taneously (AND operation). The polarization of the VCSEL is changed from 0° to 90° by the reset pulses. The 2.5 Gbits/s demultiplexed output signals are selected once every 40 bits from the 100 Gbits/s optical input signal.

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CThR2 **2:45 pm**

Phase coherence and frequency control of a hybrid mode-locked semiconductor laser by cw optical injection locking

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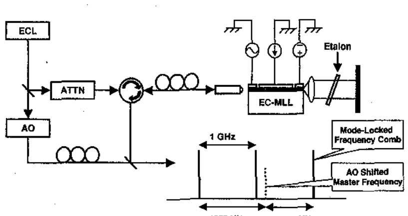
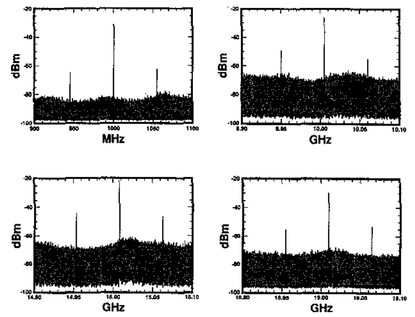
Mode-locked lasers have many versatile signal-processing applications. However, frequency control and phase coherence of the mode-locked laser optical frequency comb is often needed to make these applications possible, as in channelizer applications. We extend the principle of optical injection locking of cw lasers to optical injection locking of mode-locked semiconductor lasers[1–3] to establish phase coherence and frequency control. This method allows us to phase lock an entire comb of frequencies to a single frequency source. Compared to pulsed injection locking of mode-locked semiconductor lasers,[4] cw injection locking to mode-locked semiconductor lasers offers added simplicity but does not synchronize the timing of the pulses of the mode-locked laser.

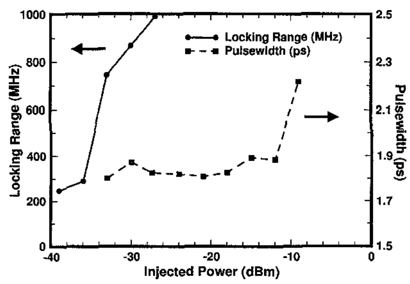
An external cavity hybrid mode-locked laser (EC-MLL) is constructed as shown in Fig. 1. A monolithic hybrid mode-locked semiconductor laser is antireflection coated on one facet and coupled to an external cavity. The external cavity length is 15 cm, which corresponds to a repetition rate of 1 GHz. An etalon with a 5-nm FWHM is placed in the external cavity to prevent mode-locking in clusters[2] and for tunability. The EC-MLL can be tuned



CThR2 Fig. 1. Injection locking mode-locked laser setup.



CThR2 Fig. 2. Heterodyne tone centered at 1, 10, 15, and 19 GHz.



CThR2 Fig. 3. Locking range and pulsewidth vs. injected power.

over 20 nm from 1540 to 1560 nm; pulsewidths <2.5 ps were achieved over the entire tuning range and were ~1.6 times the transform limit. An external cavity laser (ECL) is used as the master laser, its output is attenuated then injected into the mode-locked slave laser via an optical circulator. Part of the master laser is frequency shifted by 55 MHz using an acousto-optic frequency shifter for heterodyne detection. Injection locking of the EC-MLL is verified when tones at 945 and 1055 MHz appear. These tones are due to the heterodyne of the adjacent modes of the EC-MLL with the frequency shifted master laser (Fig. 1) and can be observed up to an instrument-limited 19 GHz (Fig. 2).

The locking range is measured by monitoring the offset frequency of the master laser at which the tones disappear (Fig. 3). Similar to injection locking of two cw lasers, the locking range is shown to increase with injected powers. Injected power levels well below the average power of the hybrid mode-locked laser show little effect on the pulsewidth (Fig. 3). At injection powers comparable to the average power of the EC-MLL (−9 dBm), the pulsewidth broadens significantly and the autocorrelation trace shows a significant increase in substructure. The pulse-broadening effect is due to the additional optical dc bias on the saturable absorber, which reduces the pulse-sharpening effect.

In conclusion, we have demonstrated phase coherence between a cw single-wavelength master laser and a multiwavelength mode-locked slave laser by optical injection locking.

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CThR3 **3:00 pm**

Four-wave mixing mediated by the capture of carriers in semiconductor quantum-well amplifiers

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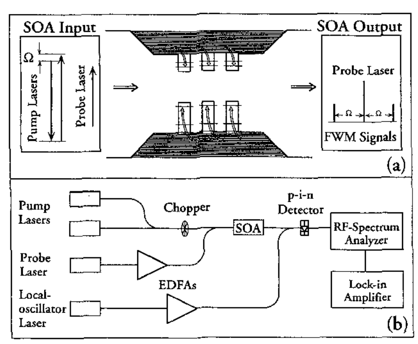
The capture and escape of charge carriers into and out of quantum wells (QWs) have been shown to affect the spectral and dynamic features of QW lasers. Measurements of the pertinent time constants often involve a compound response involving drift, diffusion, and energy relaxation along with the actual capture/escape processes. In this work, we demonstrate a technique to measure the intrinsic capture lifetime, using frequency-resolved four-wave mixing (FWM). The work is based on a frequency-domain measurement of the response function associated with the transfer of a modulation from three-dimensional states above the QW to the quantum-confined two-dimensional states.

The principle of the experiment is shown in Fig. 1. Two distributed feedback (DFB) lasers (λ = 1.31 μm) are combined with a probe at λ = 1.54 μm and coupled into the active region of a semiconductor optical amplifier (SOA). Photomixing of the two pump waves at 1.3 μm generates a small signal modulation of the carrier density in the QW barrier states. This



CThR3 Fig. 1. Pictorial description of the experiment (a) and schematics of the experimental layout (b). The total pump power at 1.3 μm was 2 mW, and the probe power was 17 mW at the SOA input. The SOA was 780 μm long and biased at 100 mA. The DFB laser frequencies were adjusted by temperature control. To remove the frequency dependence of the rf electronics, the local oscillator was at a fixed detuning relative to the FWM signal. Lock-in detection was also used for improved sensitivity.