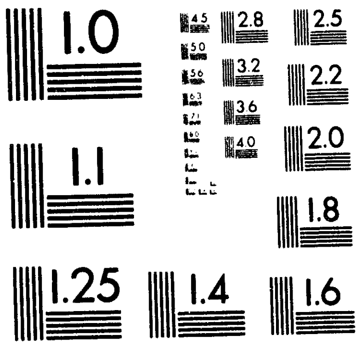
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Spectrally and Temporally Resolved Laser Emission from Vertical Cavity Surface Emitting Lasers *

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Abstract: We have measured the laser emission spectra of several vertical cavity surface emitting lasers following pulsed laser excitation, with a time resolution of < 1 ps. Correlations between the observed pulse widths and cavity lifetimes were observed.

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The use of vertical cavity surface emitting lasers (VCSELs) in ultrafast optical switching and information processing depends upon the development of laser structures capable of producing short optical pulses. Hence, determination of the effect of various laser design parameters on the output pulse width is of interest [1–4]. Toward this end, we have measured the transient laser spectra of a number of VCSELs.

The laser spectra were measured using pump and probe upconversion techniques. The VCSELs were photopumped using the filtered (RG715) white-light continuum generated by focussing an amplified dye laser pulse (620 nm, 115 fs, 0.7 mJ) into a 3 mm fused silica plate. The output from the VCSELs was then upconverted by a small portion of the amplified dye laser pulse in a thin KDP crystal. The upconverted spectra were recorded using a 0.25 m spectrograph equipped with a CCD array. The spectra were temporally resolved by adjusting the relative delay between the arrival of the dye laser pulse and the VCSEL output pulse at the KDP crystal.

Figure 1 shows the laser spectra at various delay times for sample DK151. The active region of this sample had an effective width of 3 μm, and contained quantum wells of $GaAs/Al_{0.3}Ga_{0.7}As$ positioned for resonant periodic gain. The bottom (top) mirror consisted of 25 1/2 (18) periods of alternating AlAs and $Al_{0.3}Ga_{0.7}As$. Note that emission first occurs in short pulses centered at 904 nm and 846 nm. This corresponds to emission from the longitudinal modes positioned near the long and short wavelength edges of the high reflecting zone. At later times, a much longer pulse is observed at 876 nm, corresponding to the longitudinal mode which is centered on the high reflecting zone. The transient waveforms obtained at the spectral peaks of the longitudinal modes at 876 nm and 904 nm are displayed in Fig. 2. A simple explanation for the large difference in pulse widths is that the cavity lifetime is much longer near the zone center, where the product of mirror reflectivities is largest.

To further investigate the effects of cavity lifetime on the output pulse width, we measured the emission spectrum of a sample which had been sequentially step-etched. Each etching step removed one period from the top mirror, thus decreasing its reflectivity and hence the cavity lifetime. Figure 3 shows the transient waveforms obtained for the zone center mode for four different mirror reflectivities. We observe that the output pulse width decreases with the mirror reflectivity, as is expected for a decreasing cavity lifetime. Finally, we measured the output spectra for a number of different VCSELs whose calculated cavity lifetimes varied by over an order of magnitude. Good correlation was observed between the observed pulse widths and the calculated cavity lifetimes.

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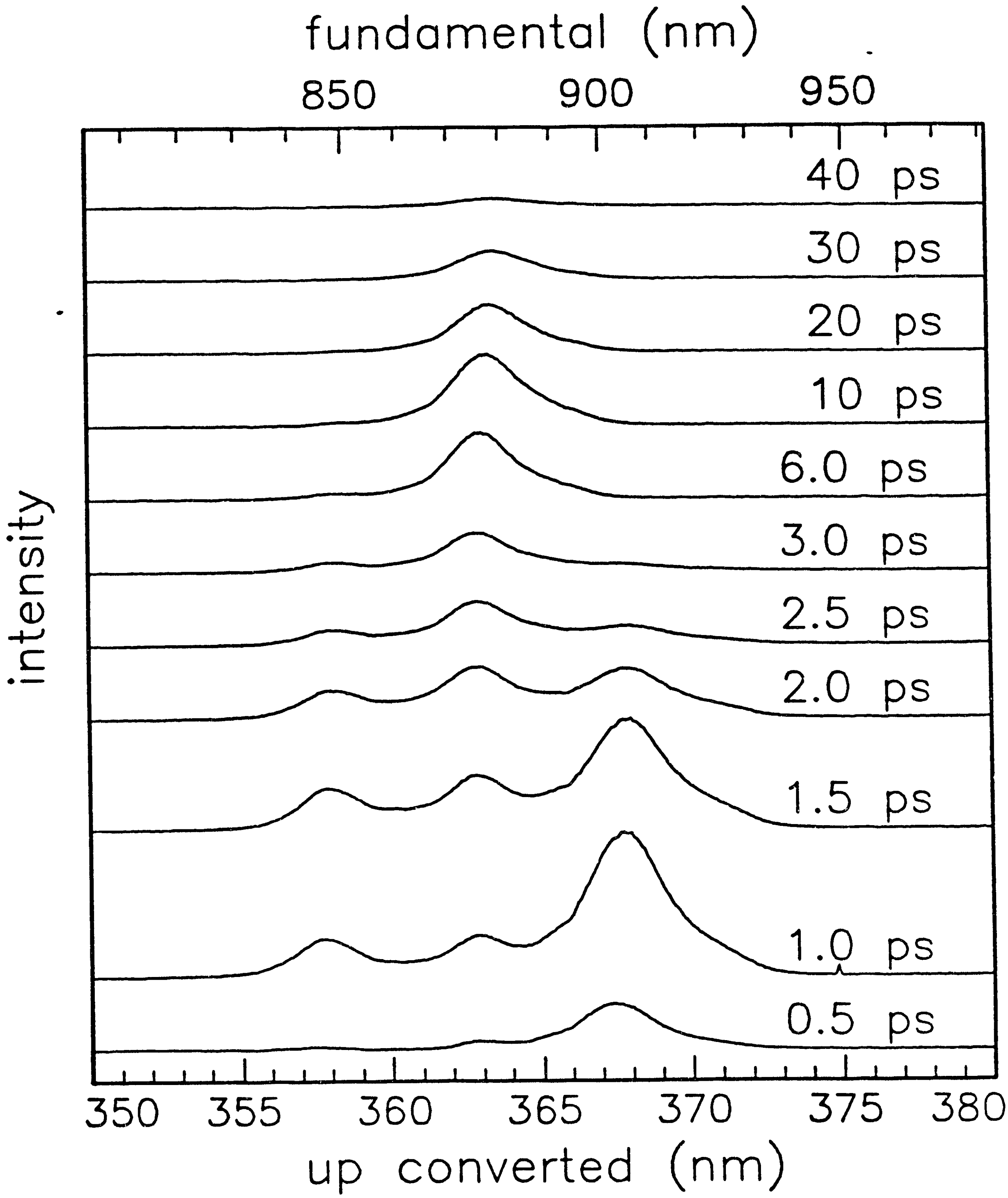
FIGURE CAPTIONS

Figure 1. The output spectra of a photopumped VCSEL measured at various delay times. The bottom axis shows the measured wavelength, while the top axis shows the actual lasing wavelength (before upconversion with the 620 nm pulse).

Figure 2. The temporal waveforms at 876 nm and 904 nm obtained from the data of Fig. 1. The inset shows an expanded view of the 904 nm waveform.

Figure 3. The temporal waveforms of the 876 nm mode obtained from a sample which was step-etched to remove mirror periods. The inset indicates the number of periods removed for each waveform.

FIGURE 1. M. SINCLAIR, ET AL.



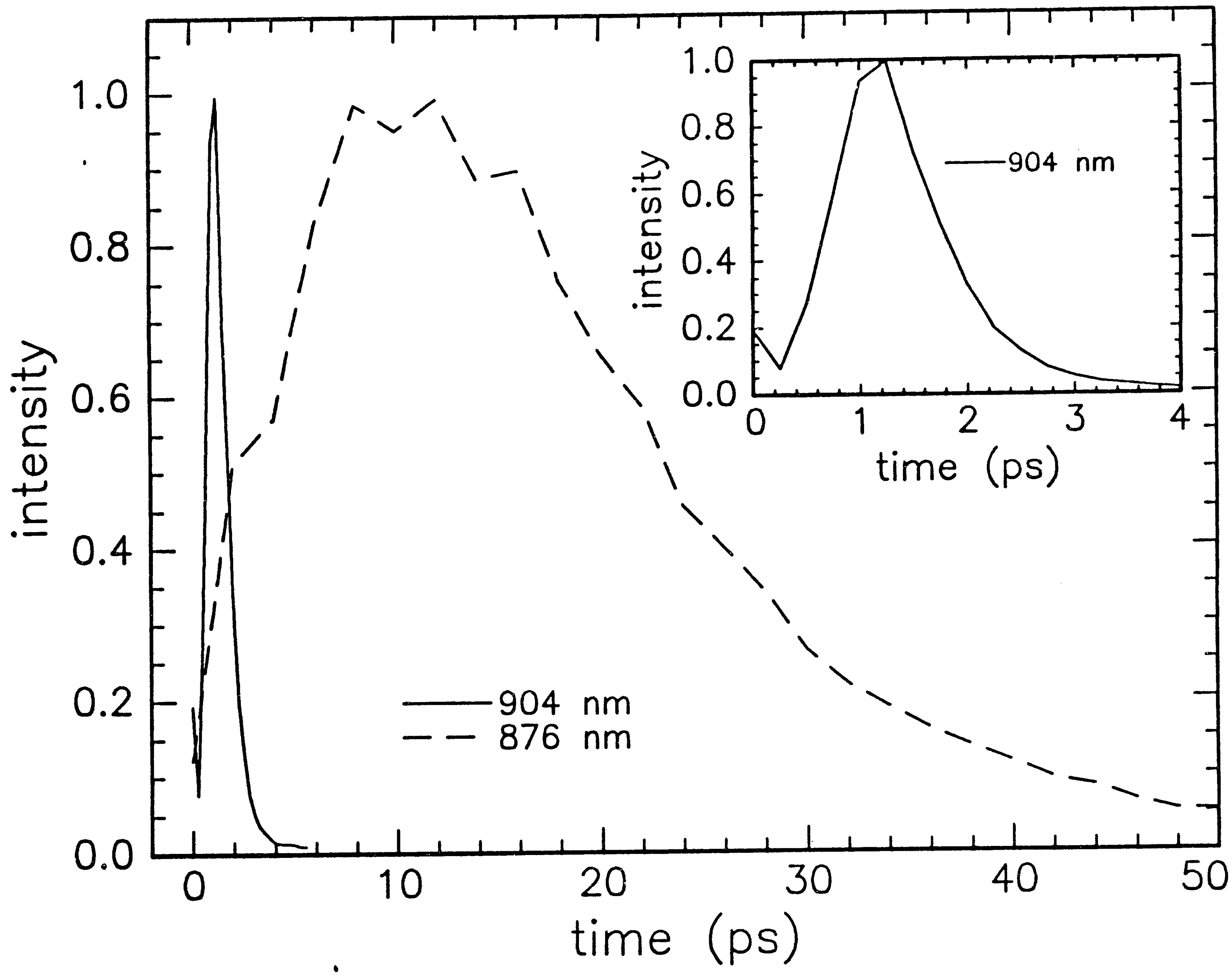


FIGURE 2. M. SINCLAIR, ET AL.

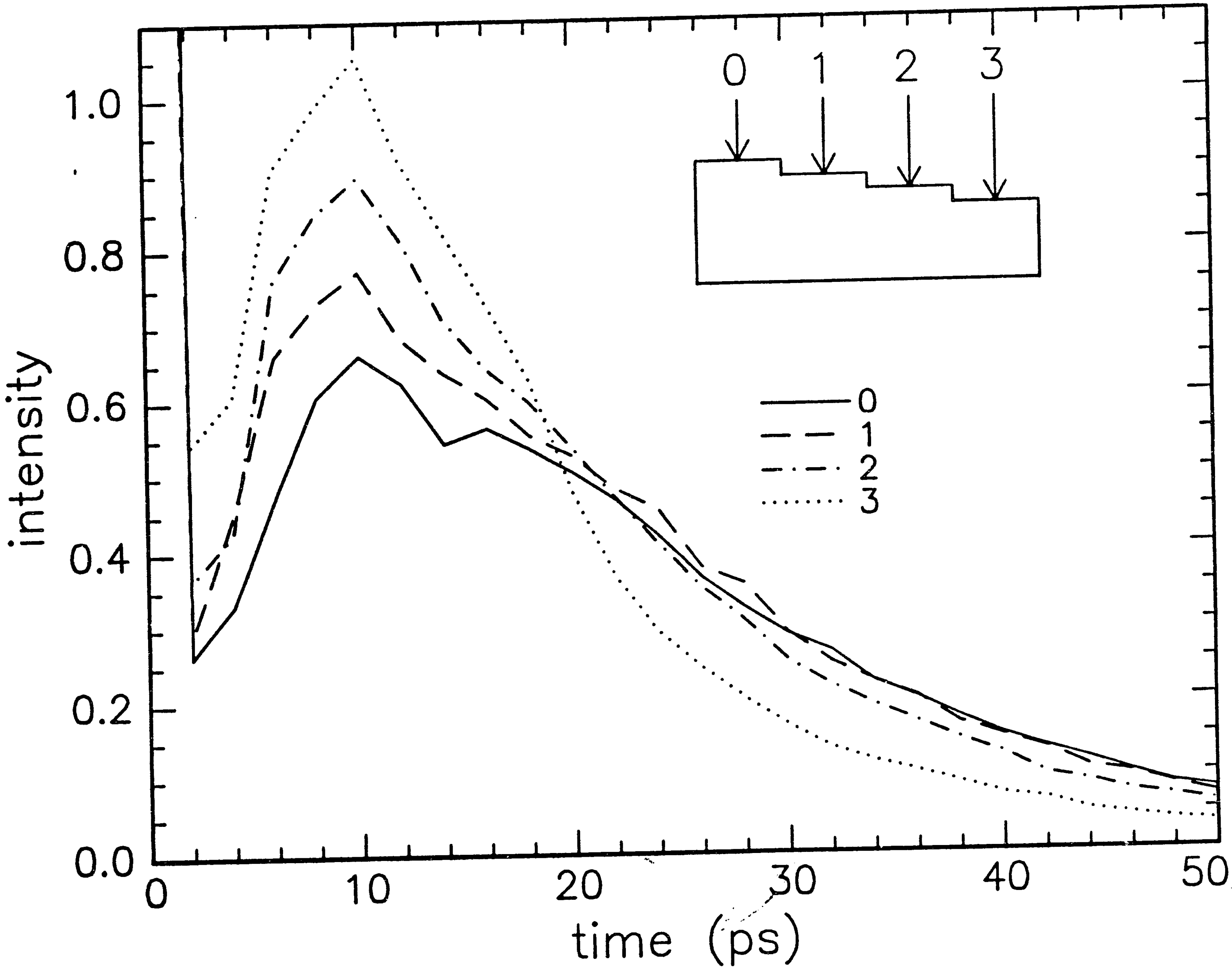


FIGURE 3. M. SINCLAIR, ETAL

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