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High power surface grating long aperture VCSEL

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Abstract, We demonstrate single-mode surface grating VCSELs with mm-long oxide-aperture, exhibiting 3W pulsed output power and high beam quality. Stable single mode operation is obtained by shallow surface grating with beam divergence angle of 0.053°.

Introduction

A Vertical cavity surface emitting laser (VCSEL) has been used for various applications because of its distinguish properties such as low power consumption, low cost and high efficiency. The next generation of 3D sensing may need higher powers and high beam quality of lasers. In our group, we work to realize high power VCSELs with a high beam quality using a VCSEL-based amplifier structure. A slow-light mode is propagated laterally in the VCSEL structure with large waveguide dispersion near the resonant wavelength [1]. By coupling an external light in the VCSEL amplifier, we obtained high power single-mode operation of several watts with a narrow beam divergence lower than 0.024° for a 10mm long amplifier [2]. Also, we recently obtained the high-power and single-mode operation of mm-long oxide aperture VCSELs [3]. Without using an external light, a single mode slow light can be selected and stabilized by coupled cavities effect coming from the oxidized edge at the end of the mesa [3]. Unfortunately, increasing the current injection leads to high order modes operations. In this paper, to overcome this problem, we experimentally demonstrate the "slow-light" VCSEL with surface grating, which provides high power and a nearly-diffraction-limited beam divergence.

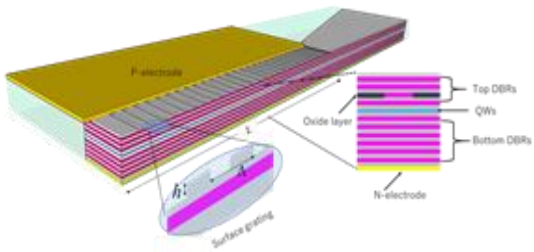

Fig. 1: Schematic diagram of surface grating slow light VCSEL. The grating is defined by its period Λ and depth h.

Structure of the device

Figure 1(a) shows the schematic diagram of the fabricated device. The epi-wafer structure is the same as conventional 850nm oxide confined VCSEL. We formed a long-oxide aperture with an aperture length from 1mm to 6mm and a width of 3-5μm. We formed the surface grating to stabilize a lasing mode by a photo lithography followed by wet etching. The calculation shows that a shallow grating (50- 60nm od depth) provides large enough grating coupling strength. 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 0.4 μm at 850 nm, which makes the grating fabrication easier. The fabricated grating pitch is as large as 2.5 and 3.35μm for the 6th and 8th order grating, respectively.

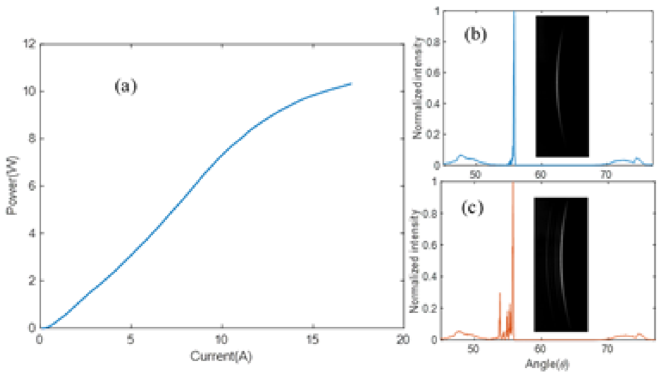

Fig. 2: (a) 50 ns pulse light current characteristics of 6mm device. (a) and (b) are FFP at 5 and 7 A respectively

Results

Figure 2(a) shows the light-current characteristic under pulsed operation with a pulse width of 50 ns. An output power of 10 W is obtained at 17A. Figs. 2(a) and (b) show FFPs at currents of 5A and 7A, respectively. The radiation angle is almost constant. The single line FFP in Fig. 2 (b) shows single mode operation with an output power of 3 W. Side peaks appear by pumping harder at 7A because of lasing of high order modes.

Conclusions

We proposed and demonstrated surface grating VCSELs with mm-long oxide-aperture, exhibiting watt-class high power and high beam quality. The result shows a possibility of high-power single-mode VCSELs for use in 3D sensing and laser processing.

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