

5.2 mW Single-Mode Power from a Coupled-Resonator Vertical-Cavity Laser

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Abstract:

We have achieved 5.2 mW of single fundamental-mode power from a coupled-resonator vertical-cavity laser. The enhanced mode selectivity is due to gain profiling combined with current-induced changes in cavity coupling.

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Vertical-cavity surface-emitting lasers (VCSELs) which emit into a single optical mode are increasingly sought for emerging VCSEL applications, which include data communications with single-mode fiber, bar code scanning, laser printing, optical read/write heads, and modulation spectroscopy. We have achieved a record high fundamental-mode power of 5.2 mW from our coupled-resonator vertical-cavity lasers (CRVCLs) [1]. In conventional VCSELs, the extent to which the gain volume may be increased is limited by the onset of multi-mode operation. Our results indicate that this limitation is circumvented in a coupled-resonator device allowing high power fundamental-mode operation.

As shown in Fig. 1, the coupled-resonator is composed of a bottom p-type distributed Bragg reflector (DBR) with 35 periods, a middle n-type DBR with 11.5 periods, and a top p-type DBR with 22 periods [2]. The top and bottom one-wavelength cavities each contain five 8 nm GaAs quantum wells. The device was fabricated using a two-tier etch with two metal ring contacts on the top as well as a back side contact. A $6 \times 6 \mu\text{m}$ proton implant was used for current injection in the top cavity while a $10 \times 10 \mu\text{m}$ oxide aperture was used in the bottom cavity.

Figure 2 shows a light-current curve for a CRVCL device where the implant cavity current is fixed at 5.0 mA with a varying oxide cavity current. The inset of the figure shows the lasing spectrum with $I_{\text{implant}} = 5.0 \text{ mA}$ and $I_{\text{oxide}} = 13.7 \text{ mA}$. The main lasing peak is at 853.8 nm and the next largest intensity higher-order mode is 32 dB lower. At 13.7 mA, the device is lasing single-mode with an output power of 5.2 mW.

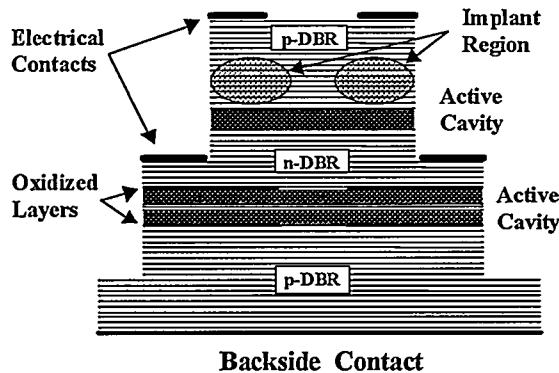


Figure 1: Schematic Diagram of Coupled-Resonator Vertical-Cavity Laser. Note the use of both oxide and implant current apertures.

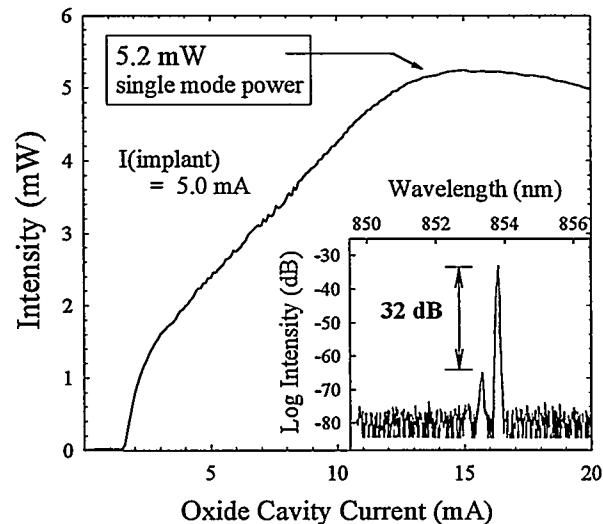


Figure 2: Light-current curve showing 5.2 mW single-mode power. The inset shows the single mode lasing spectrum.

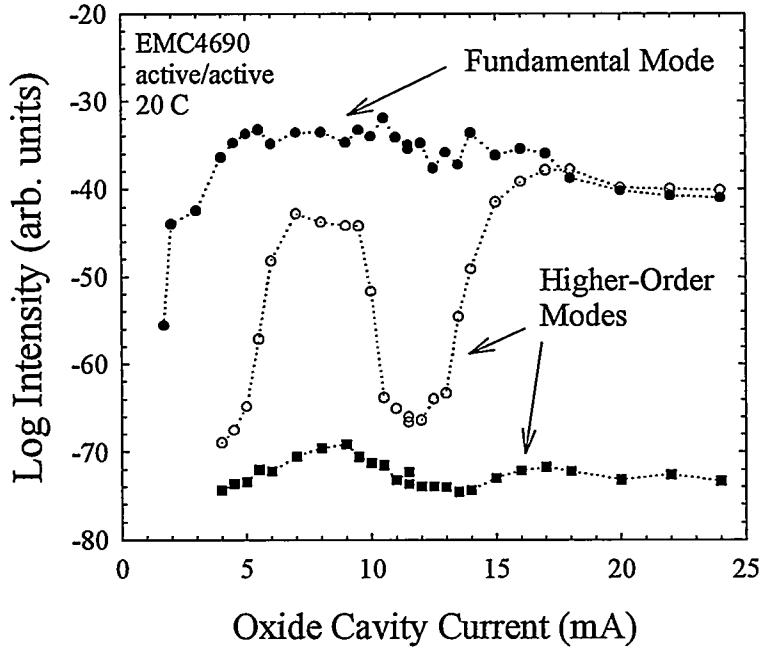


Figure 3. Emission wavelength plotted as a function of oxide cavity current for all observable cavity modes at an implant cavity current of 5.0 mA.

Figure 3 shows the lasing wavelength for all detectable transverse modes as a function of oxide cavity current with the implant cavity biased for single-mode operation. The device begins lasing single-mode near threshold and, at 6 mA, a second mode appears. Near 12 mA this second mode decreases and we observe our record high 5.2 mW single-mode power. Above 15 mA the device operates multi-mode.

Modeling of the CRVCL indicates that gain profiling combined with coupled-cavity modal selection enables high fundamental power operation. Fundamental mode discrimination is enhanced by the gain profiling provided by the top 6 μm diameter implant. Independent current injection into the two cavities allows selection of the fundamental coupled mode. Note that high power fundamental-mode operation is achieved with an oxide transverse cavity size of 10 μm which would be multi-mode in a conventional VCSEL.

Further experimental and theoretical work is in progress to understand the changes in coupling and to optimize these structures. Future devices are expected to show even larger single-mode powers. The flexibility provided by these three-terminal coupled-cavity devices will enable high-speed switching applications where high single-mode power is required [3].

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References

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