MULTI RATE TIMING EXTRACTION USING OPTICAL INJECTION LOCKING OF A SELF OSCILLATING InGaAs / InP HETEROJUNCTION BIPOLAR PHOTO – TRANSISTOR

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Abstract: *We demonstrate direct optical injection locking in a self oscillating InGaAs / InP Heterojunction Bipolar Photo – Transistor for timing extraction at multiple bit rates. One oscillator is used for 10 to 40 Gbit/s signals.*

Introduction

Timing extraction in high speed optical communication systems has been previously implemented using various methods. Examples include all optical techniques with mode locked or self pulsating lasers [1] [2] and narrow optical filters based on stimulated Brillouin scattering [3]. Electro optic methods with injection lockling of microwave oscillators such as resonant tunneling diode oscillators have also been demonstrated [4].

This paper describes the use of *direct* optical injection locking to extract the clock of high speed optical signals from a heterojunction bipolar photo – transistor (photo – HBT) based microwave oscillator [5]. The HBT based oscillator operates at several harmonics all of which can be injection locked [6] and therefore one oscillator can be used for timing extraction of multiple rate signals. In the present experiment we demonstrate a 10 GHz oscillator in which we extracted the clocks of both 10 Gbit/s and 40 Gbit/s RZ data streams. The configuration is similar to our previously demonstrated [5] [6] optical injection locking of microwave oscillators where the purpose was improvement the spectral properties.

Experimental Arrangement

Figure 1 illustrates the experimental schematic. The clock recovery system comprises a 10 GHz oscillator based on an InGaAs/InP photo – HBT operating in the common emitter configuration with the collector fed back to the base via a 10 Ghz filter and an attenuator. A coupler placed at the collector serves as the output port and a typical output spctrum contains, in addition to the 10 GHz fundamental line, several harmonics with rather large amplitude. An opening in the base electrode serves as the optical input port on to which the received optical signal is coupled.

The transmitter consists of a gain switched DBR laser generating 10 GHz, ~30 ps wide pulses at λ=1.55μm. The pulses were linearly compressed using a dispersion compensating fiber followed by amplification and soliton compression yielding pulses of ~ 3 ps duration. The pulses were modulated using a Mach Zender modulator driven by a 10 Gbit/s BER data sequence of 2^{31}-1 PRBS. This 10 Gbit/s RZ data stream was optically multiplexed to 40 Gbit/s using the standard split and delay technique.

The 10 Gbit/s or 40 Gbit/s signals are coupled to the photo-HBT which gets optically injection locked so its output is phase locked to the incoming signals. The HBT output is monitored by a spectrum analyzer and also feeds the receiver part of the BER tester.

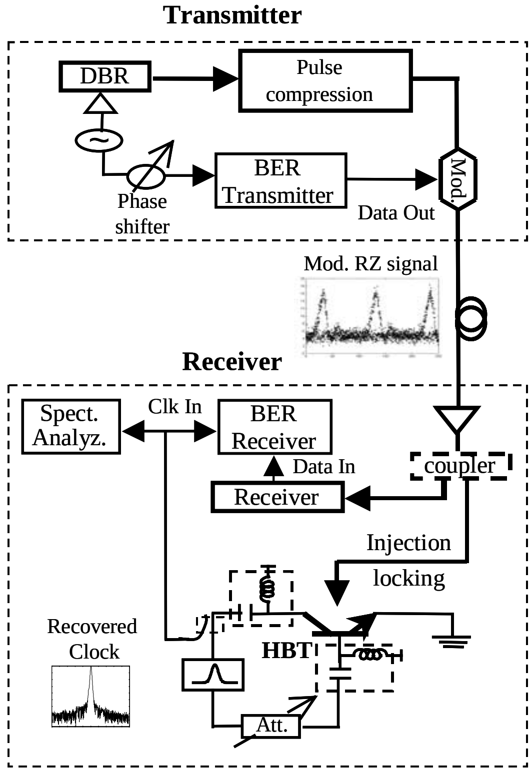

Figure 1: Experimental schematic.

Results

<u>10Gb/s timing extraction:</u> The modulated 10 Gbit/s RZ data signal was amplified and split by a 3-dB coupler. One part is focused onto the optical window of the self oscillating photo – HBT. The second part fed a PIN diode receiver whose output was amplified and fed back to the BER system receiver.

Optical injection locking by the 10 Gbit/s signal is described in Fig. 2. Figure 2(a) shows the output spectrum when the injected signal is outside the locking range. Shown are the free running signal, the injected signal and several mixing products generated by the nonlinear mixing process. Figure 2(b) shows in contrast a completely locked

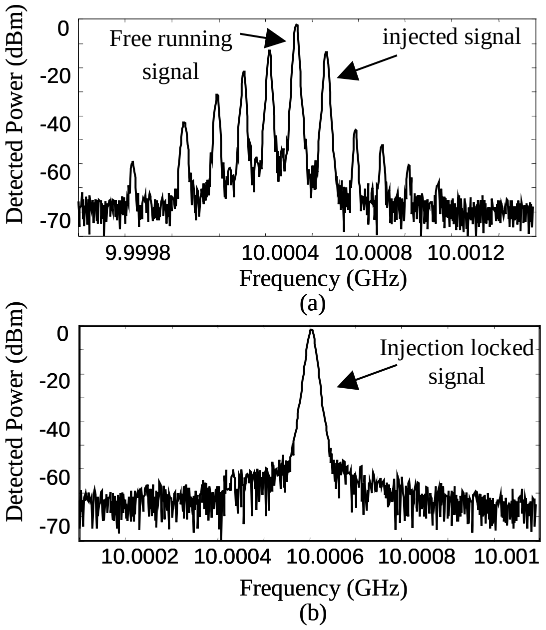

Figure 2: Injection locking at 10 Gbit/s.

spectrum. The locking range was measured to be ~250 KHz for a –4 dBm optical input power. This locking range can be increased with a higher optical power.

To confirm the timing extraction operation, we measured the bit error rate (BER) performance using the recovered clock and compared the results with that of the system clock signal from the BER transmitter (back-to-back measurement). The results shown in Fig. 3 imply that no power penalty is introduced by the recovered clock signal.

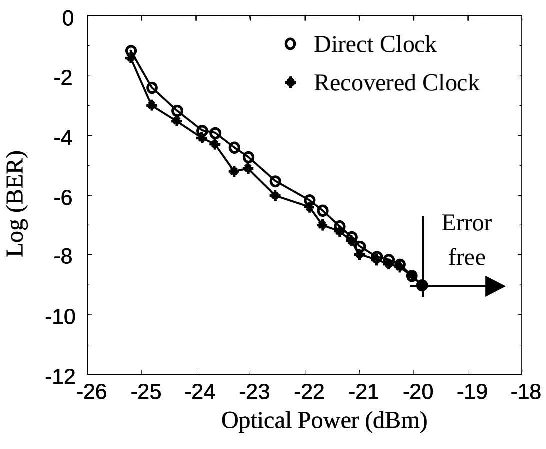

Figure 3: Bit error rate measurement at 10 Gb/s.

<u>40Gb/s timing extraction</u>: For 40Gb/s RZ signal we used the same 10 GHz oscillator and optically injection locked its fourth harmonic as shown in the spectra of Fig. 4. Figure 4(a) shows the fourth harmonic of the free running oscillator. Figure 4(b) describes the case where the injected signal is outside the locking range. The locking range of the fourth harmonic is somewhat smaller than that of the fundamental since it depends linearly on the amplitude of the injected signal which decreases with frequency (corresponding to the frequency response of the HBT).

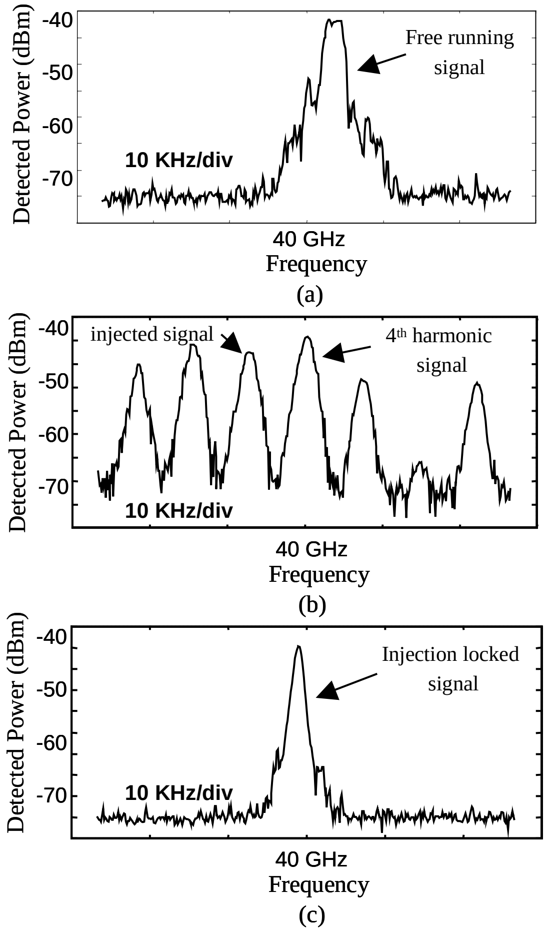

Figure 4: Injection locking at 40 Gbit/s.

Figure 4(c) exhibits the oscillator spectrum when it is completely locked to the incoming 40 Gb/s data stream.

Summary

We have demonstrated timing extraction of high speed, multiple rate RZ signals using direct optical injection locking of an InGaAs / InP photo HBT. The system enables one 10 GHz oscillator to be locked by either 10 or 40 Gbit/s signals with high efficiency and low noise.

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