Composite Resonator Vertical Cavity Laser Diode

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Abstract

We report the first composite resonator vertical cavity laser diode consisting of two optical cavities and three monolithic distributed Bragg reflectors. Cavity coupling effects and two techniques for external modulation of the laser are described.

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The use of two coupled laser cavities has been employed in edge emitting semiconductor lasers [1] for mode suppression and frequency stabilization. The incorporation of coupled resonators within a vertical cavity laser opens up new possibilities due to the unique ability to tailor the interaction between the cavities. Composite resonators can be utilized to control spectral and temporal properties within the laser; previous studies of coupled cavity vertical cavity lasers have employed photopumped structures [2],[3]. We report the first electrically injected coupled resonator vertical-cavity laser (CRVCL) diode and demonstrate some of the novel characteristics arising from the cavity coupling, including methods for external modulation of the laser.

Fig. 1 depicts the CRVCL which consists of a lower 1-λ thick active resonator containing 3 InGaAs quantum wells and a passive upper resonator composed of 1-λ thick GaAs. In the bottom active cavity we employ selective oxidation of AlGaAs to form buried oxide layers for efficient electrical and optical confinement [4]. Separate electrical contacts to each cavity provide independent current injection into the two resonators. The coupling between the resonators is controlled by the transmission of the shared middle distributed Bragg reflector. Fig. 2(a) is a plot of the cavity resonances as a function of mirror periods in the middle distributed Bragg reflector (DBR). As the DBR reflectivity decreases, the resonance splitting and thus cavity coupling increases. The resonances shift in opposite directions in Fig. 2(a) which may be important for frequency tuning applications. In Fig. 2(b) we show the measured reflectance

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of a CRVCL with a 11.5 period middle DBR: the two cavity resonances are 14 nm apart in Fig. 2(b), in agreement with our calculations in Fig. 2(a).

In Fig. 3 we show the cw light output from a large aperture (20 x 20 μm) CRVCL with injection current into the lower active cavity. A single lasing emission at 997 nm corresponding to the longer resonance in Fig. 2(b) is observed. Lasing emission from only the eigenmode of the lower active cavity is apparent, since the upper passive cavity eigenmode is not adequately pumped even with current injection into the passive resonator (although increased spontaneous emission is observed). For increasing current applied to the top passive cavity, the lasing output decreases in Fig. 3, while the spontaneous emission continues to increase below threshold. Injection current into the passive cavity changes its optical path length which modifies the composite cavity wavefunction, leading to decreased overlap with the quantum wells in the active cavity. Thus the behavior in Fig. 3 conclusively demonstrates that a coupled resonator effect is responsible for the reduction of light output above lasing threshold. Moreover, by slightly reverse biasing the top cavity, the lasing is completely extinguished, due to cavity enhanced absorption in the top cavity. Using this effect, 50 MHz large signal modulation of the CRVCL (apparatus limited) has been achieved. Note with the bottom cavity maintained above threshold and employing coupled cavity effects for modulation, chirp-free high speed modulation should be possible and is under investigation. This work was supported by the U. S. DOE under contract No. DE-AC04-94AL85000.

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Figure Captions

Figure 1. Top view and sketch of coupled resonator vertical cavity laser (CRVCL).

Figure 2. (a) Cavity resonances resulting from CRVCL with varying mirror periods (reflectivity) in the middle mirror between the cavities. (b) Measured reflectivity of CRVCL with 11.5 periods in the middle mirror showing two resonances (denoted by arrows).

Figure 3. Light output versus injection current into the bottom active cavity for various values of constant current injected into the top (passive) cavity.

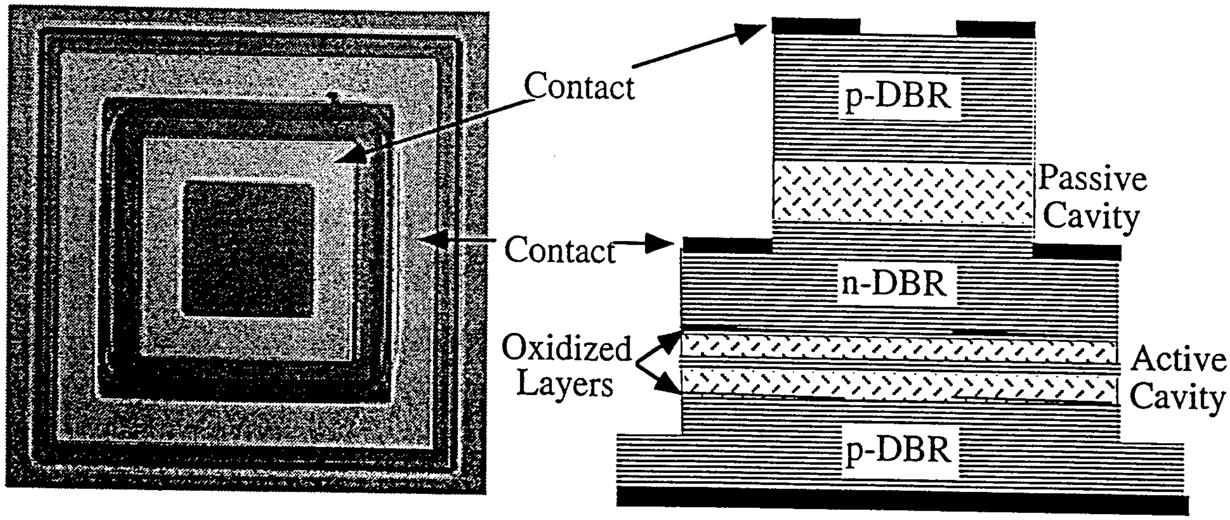

Figure 1
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Composite Resonator VCL

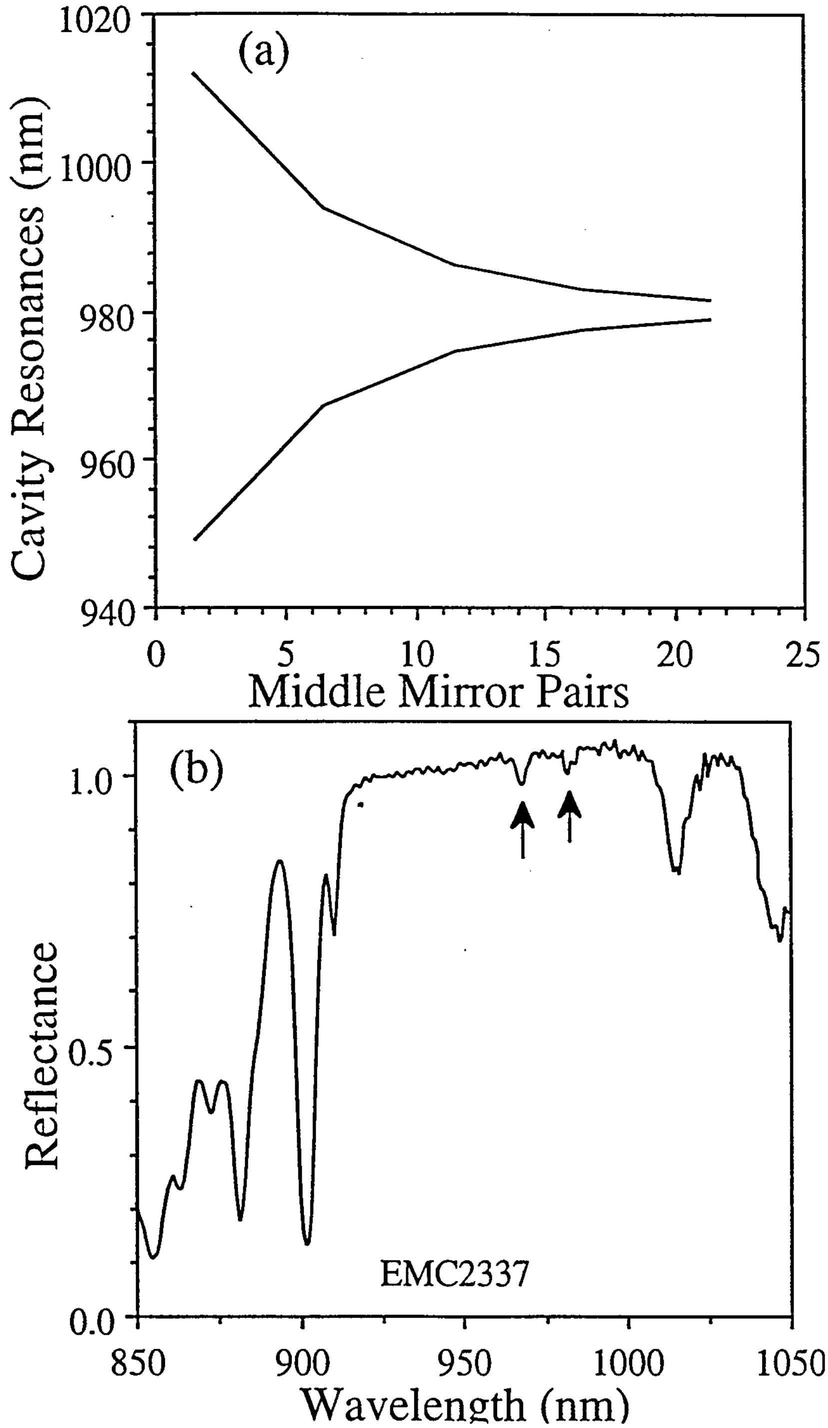

Figure 2
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Composite Resonator VCL

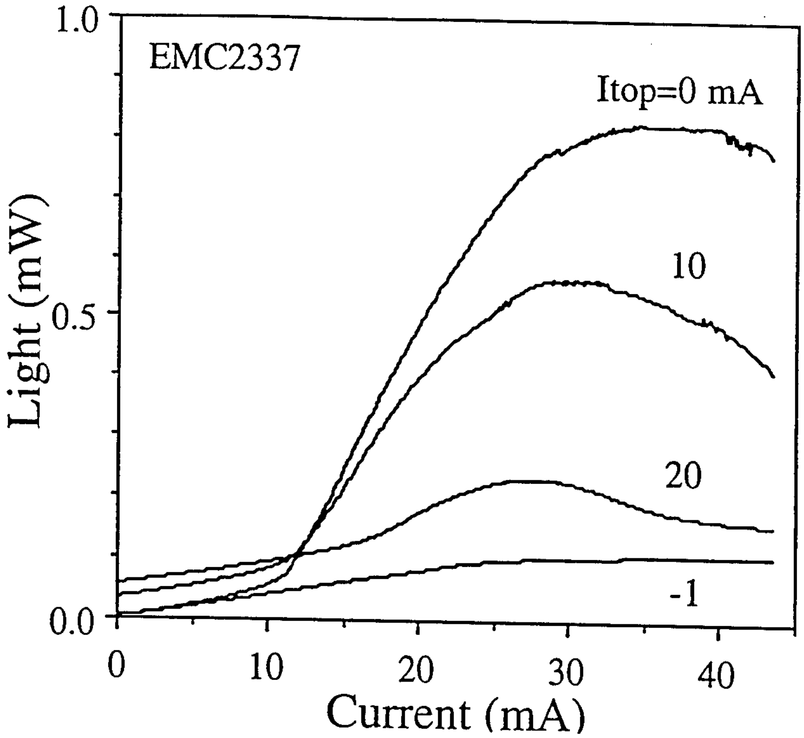

Figure 3
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