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Optimization of 40 Gbit/s Transmission Systems using Frequency Resolved Optical Gating Characterization Techniques

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SUMMARY

To achieve multiterabit/s capacities in long-haul transport networks, it is anticipated that Wavelength Division Multiplexed (WDM) systems will be upgraded to operate at line rates of 40 Gbit/s [1,2,3]. As optical systems move towards data rates of 40 Gbit/s on each wavelength channel, the effect of chromatic dispersion in the transmission fiber becomes more dramatic, and the use of dispersion management techniques, and/or optical fiber non-linearities to counteract the dispersive effects, must be precisely regulated [2,3]. Regardless of the transmission technology used, in addition to knowing the dispersion and non-linearity of the transmission fiber, it is essential to know the exact phase of the optical data signals generated at the transmitter. This is necessary since the propagation of the optical data is determined by the intensity and phase of the optical pulses from the transmitter, and the dispersion and non-linearity of the transmission fibre. To optimize the overall performance of 40 Gbit/s systems therefore, it is vital to characterize accurately the intensity and phase of the optical data signals generated at the transmitter.

A suitable technique for generating return-to-zero (RZ) data signals for 40 Gbit/s systems involves using a CW laser diode followed by a sinusoidally driven external modulator [2]. By biasing the modulator at its null point, and driving it with a RF data signal with a peak-to-peak voltage of twice the modulator's switching voltage, optical pulses at twice the frequency of the applied RF signal can be generated. The usefulness of these pulses in high-speed systems is dependent on the frequency chirp acquired in the modulator, and it is thus vital to accurately characterize this chirp. In this paper we initially demonstrate the characterization and optimization of optical pulses (suitable for use in 40 Gbit/s systems) generated using a CW laser followed by an external modulator, using the technique of Frequency Resolved Optical Gating (FROG) [4,5]. We then use numerical simulations to show how the optimization of the pulse source is vital for enhancing the performance of a 40 Gbit/s soliton transmission system.

A 40 GHz optical pulse train was generated using a 1550 nm CW laser diode followed by a sinusoidally driven external modulator. The modulator has a bandwidth of 30 GHz and a switching voltage of around 6 volts. The 40 GHz optical pulses were generated by biasing the modulator at its null point (as specified in the data sheets of the modulator) and then applying a 20 GHz sine wave to the RF input (with a peak-to-peak voltage of around 12 volts). The optical pulses were then amplified to an average power of 10 mW, and characterized using the standard Second Harmonic Generation (SHG) FROG technique as fully explained in [5]. In addition, the generated pulses were examined using an optical spectrum analyzer, and a 50 GHz oscilloscope in conjunction with a 50 GHz detector.

The bias voltage and RF power applied to the external modulator were initially set to those values thought to generate optimum pulses from the set-up, as deduced from the specifications of the modulator (bias voltage: 6.5 V, peak-to-peak RF signal: 12 V). When observing the generated pulses using a 50 GHz photodiode and oscilloscope, the resulting output trace was as shown in Fig. 1(a). Due to the limited response time of this detection system is difficult to obtain information about the characteristics of the generated pulses. In addition, as the bias and RF signal voltage applied to the modulator were varied, the trace on the oscilloscope did not change from a 40 GHz sinewave.

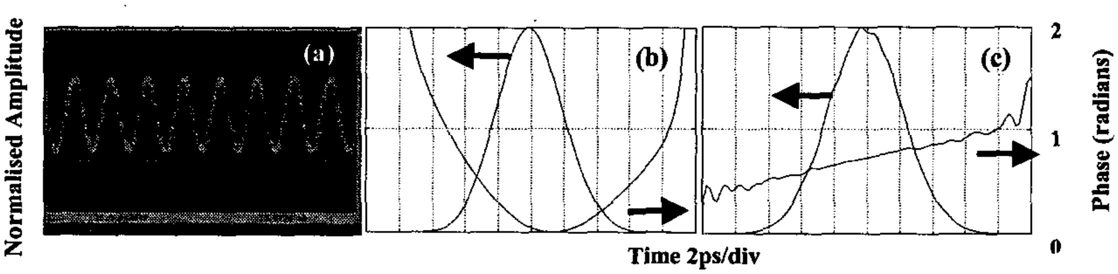

Fig. 1 (a) Generated 40 GHz optical pulse train viewed using 50 GHz detector and oscilloscope. (b&c) Retrieved intensity (left axis) and phase (right axis) of generated optical pulses measured using FROG technique with (a) driving conditions of modulator not optimized and (b) optimised bias voltage and RF power applied to modulator.

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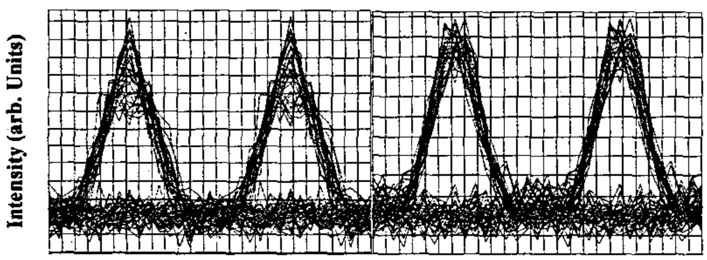
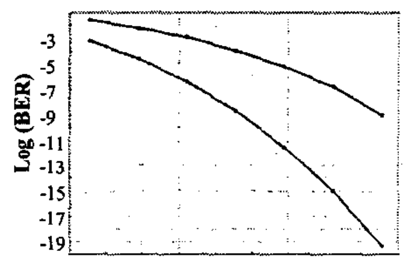
The pulses from the transmitter were subsequently characterized using the FROG technique, and the retrieved intensity and phase of the pulse is shown in Fig. 1(b). The retrieved pulse had a duration of 6.6 ps, and a quadratic phase, indicating a linear frequency shift across the pulse. The retrieved spectral width of the pulse from the FROG measurement was 0.63 nm, while independent measurements of the pulse spectrum using an optical spectrum analyzer yielded a spectral width of 0.61 nm, indicating the accuracy of the FROG measurement set-up.

To optimize the pulses generated from the modulator, we proceeded to slightly adjust both the bias voltage and RF signal applied to the modulator, and characterize the resulting pulses using the FROG technique. Using this method we were able to determine the optimum operating point (bias voltage of 6.35 volts and RF peak-to-peak voltage of 11.9 volts) to generate chirp free pulses using this specific external modulator. Fig. 1(c) presents the retrieved intensity and phase of the optimum pulses that could be generated. The pulse duration was 7.3 ps, and the spectral width was 0.51 nm. As we can see, the phase is linear across the pulse indicating that it is essentially chirp free.

We then proceeded to examine the importance of pulse optimization using the FROG technique in a 40 Gbit/s soliton communication system. This was achieved by designing a 40 Gbit/s soliton transmission link operating over 40 km using Virtual Photonics Inc. software package. The basic system consisted of a 40 GHz pulse train followed by an external modulator to encode data onto the pulse train. The data was then propagated over dispersion shifted fibre (loss coefficient: 0.15 dB/km; dispersion parameter: 1.25 ps/km.nm), and subsequently detected and analyzed. The intensity and phase of the optical pulses (retrieved from the FROG measurements) for the unoptimized and optimized pulse generation set-ups were used for the optical pulse model in the complete 40 Gbit/s soliton system simulation. We initially determined the optimum pulse power for the two different pulses operating in the overall soliton transmission link. The optimum value of peak pulse power (190 mW) for the pulses from the unoptimized pulse generation scheme was higher than that (175 mW) for the optimized and unchirped pulses. We then examined the performance of the soliton system using the different pulse transmitters (with the launched power of each optimized). Fig. 2 displays the received eye-diagrams for a received power level of –20.5 dBm, with the two different pulse sources used as transmitters. Fig. 3 displays the BER vs. received power curve for the two cases, and we can clearly see that by ensuring that the pulse generation scheme is optimized, the performance of the system is enhanced. The power penalty for the in-optimized pulse source is 1.9 dB.





In conclusion, we have shown that by employing the FROG measurement technique to optimize the generation of optical pulses for use in a 40 Gbit/s soliton transmission link, we ensure that the performance of the overall system using the generated optical pulses is optimum.

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