3 Optical Signal Processing Techniques for Signal Regeneration and Digital Logic


Abstract. This chapter presents recent developments in optical signal processing techniques and digital logic. The first section focuses on techniques to obtain key functionalities as signal regeneration and wavelength conversion exploiting nonlinear effects in high nonlinear fibres and semiconductor optical amplifiers. The second section covers techniques for clock recovery and retiming at high-speed transmission up to 320 Gb/s. In addition a technique to obtain OTDM demultiplexing based on cross-phase modulation is reported.

3.1 Optical Regeneration and Wavelength Conversion

3.1.1 640 Gbit/s Wavelength Conversion Based on XPM in HNLF

The single channel bit rate has continuously increased in deployed optical transmission systems and networks, reaching 10 – 40 Gbit/s in today’s commercially available systems. With the appearance of new technologies for optical transmitters and receivers operating near 100 Gbit/s [1], ultra fast signal processing becomes increasingly relevant. At such high bit rates optical signal processing must be considered as a useful supplement to electronic processing. Several signal processing tasks must be addressed in high speed communication systems and networks, including the indispensable wavelength conversion of data signals. Several approaches based on non-linear effects in optical fibres as well as semiconductor structures have been investigated and two wavelength conversion set-ups have been demonstrated up to 320 Gbaud symbol rates [2-3].

In this subsection, wavelength conversion by cross-phase modulation (XPM) in highly non-linear fibre (HNLF) is demonstrated for a 640 Gbit/s (640 Gbaud OOK) single channel, single polarization optical time division multiplexed (OTDM) data signal. This constitutes the highest reported operating speed of a wavelength converter to date. Error free conversion is achieved for all channels, and the best-case penalty in receiver sensitivity is only 2.9 dB compared to the original 640 Gbit/s data signal.

The original version of this chapter was revised: The copyright line was incorrect. This has been corrected. The Erratum to this chapter is available at DOI: 10.1007/978-3-642-01524-3_13

3.1.1.1 Experimental Procedure

The experimental set-up is shown in Fig. 3.1. The optical signal is generated by an erbium glass oscillator pulse generating laser (ERGO-PGL) with a pulse repetition rate of 10 GHz and a wavelength of 1557 nm. The pulses are data modulated with a 2^7-1 PRBS in a Mach-Zehnder modulator (MZM) and subsequently multiplexed to 40 Gbit/s in a passive fibre delay 2^7-1 PRBS maintaining multiplexer (MUX). The 40 Gbit/s data pulses are then chirped and spectrally broadened by Self Phase Modulation (SPM) in 400 m of dispersion flattened highly non-linear fibre (DF-HNLF, $\gamma \sim 10 \text{ W}^{-1}\text{km}^{-1}$, dispersion $D = -1.2 \text{ ps/nm/km}$ at 1550 nm and a dispersion slope of 0.003 ps/nm^2/km – kindly provided by OFS Fitel Denmark). The positive dispersion in the remainder of the transmitter linearly compresses the data pulses to ~560 fs FWHM in the resulting 640 Gbit/s data signal. The signal is amplified by an EDFA to ~28 dBm and combined with a ~25 dBm CW at 1544 nm before injection into 200 m of HNLF ($\gamma \sim 10 \text{ W}^{-1}\text{km}^{-1}$, zero dispersion at 1552 nm and a dispersion slope of 0.018 ps/nm^2/km – kindly provided by OFS Fitel Denmark). The CW is phase modulated at 100 MHz to reduce Stimulated Brillouin Scattering (SBS). A counter-propagating 800 mW Raman pump enhances the wavelength conversion in the HNLF. The sidebands on either side of the CW are temporally off-set and it is thus necessary to select only one sideband to form the wavelength converted signal [2]. This is done using a Fibre Bragg Grating (FBG) as a notch filter to suppress the CW and part of one XPM sideband. A 9 nm band pass filter is used to further isolate the converter output, by suppressing the original data signal. The FBG has its centre wavelength at 1545.5 nm, a bandwidth of 3.2 nm and a suppression of ~40 dB.

The wavelength converted signal is demultiplexed to the 10 Gbit/s base rate in a non-linear optical loop mirror (NOLM) using 780 fs control pulses generated by adiabatic soliton compression of a 10 GHz pulse train (from a second ERGO PGL) in a dispersion decreasing fibre (DDF). The NOLM comprises 50 m of HNLF with the same fibre parameters as the one used for XPM wavelength conversion. Bit error rate (BER) measurements of the 10 Gbit/s OTDM tributaries are performed to evaluate the system performance.

![Fig. 3.1. Setup for 640 Gbit/s XPM wavelength conversion.](image-url)