The effect of cavity length on picosecond pulse generation with highly rf modulated AlGaAs double heterostructure lasers

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The effect of cavity length on picosecond pulse generation with highly rf modulated AlGaAs double heterostructure lasers

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We report the generation of picosecond pulses with oxide-isolated-stripe, double heterostructure GaAlAs laser diodes of varying lengths. A pulse width of 15 ps at a repetition frequency of 1 GHz is achieved with a 60-μm-long device. The experiments indicate a linear relation between pulse width and laser length.

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Recently there has been considerable interest shown in the generation of picosecond light pulses from semiconductor lasers. Mode locking has been demonstrated to be capable of producing pulses down to a few pioseconds[1-3], but requires extremely careful alignment of an external resonator. A number of other schemes for producing pulses of 20–30-ps duration have been reported [4-10], and perhaps the simplest of these involves driving the laser with a large sinusoidal current pulse with the dc bias at, or below, threshold[8-10]. This forces the gain and hence, the optical intensity to switch rapidly, resulting in the emission of a single pulse of a few tens of picoseconds duration at the period of the sinusoidal drive. The pulse widths have been shown[10] to be fairly insensitive to the drive frequency at microwave rates, the effect being due to the electron-photon interaction within the laser. The large sinusoidal modulation scheme is thus a useful method for producing fixed width pulses at externally controllable repetition rates.

Other workers[8] have suggested that the photon lifetime in the cavity will play a crucial role in determining the pulse width, with shorter lasers producing shorter optical pulses. In this letter we wish to report experimental results of the effect of laser length on the production of picosecond pulses by the gain switching method.

The semiconductor lasers used in our experiments were oxide-isolated-stripe, double heterostructure GaAlAs laser diodes (17-μm stripe width), operated in pulsed mode to alleviate heat sinking problems. A set of diodes with lengths varying from 60–500 μm was fabricated from the same wafer to try to ensure unification of material properties. Figure 1 shows the variation of threshold current with laser length for the various devices, and is in good agreement with results from other workers.[11] The laser spectra show single dominant mode when driven at 10% above threshold, and the light-current characteristics show no kinks up to 5 mW light output per facet. The lasers were pressure mounted at the end of a 50-Ω triplate line, with a 50-Ω chip resistor in series as a first approximation to impedance matching.

The optical output was collimated with a 3.6-mm-diam, 3.5-mm-focal length microlens, and monitored with a fast photodiode [200-ps full width at half-maximum (FWHM)]. Pulse widths were measured in a standard manner by intensity autocorrelation using type I, phase-matched second-harmonic generation in $LiIO_3$. The output at the second harmonic was detected with a photomultiplier and amplifier followed by a boxcar detector (sampling integrator) locked to the period of the bias drive.

In agreement with Paoli[12] we found that the large (~ 1

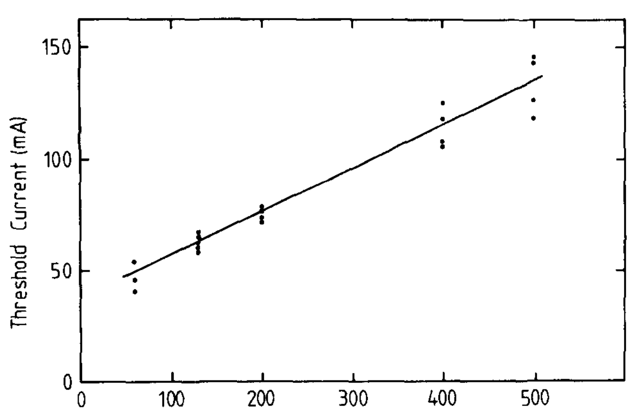

FIG. 1. Threshold current vs laser length for the set of laser diodes used in this study.

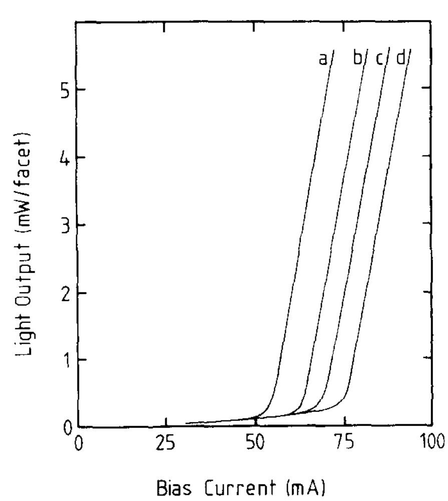

FIG. 2. Variation of the average optical power emitted per facet for a typical 200-μm laser diode as a function of the dc bias current for various relative levels of applied sinusoidal power at 1 GHz. (a) Full rf, (b) − 3 dB, (c) − 10 dB, (d) no rf.

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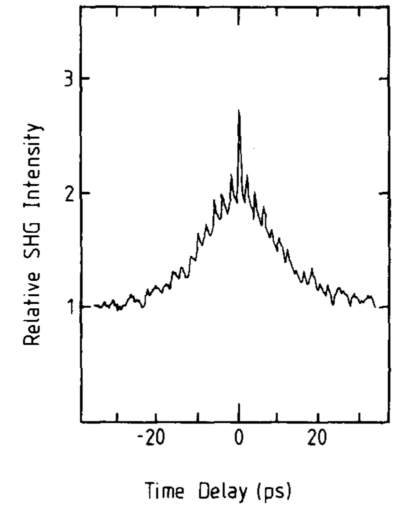

FIG. 3. SHG autocorrelation measurement of optical pulses from a 60-μm laser diode. The laser is biased at zero rf threshold with full rf on. The pulse width (FWHM) is 15 ps assuming a Gaussian profile.

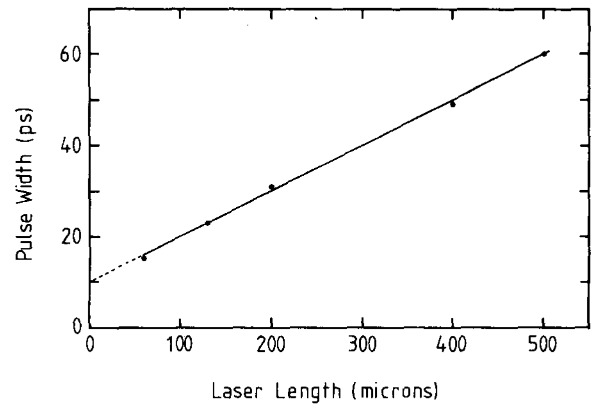

FIG. 4. Pulse width vs length calculated from SHG measurements assuming Gaussian profiles.

W) rf drive caused a considerable decrease in threshold (Fig. 2), and that with the lasers biased just under their zero-rf threshold, photodiode limited pulses were produced. Figure 3 shows an autocorrelation trace for the optical pulses from a 60-μm laser. The pedestal has a FWHM of 21 ps, and assuming a Gaussian pulse shape, we estimate the pulse width to be 15 ps FWHM. We believe this to be the shortest pulse reported from a semiconductor laser using the gain-switching method. The coherence spikes, which indicate the presence of more than one randomly phased longitudinal mode, although not clearly resolved due to the integration times, are seperated by about 1.9 ps. This corresponds approximately to the cavity round trip time of 1.7 ps, assuming a group velocity of c/4.3.

In Fig. 4 we plot the variation of pulse width with laser length. The lasers were biased close to the zero-rf threshold, and the pulse widths produced were found to be fairly insensitive to rf drive level. It can be seen that the variation is approximately linear, and if we extrapolate the laser length to zero, the line crosses the vertical axis at a pulse width of about 10 ps. We surmise that this is the limiting pulse width for these lasers using the gain-switching method, and theoretical efforts are in progress to explain this limit.

In conclusion, we have investigated the effect of cavity length, and hence photon lifetime, on the width of picosecond pulses produced by gain switching in injection lasers. We have obtained 15-ps pulses at 1 GHz with a short (60 μm) cavity laser and our results indicate a minimum pulse width of about 10 ps using the gain-switching mechanism.

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