Self-pulsating laser diode for the generation of multiple RF data channels in hybrid radio/fiber systems

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Summary

Future mobile networks, capable of delivering broadband services, are likely to use high frequency microwave signals as the access medium (15-60 GHz). These high capacity microwave access networks will employ an architecture in which signals are generated at a central location, and then distributed to remote base stations using optical fibre, before being transmitted over small areas using microwave antennas. On the transmission side of these networks it is necessary to generate the microwave optical data signals using a semiconductor laser diodes. The simplest technique available to generate such signals involves direct modulation of the laser. However, the limited bandwidth of laser diodes means that we are normally unable to generate high frequency RF carriers (> 10 GHz) in this manner. One way to overcome this limited bandwidth is to employ external optical injection into the laser diode as this can greatly increase the intrinsic modulation bandwidth of the laser [1,2,3]. In addition, at high injection levels the laser can start to self-pulsate at frequencies that are suitable for RF transmission, thus making the device useful for the generation of microwave optical signals in hybrid radio/fiber networks [4,5]. In this paper we characterize the self-pulsation in the laser under external injection, and demonstrate how the injection-locked commercial laser maybe used in a hybrid radio/fiber system for the distribution of multiple carrier RF data signals.

The laser diode used for the experiment is a standard multiple-quantum-well DFB device with a threshold current of 26 mA, a central lasing wavelength of around 1543 nm, and an intrinsic modulation bandwidth of around 8 GHz. By injecting light from a wavelength tunable external cavity laser, at the DFB's emission wavelength, we significantly alter the modulation response of the device and can achieve excellent response at frequencies from 14 to 25 GHz. The enhanced response at these frequencies is caused by the external injection inducing instability in the laser diode, which in turn results in strong oscillations in the laser output power [4]. Fig. 1(a) displays the optical spectrum from the laser when it is biased at 60 mA and the externally injected power from the external cavity laser is 5 mW. We can clearly see the modulation on the spectrum at a frequency of around 20 GHz. Figure 1(b) shows the detected temporal optical output from the laser under external injection. We can clearly see the oscillation at a frequency of around 20 GHz and also the significant level of noise and jitter on the signal. This noise and jitter on the oscillation from the laser is also evident in the detected electrical spectrum (Fig. 1c).

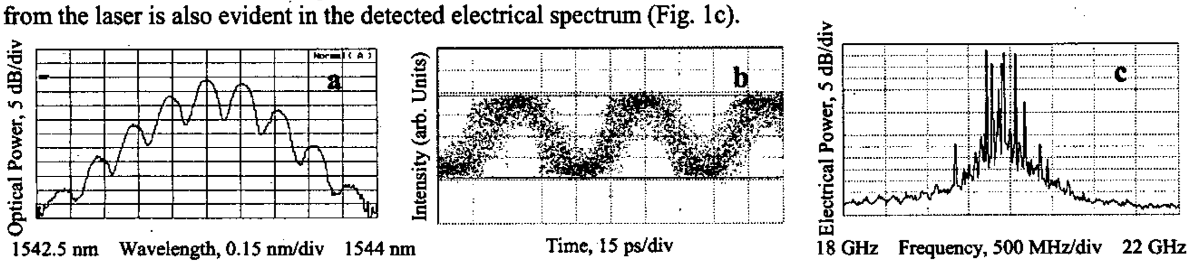

***Fig. 1:** (a) Optical spectrum, (b) detected output power oscillation, and (c) electrical power spectrum of DFB laser biased at 60 mA with external injection level of 5 mW*

The frequency of the oscillation from the injection locked DFB laser depends on the strength of the injected optical signal [4]. In addition, by measuring the peak-to-peak voltage of the oscillation on the oscilloscope, we have been able to determine that the optical output from the laser is 100% modulated (using the average power level falling on the detector and the responsivity of the detector).

Future broadband RF networks will require multi-carrier microwave systems to overcome multi-path fading, it will thus be necessary for optically fed microwave systems employing self-pulsing laser diodes to be capable of handling multiple RF carrier data signals. To demonstrate this we have used the experimental arrangement shown in fig. 2. A 155 Mbit/s NRZ data stream from an Anritsu pattern generator is split in a RF coupler. Each one of the two data streams is then mixed with a different RF-carrier (18.5 GHz and 18.9 GHz), resulting in two Binary Phase Shift Keyed (BPSK) data signals. The RF data signals are then combined in another RF coupler, and the resulting multi-carrier signal is used to directly modulate the DFB laser. Two RF carriers can be applied either to the free running laser or to the laser diode under the external injection. In both cases the RF data signal is combined with a DC bias current of 60 mA. The resulting optical microwave data signal from the laser is then passed through 5 km of dispersion-shifted fiber before being detected with a 50 GHz pin photodiode.

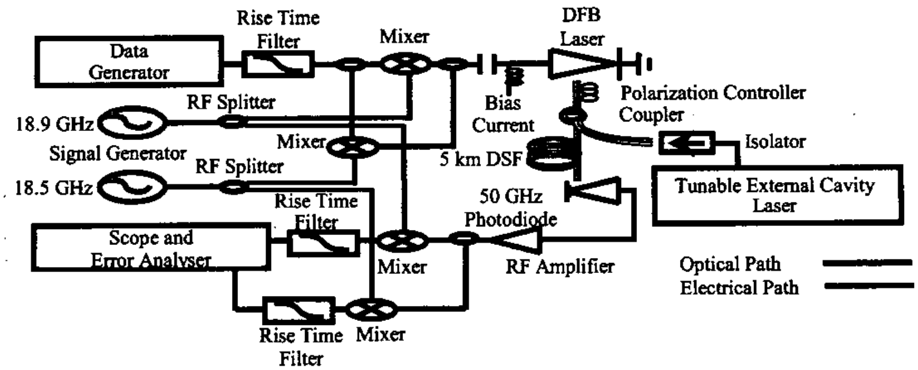

Fig. 2: Experimental set-up for multi-carrier hybrid radio/fiber system using self-pulsating laser diode.

In our experiment we have concentrated on the optical part of the system, hence the down conversion of the two RF carrier data signals takes place after the photodiode. To recover the two data channels simultaneously, the detected signal is split in two. The data signals are then down-converted by mixing with the 18.5 GHz and 18.9 GHz local oscillators. The received data signals are subsequently passed through low-pass filters to ensure that only the required base-band signal is examined. Using a 50 GHz oscilloscope and an error analyzer we were able to characterize the received eye-diagrams and Bit Error Rate of the two 155 Mbit/s data signals.

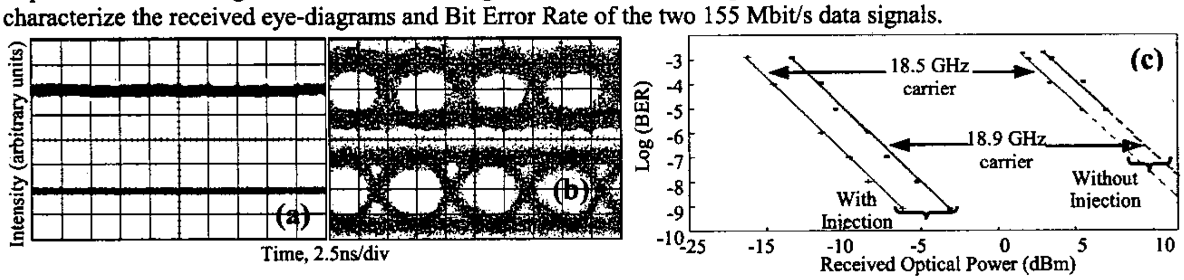

Fig. 3: Received eye diagrams of the two 155 Mbit/s data signals from the optically fed microwave system using (a) free running laser diode, (b) laser diode with the external injection level of 4 mW, (c) BER vs. received optical power for the two RF data channels using directly modulated laser with and without external injection.

Fig. 3(a) displays received eye diagrams (displayed simultaneously on the scope) of the two down-converted 155 Mbit/s data signals using the laser with no external light injection (detected optical power –9 dBm). Due to the poor response of the laser at 18 GHz, the eyes are completely closed. When using the laser with external injection (Fig.3(b)) we received a clear eye diagram (the same optical power). The injection level is set to around 4mW, as this is the level that optimizes the modulation response of the laser at the required frequency. The system performance was verified by measuring BER of the signal for different received optical powers (with and without the external injection (fig. 3c)). A 17 dB improvement for both channels can be seen. The slight difference in performance of the channels is primarily due to the different synthesizers used for the 18.5 and 18.9 GHz carriers.

We have demonstrated the use of a self-pulsating laser (achieved using external injection into a commercial DFB laser) for the distribution of multi-carrier RF data signals in a hybrid radio/fiber system. As the frequency of the generated signal can be varied by changing the injected power, our laser can be used to operate in different frequency bands. Our results show that we can successfully modulate the self-pulsating laser with two RF data signals simultaneously, giving us a 17 dB improvement in system performance, for each RF data channel, above what would be achieved using the laser diode without external light injection.

References

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