

Wavelength conversion with multicasting capabilities deploying Highly Nonlinear Fiber for time-serial labeled networks

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All-optical wavelength conversion with multicasting capabilities is a desired feature in optical label swapping packet-switched networks, in order to facilitate broadcast services. The time-serial IM/IM modulation format for payload/label encoding is a promising technique for optical label switching, because it enables to exploit fully all-optical processing techniques. We report on the experimental demonstration of wavelength multicasting to three different channels simultaneously of a signal at 10 Gbit/s by using four wave mixing in a highly nonlinear fiber. The channels are spaced by 200 GHz, in compliance with the ITU grid.

Introduction

Optical label swapping (OLS) is a promising technique for implementing optical packet switching (OPS) functions in wavelength division multiplexed (WDM) optical networks [1]. All-optical label swapping techniques are a promising solution for packet routing speeds matching line rates and therefore avoiding any electronic processing bottleneck. An all-optical architecture for a core node is proposed in [2]. This architecture is based on optical X-OR correlators for the processing of the label, optical flip-flops acting as a decision maker (by setting wavelength of the outgoing packet), a passive arrayed-wave guided (AWG) as a routing element, and a wavelength converter. Figure 1 shows the proposed architecture.

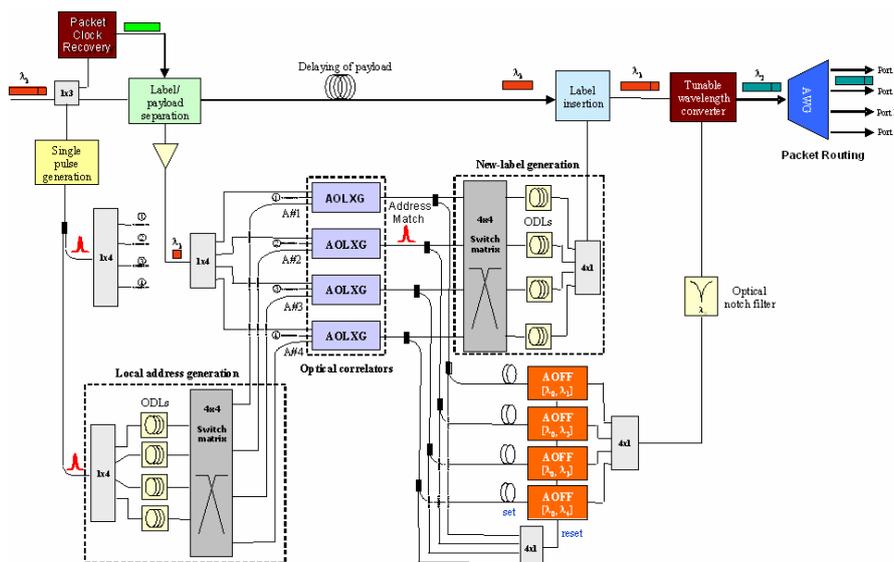


Figure 1: Architecture for an all-optical core node.

Wavelength conversion investigations have focused historically on conversion of only one wavelength. However, in advance WDM networks supporting services like video distribution and teleconferencing, a multicast connection to be established is needed [3,4].

Therefore, multicasting capability is a new feature requested to the physical wavelength converter. Recently, multicasting capabilities were demonstrated exploiting four wave mixing (FWM) in a single SOA [5]. However, this approach used a polarization diversity scheme, interleaving the polarization of each single pumping signal, and hence adding a new degree of complexity to the setup.

In this paper, we demonstrate wavelength multicasting using the FWM process in a highly nonlinear fiber (HNLF). An incoming signal is successfully multicasted to three different wavelength channels, with no substantial degradation in the extinction ratio (ER). The bit-error rate measurements show also no substantial degradation of the quality of the signals. This multicast capability combined with all-optical processing of the signals in the node could lead to a new level of real-time broadcast services

Four wave mixing in highly nonlinear fiber

FWM can be both harmful and useful in optical fiber systems. It can degrade the performance in WDM systems. On the other hand it can also be used for wavelength conversion, time demultiplexing, phase conjugation, squeezing and super continuum generation [6]. FWM wavelength conversion offers two advantages over other methods: high conversion speed due to the ultrafast fiber nonlinearities and the ability to simultaneously convert signals within a wavelength bandwidth [7]. A critical issue in FWM wavelength conversion is the low conversion efficiency. However with the use of HNLF high conversion efficiencies can be obtained [8]. To achieve wavelength conversion in the fiber using FWM we must put the pump wavelength close to the zero-dispersion wavelength and the dispersion slope should be minimized. Moreover the state of polarization of the pump and signals must coincide. The zero-dispersion wavelength of the HNLF is 1545 nm, the dispersion slope is 0.03 ps/km/nm², and the nonlinear coefficient is about 15 W⁻¹km⁻¹. The length of the fiber is 500 m.

Wavelength conversion and multicasting in a time-serial labeled network

The experimental setup is depicted in Fig. 2.

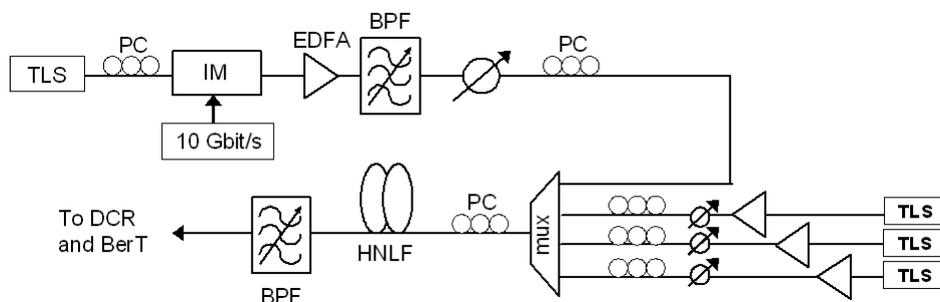


Figure 2: Experimental setup.

The original signal was obtained by modulating the lightwave carrier generated by a tunable laser source (TLS) at 1555.75nm. The modulation signal was in the non return-to-zero (NRZ) format based on a $2^{31}-1$ pseudo-random bit sequence (PRBS). The average output power after the generation was measured to be -3dBm. An erbium-doped fiber amplifier (EDFA) was used to amplify the signal up to 18dBm, and a band-pass filter (BPF) used to remove the amplified spontaneous emission (ASE) noise. The polarization of the signal was controlled in all the point by using polarization controllers (PC), and then sent into a multiplexer filter, and then to the HNLF. At the same time, three TLS sources were amplified using independent EDFAs, and then injected also to the HNLF through the demultiplexer. The TLS were emitting at 1557.36nm, 1558.98nm and 1560.61nm, hence with 200GHz channel spacing. In order to assess the individual quality of each multicasted channel, a BPF was used to filter out the signal at the output of the HNLF, and then sent into a data/clock recovery (DCR) block and a bit-error rate test (BerT).

Figure 3 shows the optical spectra at different points of the setup and the results of the BER characterization. For single wavelength conversion, the power penalty at 10^{-9} is around 2 dB. When all the pumping signals are injected simultaneously and hence reproducing a multicasting scenario, the power penalty increases 0.5 dB. However, the BER performance remains within acceptable levels. The power penalty could be explained by the fact that the channels are located far from the zero dispersion wavelength of the HNLF. Therefore, the results could be improved by either locating the channels closer to this point or using a HNLF with different specifications.

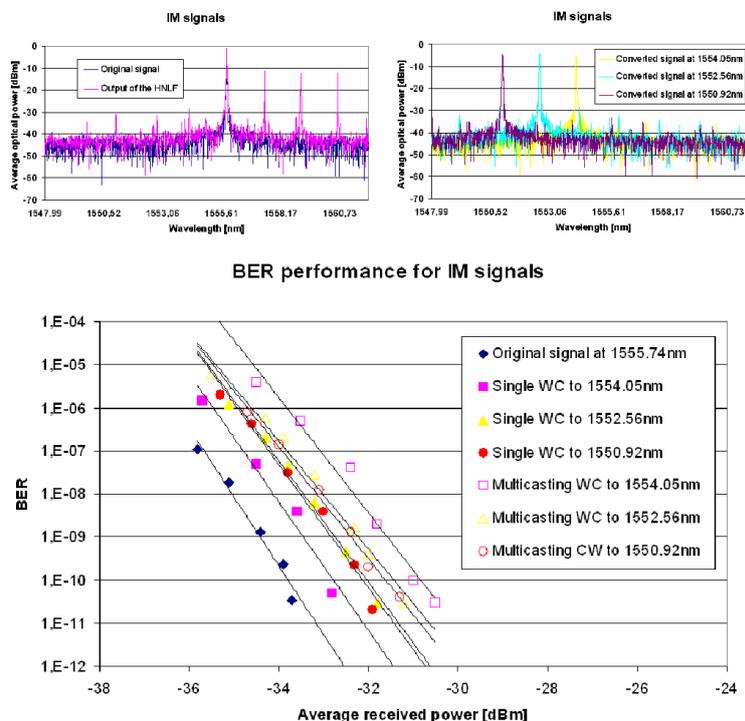


Figure 3: Optical spectra at different points of the system. Namely, the original signal, at the output of the HNLF, and the recovered channels after wavelength conversion. The BER measures correspond to the single wavelength conversion and the multicasting case.

Conclusions

We demonstrated wavelength multicasting using the FWM process in a HNLF. An incoming signal at 10 Gbit/s with PRBS $2^{31}-1$ was successfully multicasted to three different wavelength channels with 200 GHz channel spacing. The resulted multicasted signals experienced less than 2.5 dB of power penalty at bit error rate of 10^{-9} . This multicast capability combined with all-optical processing of the signals in the node can lead to a new level of real-time broadcast services.

Acknowledgements

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