Interferometric crosstalk suppression using polarization multiplexing technique and an SOA

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Interferometric crosstalk is one of the biggest issues in transparent wavelength-division-multiplexing (WDM) networks, and should be overcome by either decreasing the crosstalk level from the components, or employing effective techniques to suppress its impact.

A gain-saturated laser diode amplifier has been reported to suppress cross talk, but it can’t be used for high-speed signals and the output signal suffers from extinction ratio degradation and waveform distortion.

In this paper, we use a gain-saturated semiconductor optical amplifier (SOA) to suppress the impact of interferometric crosstalk, and show that 6 dB of cross talk can be tolerated for 1 dB penalty at 10 Gb/s. Using polarization multiplexing of optical signals modulated by data and the complementary, impairments like waveform distortion and extinction ratio degradation are eliminated, and the method is also bit rate transparent.

Figure 1 shows the experimental setup and waveforms at different points. Light from a distributed feedback (DFB) laser is divided into two parts after being amplified in an erbium-doped fiber amplifier (EDFA). Each part is modulated by data or the complementary in an external modulator, and then separated into two orthogonal polarization states. The two parts are combined in the polarization beam combiner (PBC). A variable fiber delay line and a variable optical attenuator are used before the PBC, in order to obtain a constant power of the combined signal without bit transition patterns. Cross talk is added to the com-
bined signal by adding a fraction of the original signal delayed by 500 ps of fiber. The signal-crosstalk beat noise causes amplitude fluctuations, but these fluctuations are significantly suppressed after the SOA because of the gain saturation. The 3-dB saturation input power of the SOA is -10 dBm, and the input power into the SOA is -2 dBm in our experiment. The two orthogonally polarized signals are separated by the polarization beam splitter, and one of them is detected.

Because the SOA only experiences constant optical power of the combined signal, no waveform distortions will be generated by the SOA. Furthermore, because amplitude fluctuations are suppressed by the saturated SOA, crosstalk-induced penalty can be reduced. Figure 2 shows the penalties versus relative crosstalk power with and without the SOA; it can be seen that 6-dB more crosstalk power can be tolerated using the SOA at 1-dB penalty (BER = 10^-6). The insets show eye-diagrams of the 10-Gbit/s signal before and after the SOA when -13.8-dB crosstalk is introduced. A clear eye is restored after the SOA.

Because of the constant optical power in the SOA, this method is pattern independent and bit rate transparent, and there is no extinction ratio degradation. Figure 3 shows the eye-diagrams at 20 Gbit/s before and after the SOA when the relative crosstalk power is -17.8 dB; also here a clear eye can be found after the SOA. Due to lack of a 20-Gbit/s receiver, no BER curves are measured in this case.

We successfully demonstrate that the impact of interferometric crosstalk can be suppressed using a saturated SOA and a polarization-multiplexing technique. The method is pattern independent and bit-rate transparent and gives no waveform distortion or extinction ratio degradation. A 6-dB higher crosstalk level can be tolerated at 1-dB penalty using this method.


2:00 pm

200-Gbit/s polarization-multiplexed transmission over 100 km of dense-dispersion-managed fiber

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High-rate time-division-multiplexed return-to-zero transmission has been demonstrated using both linear and nonlinear transmission in systems employing dispersion-shifted fiber as the transmission medium. 1,2 However, dispersion-managed transmission links, in which the local nonlinearity is utilized to balance the average dispersion of the system, provide another avenue for high-bit-rate communication. Theoretical studies have demonstrated the feasibility of transmitting 100 Gbit/s over distances greater than 1000 km. 3-4 Using a dense-dispersion map we have successfully transmitted an error-free 200 Gbit/s return-to-zero data stream over 100 km.

The details of the experimental configuration are described in Ref. 5. A mode-locked fiber laser capable of producing 1.5-25 ps soliton-like pulses served as the source of a 12.5-GHz pulse train. 5 The pulses were encoded with a pseudo-random binary sequence (2^11-1 bits; 1/2 mark ratio) at 1561.6 nm. The encoded stream is then split, delayed, and recombined using 3-dB polarization-maintaining couplers to produce a 100-Gbit/s time-division-multiplexed data channel. To achieve an aggregate data rate of 200 Gbit/s, the 100-Gbit/s channel was multiplexed using the walk-off between the orthogonal polarization axes in high birefringence fiber. The pulse trains were delayed by one and a half bit periods to avoid nearest-neighbor interactions during transmission. The autocorrelation trace of the 200 Gbit/s pulse train at launch is illustrated in Fig. 1.

To facilitate clock recovery, a cw signal at 1555.0 nm, modulated at the data base rate, was transmitted along with the data signal. The clock wavelength was filtered from the data using a fiber Bragg grating and optical circulator; the clock frequency was then extracted via a phase-locked loop scheme. Operation of the clock recovery was demonstrated and provided an absolute timing reference for the received channels. The presence of the clock recovery signal necessitates the removal of all filters from the link, reducing the signal-to-noise ratio at the receiver.

The transmission span has zero-dispersion wavelength of 1560.9 nm, and an average dispersion of 0.03 ps/nm/km at the operating wavelength. The pulses are 1.8-ps full-width at half-maximum, which corresponds to a dispersion length of approximately 15 km. To overcome the deleterious dispersive effects over the total transmission distance (107 km), the output power levels of the in-line amplifiers were set to nonlinearly balance the dispersion. Optimal performance was obtained with a pulse energy of 150 fJ after amplification, which corresponds to a peak pulse power of 83 mW.

At the end of the span, the 200 Gbit/s stream is polarization demultiplexed, then time-division-demultiplexed to 12.5 Gbit/s using a LNBO, modulator-based demultiplexer. 6 The received bit error-ratio was measured to be better than 10^-10. A typical error-free eye pattern using a 2 fJ bit word is shown in Fig. 2.

This experiment demonstrates the feasibility of using dense-dispersion management for transmitting rates as high as 200 Gbit/s over...