λ cavity VCSEL as shown in Fig1 (a) [3]. An active region and an oxidization confinement layer are sandwiched by two DBR mirrors. Slow-light mode is then excited along the waveguide and radiates light through the top mirror. The top-mirror reflectivity depends on the number of DBR pairs. So, it's important to optimize pairs of DBR layers to get enough radiation output. The bottom mirror is designed to provide full reflection. High loss from travel waves can be compensated by inject current above threshold of amplifier. By increasing injection current, the light intensity become more uniform along VCSEL and the beam divergence get smaller and smaller by increasing length of VCSEL amplifier [3].

Results

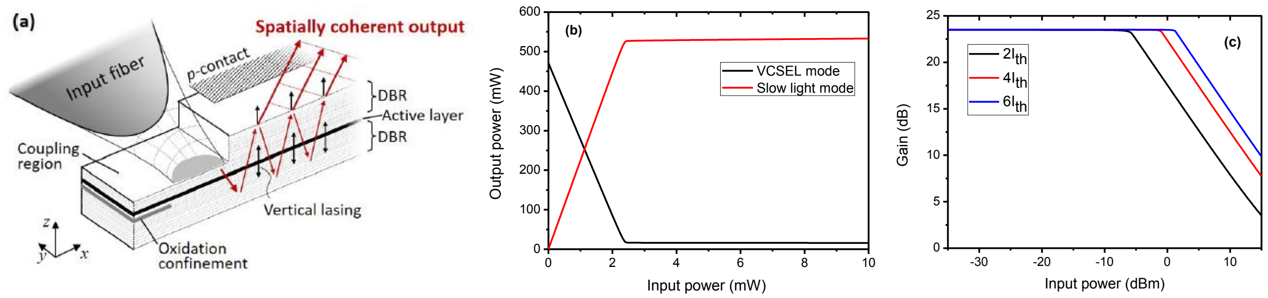

Figure (1) shows: (a) Schematic cross-section view of VCSEL amplifier [3]. (b) Suppression of VCSEL lasing mode by increasing input power for (length of amplifier = *1mm*). (c) Gain of amplifier at different injection current.

Rate equation of VCSEL amplifier is solved numerically in steady state. Amplifier is divided into small sections, every section work as small VCSEL. For amplifier with length 1mm, threshold current was 77 *mA*. Fig.1 (b) shows dependency of output power of slow light mode on injection current and coupled input power. By increasing input power, VCSEL lasing mode will be suppressed completely when the input power equals 2.4 *mW* and the output power will saturate at 527 *mW*. Fig.1(c) shows the gain of amplifier as function of input power, maximum gain equals 23 *dB*. Saturation input power increased by increasing the injection current.

Conclusion

Travel wave model has been devolved for VCSEL amplifier. The model describe amplification of slow light mode through amplifier biased above threshold. Operation critical parameters; input power, length of amplifier and bias current is analyzed. Our calculation takes in to account two modes, vertical lasing mode and slow light mode. Numerical results show possibility to obtain Watt-class output power by extend length of amplifier to several centimeters.

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References

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