160 Gb/s OTDM Wavelength Conversion using XPM in Dispersion Shifted Fiber

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Abstract: Wavelength Conversion of 160 Gb/s OTDM data using cross-phase modulation in 500m of dispersion-shifted fiber is demonstrated for the first time. The converted channels can be received with a BER better than 10^{-9} and have a power penalty of < 5dB as compared to the 10 Gb/s baseline across all 16 x 10 Gbps channels.

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1. Introduction

Ultra-high data rate all-optical wavelength conversion (AOWC) is an enabling technology for future optical time division multiplexed (OTDM) all-optical network architectures. Various AOWC approaches utilizing semiconductor optical amplifiers [1], non-linear fibers [2] and electro-absorption modulators [3] have been demonstrated at data rates from 40 Gb/s to 100 Gb/s. Wavelength conversion at 168 Gb/s was previously demonstrated using a symmetric Mach-Zehnder type switch [4] however the converter operation severely limited the pattern length and the converted channels had a power penalty of 10dB relative to the base rate.

In this paper we demonstrate for the first time wavelength conversion at 160 Gb/s using cross-phase modulation (XPM) in 500 m of dispersion-shifted fiber (DSF) over a 9 nm optical bandwidth. The BER and receiver sensitivities were measured for all 16 x 10 Gb/s channels and less than 5dB power penalty achieved for all channels relative to an optically de-multiplexed OTDM link without the converter. Previous results using this type of fiber XPM converter achieved error-free wavelength conversion at 40 and 80 Gb/s [5,6] demonstrating the scalability of this technology.

2. Experimental Setup

The experimental setup is shown in Figure 1. A Calmar Optics actively mode-locked fiber ring laser was used to generate pulses with full width half maximum (FWHM) of 1.5 ps at a repetition rate of 10 Gb/s at 1554.5 nm. An electro-optic modulator was used to encode 10 Gb/s 2^{31}-1 PRBS data on the generated pulse stream. The data encoded stream was passively multiplexed using a split and interleave scheme to 160 Gb/s. The polarization states of all channels in the 160 Gb/s OTDM data were adjusted to be equal.

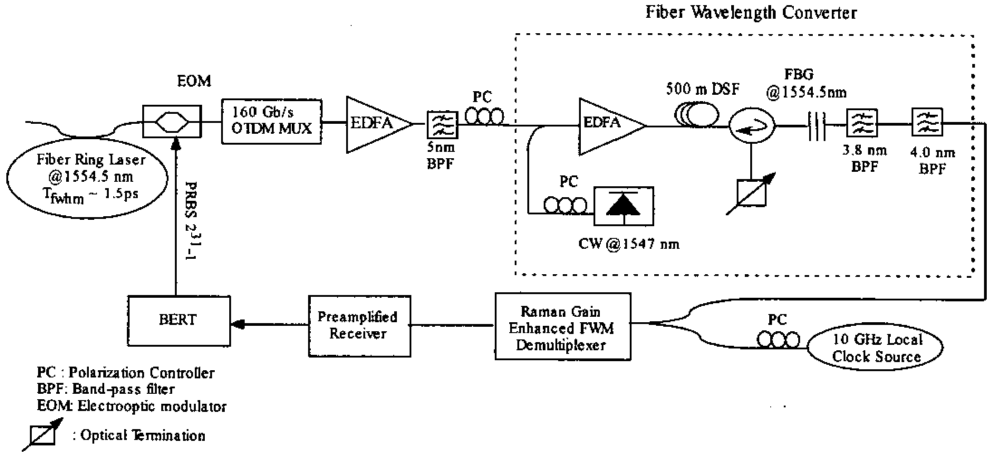

Figure 1: Experimental Setup of 160 Gb/s Mux/Demux link with fiber XPM all-optical wavelength converter.

At the wavelength converter, the 160 Gb/s OTDM data stream was combined with a 1547 nm CW signal yielding an average power of 3.2 dBm before being amplified in a high power Erbium Doped Fiber Amplifier (hp-EDFA). The power of the CW signal in the hp-EDFA is 7.8 dB lower than the power of the 160 Gb/s data signal. It is important to maintain this ratio between the CW and the data signal to maintain a good SNR of the converted signal. In the hp-EDFA the CW and the data signals are amplified to 930 mW and injected into 500 m of DSF with zero dispersion wavelength at 1559 nm. The walk-off between the data and the CW signal is less than 1 ps. The data signal imposes cross-phase modulation on the CW signal and generates side-bands as shown in Figure 2. Phase modulation is converted to amplitude modulation by filtering one of the side-bands. A fiber grating and circulator is used at the output of the wavelength converter to notch out the original data signal and reduce the amount of optical power input to the optical filter. To filter the phase-broadened part of the CW we use a combination of a 3.89 nm and a 4 nm optical filter, resulting in an effective filter bandwidth of 3.09 nm centered on the converted signal.

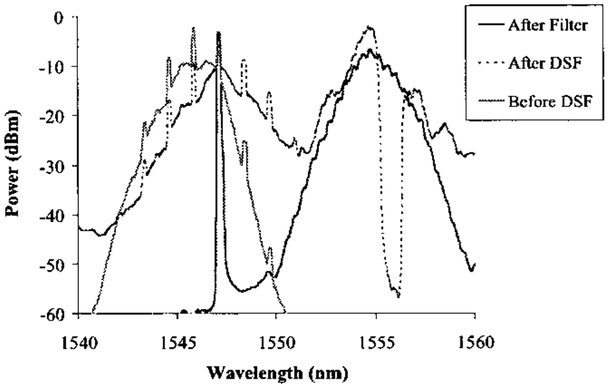

Figure 2: Spectrum before DSF (solid black line), after DSF (dotted black line) and after filter (solid gray line)

3. Results & Discussion

To measure the performance of the converted 160 Gb/s data, each of the 16 x 10 Gb/s OTDM channels were demultiplexed down to 10 Gb/s using a Raman gain enhanced four wave mixing (FWM) demultiplexer described in [7] and detected using a pre-amplified receiver. The eye diagrams for the 16 x 10 Gb/s converted signals are shown in Figure 3.

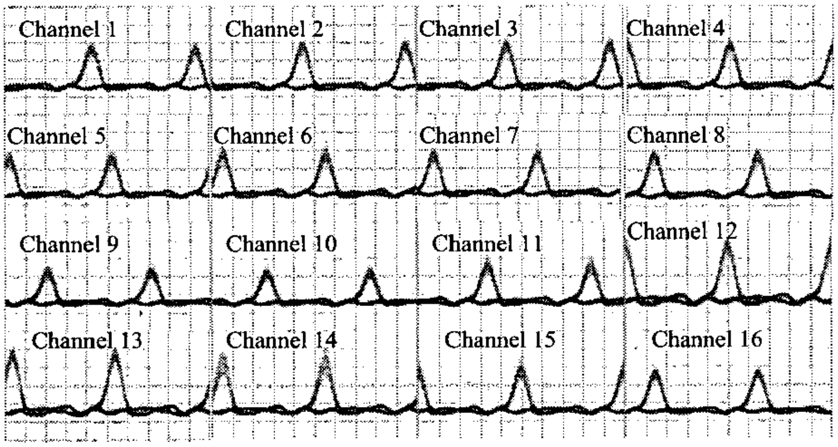

Figure 3: Eye Diagrams of the 16 wavelength converted channels after demultiplexing

Bit-error rate (BER) measurements were performed on each channel and are shown in Figure 4. All channels measured a BER better than 10^{-9} and the spread in the receiver sensitivity (at 10^{-9}) was about 4 dB. This spread in receiver sensitivity is most likely due to the variation of polarization of the different time channels in the original signal resulting from the passive time multiplexer. We believe that the change in slope and crossing of de-multiplexed channels with back-to-back curves is due to coherent ISI, caused by the converter filter, at higher incident power levels at the receiver overcoming the converter 2R regenerative behavior which is visible at lower power received power levels. We also believe this ISI to be worse for certain channels due to the deviation from PRBS at the OTDM multiplexer output and sub-interval channel misalignment in the multiplexer. Environmental induced polarization fluctuations combined with converter filter induced ISI made it difficult to measure 10^{-11} and 10^{-12} BER over long enough periods of time. We expect this problem to be addressed and overcome in the near future.

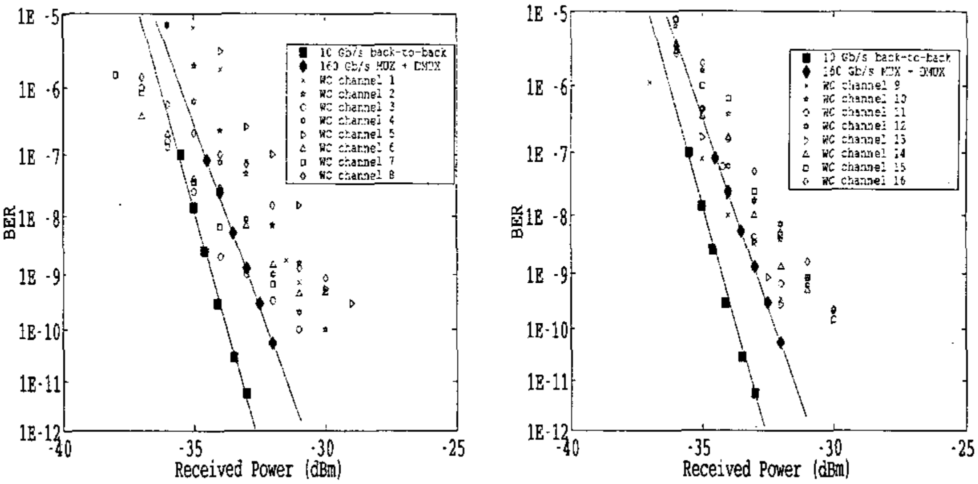

Figure 4: BER curves for the 10 Gb/s baseline (solid squares), best 10 Gb/s multiplexed and demultiplexed channel (solid diamonds) and wavelength converted channels 1-8 (left) and 9-16 (right).

4. Conclusion

We have demonstrated for the first time wavelength conversion at 160 Gb/s using cross-phase modulation in 500 m of DSF over 9 nm bandwidth with less than 3 dB power penalty compared to the original 160 Gb/s signal. The measured sensitivities for all channels at 10^{-9} ranges from -29 to -33 dBm, which can be improved by using a polarization maintaining optical time division multiplexer and obtaining a higher extinction ratio with an optimal filter design.

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