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# 40 TO 10 Gbit/s DEMULTIPLEXING USING A SELF-PULSATING DFB LASER FOR CLOCK RECOVERY

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*Abstract: A self-pulsating DFB laser has been used as the clock recovery unit in an OTDM demultiplexing system experiment. Error free demultiplexing from 40 Gb/s to 10 Gb/s is achieved.*

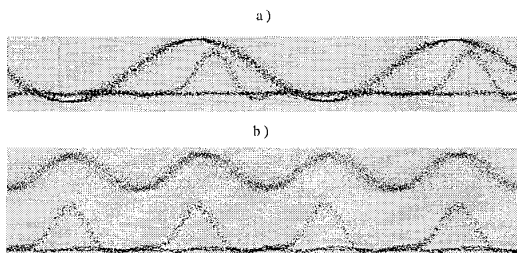
## Introduction

Optical Time Domain Multiplexed (OTDM) systems are interesting for point-to-point transmission systems and photonic networks. Demultiplexing and Add-Dropping are key functionalities. To control the demultiplexer a clock synchronised to the incoming data signal is needed. All-optical clock recovery methods are pursued at high bit rates to avoid electronic bottlenecks. Fiber ring lasers [1], monolithic mode locked lasers [2] and self pulsating DFB lasers [3,4] have been used as all-optical clock recovery units. Concerning system experiments 40 Gbit/s all-optical demultiplexing has previously been reported using a mode-locked semiconductor laser [5]. We present for the first time demultiplexing from 40 to 10 Gb/s using a self-pulsating multi-section DFB laser for the optical clock recovery.

## Optical clock recovery unit

Clock recovery (CR) is performed using a self pulsating three section laser [3]. The device consists of a DFB laser section (300  $\mu\text{m}$ ), a dispersive reflector (130  $\mu\text{m}$ ) and a passive phase section (300  $\mu\text{m}$ ) which is placed between the DFB sections. The device is packaged in a pigtailed temperature controlled module. Self pulsating frequencies between 5 GHz and 22 GHz can be chosen by correct adjustment of the three dc driving currents. The optimum synchronisation of the self pulsation frequency to the data signal is achieved by adjusting the free running self pulsation frequency to approximately 20 MHz higher than the data signal. The carrier to noise ratio of the synchronised clock is 38 dB (at bandwidth 2 MHz). The synchronisation works

**Fig. 1: a) 10 GHz clock locked to a 10 Gb/s input (20 ps/div), b) 20 GHz clock locked to a 20 Gb/s input.**



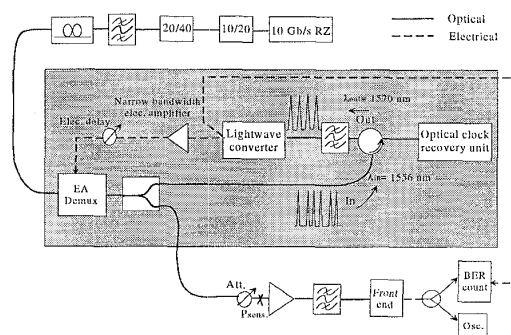
wavelength and polarisation independent in the spectral range 1540-1560 nm. The output wavelength is 1570 nm, output power is 3 dBm.

System experiments are carried out locking the CR unit to a 10 Gb/s signal. The 10 GHz clock obtained can be observed in Figure 1-a. The full width half maximum of the optical pulses obtained is 30 ps. No penalty is induced by the CR unit in a back to back measurement when compared to a synthesiser. Synchronisation of the CR unit to a 20 Gb/s signal with a 20 GHz clock signal is possible as illustrated in Figure 1-b.

## Experimental details

To investigate the performance of the CR unit in a system it is introduced in a 40 Gb/s demultiplexing testbed. The experimental set-up for demultiplexing is shown schematically in Figure 2. A 10 Gb/s RZ signal is generated by gain-switching a DFB laser ( $\lambda_1 = 1556 \text{ nm}$ ) at 10 GHz, compressing the obtained pulses in DCF (pulse widths of 11-12 ps) followed by external modulation of the pulse train using a PRBS sequence and passive multiplexing to 40 Gb/s.

**Fig. 2: Experimental set-up used in the demultiplexing with optical clock recovery.**



The demultiplexing is performed by an EA modulator [6] with an effective on-off ratio of 23 dB ( $0 \text{ V} < V_{\text{bias}} < -4 \text{ V}$ ). Measured penalty for 40 to 10 Gb/s demultiplexing using this device was 1.2 dB.

In order to have a 10 Gb/s input signal to the CR we place the unit at the output of the demultiplexer, after a 3 dB cou-

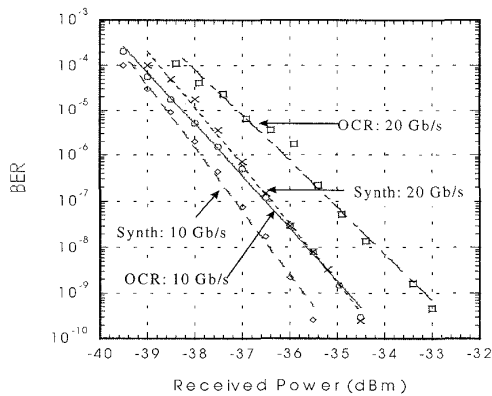
pler. We initially synchronise the CR to a specific channel (see Figure 1-a). Using attenuators in the passive multiplexers we can then launch a second channel giving a 20 Gb/s signal while the clock remains locked to the demultiplexed 10 Gb/s output signal. Following the same procedure 40 Gb/s demultiplexing is performed.

The output signal from the CR consists of the synchronised clock ( $\lambda_{\text{out}} = 1570$  nm) and the residual signal ( $\lambda_{\text{in}} = 1556$  nm). The input power to the optical clock recovery for the 20 to 10 Gb/s demultiplexing is 2.3 dBm. The optical clock is converted to an electrical signal which is used to drive the EA demux. A tuneable electrical delay allows channel selection for the BER assessment.

## Results and discussion

The bit error performance is presented in Figure 3 for the 10:10 and 20:10 Gb/s demultiplexing with the EA-modulator. In order to allow comparison, back-to-back measurements for 10 and 20 Gb/s were made by driving the EA demux and BER counter directly with a synthesiser.

**Fig. 3: Measured BER in the case of 10 Gb/s and 20 Gb/s demultiplexing to 10Gb/s. Results are presented for comparison using both a synthesiser and the optical clock recovery unit.**

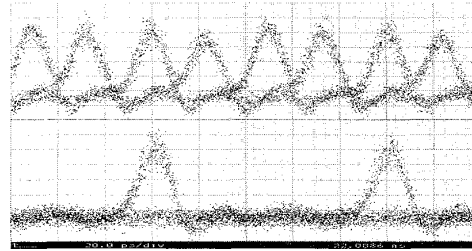


A small penalty of 1 dB can be observed for the 10 to 10 Gb/s case when the optical clock recovery is used compared to the synthesiser. When demultiplexing from 20 to 10 Gb/s the penalty increases to 1.6 dB. The jitter of the 10 Gb/s demultiplexed channel is 1.34 ps, for a jitter of 1.14 ps in the 20 Gb/s input signal and a clock jitter of 2 ps.

Eye diagrams for an injected 40 Gb/s signal and the demultiplexed 10 Gb/s signal are shown in Figure 4. Error free operation ( $\text{BER} < 10^{-9}$ ) is achieved with no sign of error floor. The sensitivity obtained is -25.4 dBm which is expected to be improved in new experiments. The jitter of the demultiplexed channel has increased to 2.1 ps. A square shaped demultiplexing window which leads to reduction in the jitter-to amplitude fluctuation, is believed to improve the result.

Interferometric devices based on semiconductor optical amplifiers have shown such a jitter suppression capability [7], and have been used previously in optical demultiplexing schemes [5,8]. For a next generation of CR units, a reduction in the width of the clock pulses will enable them to be used in the interferometric schemes.

**Fig. 4: Input 40 Gb/s eye diagram to the demultiplexer and 10 Gb/s output using the optical clock recovery (20 ps/div).**



## Conclusion

For the first time a 40 to 10 Gb/s demultiplexing scheme was demonstrated using a self pulsating DFB laser for clock recovery. The penalty induced by the optical clock recovery is small (1.6 dB for 20 to 10 Gb/s). The clock recovery unit is polarisation independent. The capacity of the clock recovery to obtain a 20 GHz clock from a 20 Gb/s signal predicts feasible a 80 to 20 Gb/s demultiplexing.

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