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Mode-Locking of High-Power Resonant-Optical-Waveguide Diode Laser Arrays

Alan Mar, Dennis Derickson, Roger Helkey, John Bowers
Department of Computer and Electrical Engineering
University of California, Santa Barbara

Dan Botez
TRW Research Center
Redondo Beach, California

Abstract
We report the first mode-locked operation of a resonant optical waveguide (ROW) semiconductor laser array. Pulsewidths as short as 23 ps and peak powers of over 1W are generated in a single-lobed beam.

Mode-locked semiconductor lasers are attractive as compact sources of short optical pulses for use in physics measurements, for instrumentation systems, and for telecommunications applications. Such lasers operate with average output powers of typically a few milliwatts, which limits their use in applications where higher power is required. The use of laser arrays results in higher output powers, but such arrays tend to emit in multi-lobed far-field patterns. This makes their incorporation into external cavities with high coupling efficiencies difficult. Resonant-optical-waveguide (ROW) diode array lasers have recently demonstrated in-phase (single main-lobed) operation at cw output powers of up to 500 mW[1]. Such arrays are therefore promising candidates for high power semiconductor laser mode-locking. In this paper, we report the first mode-locked operation of such devices, with external cavity coupling efficiencies comparable to that typically obtained using single-element lasers.

In this experiment, a 20-element array was used with a cleaved cavity length of 500 µm. The lasing wavelength was 850 nm. Half-wave Al_2O_3 coatings were applied to both diode facets. The facet used to couple into the external cavity was then additionally coated with an anti-reflective quarter-wave SiN_xO_y layer (index~1.83). Before AR coating, the device threshold current was 320 mA. The application of the AR coating resulted in an increase of threshold to 570 mA.

The array was coupled to an external air cavity of approximately 15 cm in length, corresponding to a repetition rate of 1 GHz. As shown in Figure 1, three intra-cavity lenses were used to couple the beam into the external cavity. An AR-coated GRINROD lens is used at the laser because of its high collection efficiency and numerical aperture. The cylindrical lens is used to compensate for astigmatism in the laser emission. The beam is focused onto the external cavity mirror using an achromatic doublet. This doublet is used because the non-circular beam profile fills most of the lens and would be subject to the off-axis aberrations characteristic of a singlet lens, which are compensated in an achromat. As shown in Figure 2, the external cavity feedback reduces the

threshold current from 570 to 330 mA, which is virtually the same as the threshold before AR-coating. This suggests that the cavity coupling efficiency is on the order of 30%. A GRINROD and cylindrical lens are also used to collimate the output beam with a similar collection efficiency. The current to the laser is modulated at 1 GHz using a frequency synthesizer and a 20 W RF amplifier through an impedance-matching stub tuner. A high-speed (impulse response~22 ps) GaAs pin photodetector and 40 GHz sampling oscilloscope and an autocorrelator are used to monitor the pulse output. The variation of pulsewidth (measured by autocorrelation and using a deconvolution factor of 1.55) with increasing bias current is shown in Figure 3. Pulses as short as 23 ps have been observed, with slightly broader pulses being obtained at higher output powers. The maximum power was limited by the current capacity of the bias tee used.

Peak collimated output powers of between 1 and 2 W are routinely obtained from the ROW mode-locked laser. Further reductions in pulsewidth could be achieved from the use of saturable absorbers or pumping the laser in separate sections[2], resulting in even greater peak powers. Therefore, the use of ROW array lasers is a promising technique for increasing the output powers of mode-locked semiconductor lasers.

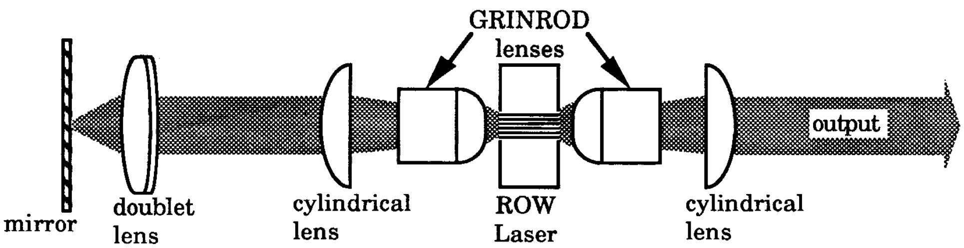

Figure 1. Schematic of the ROW array external cavity mode-locked laser.

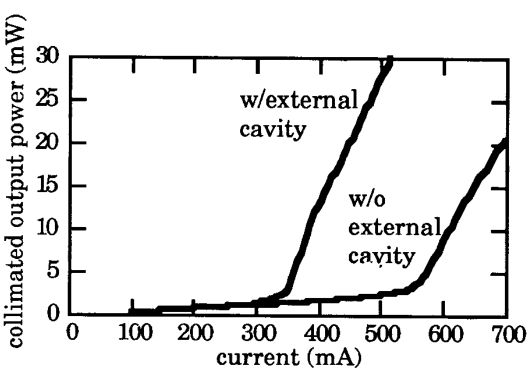

Figure 2. Light vs. current curves.

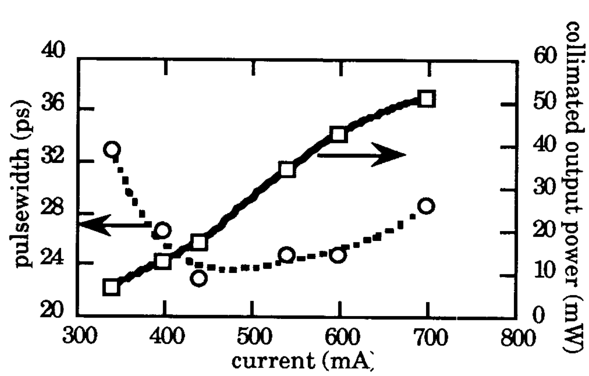

Figure 3. Dependence of pulsewidth on DC bias.

References

[1] Mawst et al., *Electronics Letters*, vol. 27, No. 17, 1991.
[2] Mar et al., 1991 LEOS Annual Meeting, paper SDL14.1, San Jose, CA.