Self-pulsing oxide-confined vertical-cavity lasers with ultralow operating current


Indexing terms: Vertical cavity surface emitting lasers, Semiconductor junction lasers

Selectively oxidised vertical-cavity lasers which exhibit self-pulsing lasing at currents as low as 470nA are reported. Characteristics including linearly polarised emission, narrow linewidths and coherent near and far-field diffraction indicate that these devices operate as lasers at DC currents < 1μA. Although self-pulsating lasing initiates at submicroampere average current, the injection current during the optical pulse can be > 1μA.

Reduced active volume for lower threshold current has long been touted as a desirable characteristic of microcavity lasers. Oxide-confined vertical cavity surface emitting lasers (VCSELs) have recently effected dramatic reductions in threshold current from 225μA to < 10μA [1 - 4]. The lower threshold currents of the oxide-confined VCSELs result from enhanced coupling of spontaneous emission [5], improved electrical/optical confinement [6] and reduced optical loss [4] which have been accomplished using buried oxide layers [1, 7] selectively formed from AlGaAs [8].

Recently we have found that reducing the VCSEL cavity volume can also lead to new electronic effects, which can complicate the interpretation of low threshold lasing. We have fabricated and characterised small cross-sectional area (≈4μm²) oxide-confined VCSELs with two buried oxide apertures on each side of a high finesse optical cavity [9]. We report current-controlled self-pulsing laser operation that occurs at submicroampere DC injection currents. The self-pulsating laser operation arises from an electronic nonlinearity, rather than optical feedback, which allows injection of relatively high current densities over a short time interval resulting in low average current.

The 5 inch diameter VCSEL wafers designed to emit at nominally 840nm are grown by metalorganic vapour phase epitaxy on a rotating susceptor. The lasers contain three GaAs quantum wells in the one wavelength thick optical cavity. The 26 period top and 40 period bottom monolithic distributed Bragg reflector mirrors consist of AlₓGa_{1-x}As/AlₓGa_{0.9}As layers with parabolic heterointerface compositional grading. After growth, oxide aperture layers are selectively fabricated in AlₓGa_{1-x}As layers on each side of the optical cavity [9] to funnel the current into the quantum wells. In this work we examine oxide-confined VCSELs with square oxide apertures which are <2μm on a side.

Fig. 1 Light output against DC injection current for a 1 x 1 μm oxide-confined VCSEL.

Inset shows output characteristics on a linear scale.

The abrupt transition in Fig. 1 does not correspond to a continuous wave threshold condition. Instead, above the transition we find the VCSEL emission to be oscillating in time at a constant frequency under DC current injection. We show in Fig. 3 a plot of the light output versus time from a VCSEL with a DC injection current of 10μA. The VCSEL emission in Fig. 3 oscillates at 3.8kHz with a pulse duration of 812ns. As the injection current is increased, the output oscillation frequency increases until a DC current of 500μA where a continuous wave mode arises and the self-pulsation ceases. The self-pulsation arises due to an electronic nonlinearity which causes injection of relatively high current densities in a short time interval producing low average current. From Fig. 3 we calculate that the instantaneous current can be as high as 1mA, which is greater than the threshold of the continuous wave lasing mode which eventually arises. As the average injection current is increased, the self-pulsation frequency increases. Thus these self-pulsing VCSELs can be used as low power current-controlled light oscillators. Larger area VCSELs (> 50μm²) are less prone to exhibit self-pulsating laser operation. A quantitative model of the self-pulsating VCSEL operation arising from an electronic nonlinearity will be presented elsewhere [10].
In conclusion, submicrosecond self-pulsation laser operation is obtained from small oxide-confined VCSELs. Laser operation at an average DC current of < 1 μA is established from narrow spectral linewidths, polarized emission and coherent diffraction features in the near and far field of the laser emission. However, the VCSELs operate in a self-pulsation mode, where the oscillation frequency of the laser emission depends on the average injection current, which can be submicrosecond. This phenomena arises in these small VCSELs as a consequence of nonlinear electronic rather than optical effects. Our results show that care must be taken to identify true continuous wave lasing at low threshold currents in VCSEL diodes.

Acknowledgments: The authors thank D. Botez for valuable discussions. The work at Sandia is supported by the United States Department of Energy under contract DE-AC04-94AL85000.

© IEE 1996 21 December 1995
Electronics Letters Online No: 1996033

References

Spectral control of a laser diode with a Michelson external cavity

T. Zhang, Y. Hashimoto and M. Yonemura

Indexing terms: Semiconductor junction lasers, Laser tuning

The authors present experimental results of spectral control of a laser diode with a Michelson external cavity. With this new method the spacing and the number of the oscillating modes can be controlled by changing the optical path difference of the external cavity. The reduction of the spectral bandwidth and the extension of the tuning range of the laser diode were observed.

There has been a great deal of interest in semiconductor laser diodes recently because they provide an economic and efficient source of coherent radiation. In addition they exhibit desirable modulation and scanning performance. Several techniques involving optical feedback from Fabry-Perot cavities [1], diffraction gratings [2] and various simple reflectors [3] have been used to induce diode lasers to tune continuously over an extended range of wavelength, thus eliminating the problems such as mode hopping and wide bandwidth at lower injection currents. However, many of these methods are difficult to implement or require expensive components. In this system the spacing between two reflection mirrors of the external cavity is substantially less than the spacing between the two laser facets. Thus, the external cavity mode spacing is several times greater than that of the laser alone. This allows us to narrow the spectral bandwidth and control the number of the oscillating modes.

The experimental setup is shown schematically in Fig. 1. The laser used was a commercially available MM41JN AlGaAs laser (Mitsubishi Electronic Corp.) with a free-running wavelength of 782nm and output ~5mW under standard operation conditions. The threshold value of the injection current is 33mA. The end facets of the laser were coated with SO for protection. Thus we could not fabricate desirable antireflection coatings on them. A commercially available collimation optics Lens-1 is employed to collimate or focus the laser beam. The output beam of the laser diode is then entering into a Michelson external cavity, where a beam splitter BS and two mirrors M1, M2 are used to form the external cavity. The mode spacing determined by the Michelson external cavity is expressed in the general form $\Delta L = L_2 - L_1 = 0.15\text{mm}$, where $L_1$ and $L_2$ are the arm lengths of the Michelson external cavity.