Simultaneous Multi-Format RZ-OOK and RZ-DPSK Optical Packet Switching Based on Tunable Four-Wave Mixing

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Abstract: We demonstrate multi-format optical packet switching using RZ-OOK and RZ-DPSK signal formats based on four-wave mixing for optical packet switching system at 10 Gb/s. Error-free performance for each packet signal is achieved.

Keywords: Optical Packet Switching, Four-Wave Mixing, Wavelength Conversion

Introduction

Optical packet switching technologies offer finer data granularity switching and high efficiency routing in optical network nodes. Recently, advanced optical signal formats for data transmission have attracted much attention in high speed, large capacity communication system fields. Optical switching systems at network nodes are required to handle many kinds of optical signal formats. There have been a number of reports on optical label/burst/packet switching systems [1-3] that include mixed data rate signal processing; however these systems demonstrated a single modulation format. Processing techniques for multi-format signals must be developed for future optical network nodes. Two important functions for optical packet switching systems in support of switching and signal regeneration include signal format conversion and wavelength conversion. Several format conversion techniques, from on-off keying (OOK) to binary phase-shift keying (BPSK) based on integrated semiconductor optical amplifier - Mach-Zehnder inter-ferometer (SOA-MZI) devices, have been proposed [4,5]. However, these schemes have limitations involving the processing speed of the device, and dedicated optical channels are required for the format conversion in the system. On the other hand, four-wave mixing (FWM) in highly nonlinear fiber (HNLF) has the potential for high speed operation [6].

This paper reports on the wavelength conversion of multi-format packets and switching based on FWM for multi-format packet switching. We achieve error-free performance of wavelength conversion for return-to-zero OOK (RZ-OOK) and return-to-zero differential phase-shift keying (RZ-DPSK) packets.

2. Multi-format packet wavelength conversion using RZ-OOK and RZ-DPSK packets in an optical router

Figure 1 shows a diagram of an optical packet switching router for multi-format switching. It consists of function blocks, called label extractor (LE) and label rewriter (LR) for sub-carrier multiplexing (SCM) techniques [1]. The key function blocks for the switching router, are the tunable wavelength converter (T-WC) and the fixed wavelength converter (F-WC). These blocks must provide format independent conversion for multi-format packets. Incoming packets from A are assumed to be two different wavelength and format packets. Passing through the arrayed waveguide grating (AWG) and LE, the packet P_1 (λ_1) is converted to λ_4, and the packet P_2 (λ_2) is converted to λ_3 based on port mapping information in the controller by T-WCs. They come out from port4 of the AWG router (AWGR) in different wavelengths. Basically, the packet contention resolutions must be solved by the loop back fiber (fixed-length buffer) in AWGR [1]. Then, two different types of packets are combined at port4 of the AWGR. The two different format packets need to be converted to λ_5 at F-WC, then the patterns can go through "C" after the label rewriting functions.

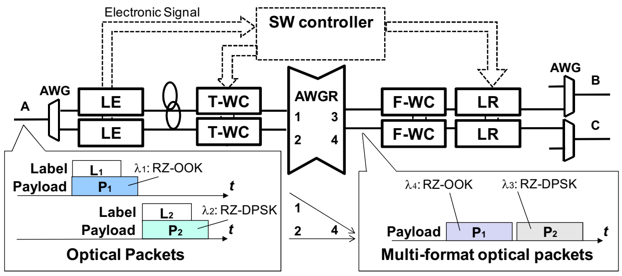


Fig. 1 : Schematic diagram of an optical packet switching router (1x2 configuration) for multi-format packets

For signal format-independent switching, we have proposed a FWM configuration of the routing system. FWM in HNLF allows multi-format packet wavelength conversion. FWM techniques require pump light sources, and we utilized converted wavelength at $\omega_{FWM} = 2\omega_p - \omega_s$, where ω_p and ω_s are optical frequencies of pump and signal waves, respectively. A relatively high powered pump light is required for FWM, however, the potential for high speed processing and format independence is promising.

3. Experimental setup

Figure 2 shows the experimental setup. There are four main blocks: the RZ-DPSK and RZ-OOK transmitters based on a 10 Gb/s pulse pattern generator, a wavelength converter based on a HNLF, and the receiver. The RZ-DPSK packets were generated by three modulators, which work as a phase modulator, a pulse curver, and a packet enveloper. For correct digital coding, InPhi's DPSK encoder was utilized in the NRZ-DATA driver. The length of the packet bit streams was 100ns, based on pseudo-random bit sequence (PRBS), and the inter packet guard time was set to 800ps. The outputs of the two transmitters were combined by an optical coupler; afterwards, multi-format packet streams were obtained. The generated packets were injected into a 500m HNLF (γ=18.0W^{-1} km^{-1}, λ_0 = 1551 nm), giving a signal power of +8.5 dBm to the HNLF. The packet gating modulator added before the BER tester allows measurements of the multi-format packets using selective packet detection.

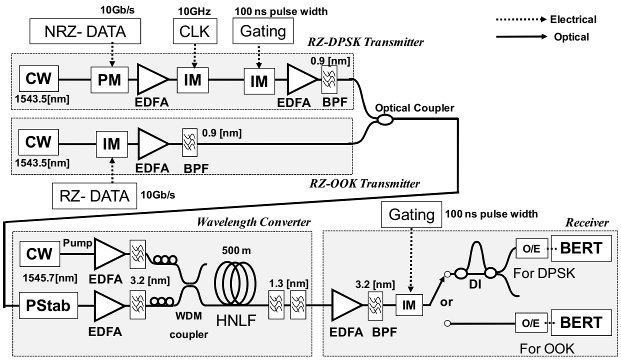


Fig. 2 : Experimental setup for multi-format packet wavelength conversion. (PM: Phase Modulator, IM: Intensity Modulator, PStab: Polarizaion Stabilizer, EDFA: Erbium-Doped Fiber Amplifier, BPF: Band Pass Filter, HNLF: Highly Nonlinear Fiber, DI: Delayed-Interferometer, BERT: Bit Error Rate Tester)

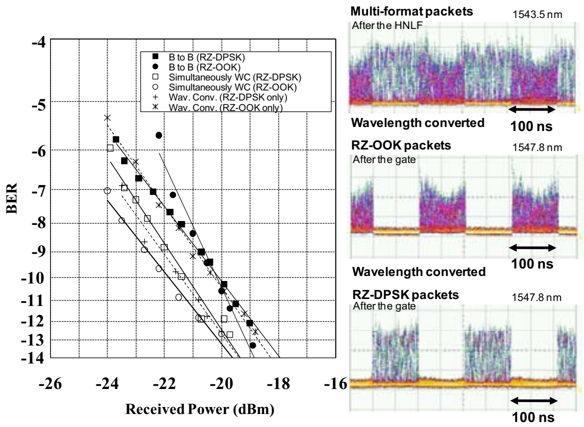
In the second part of experiment for emulation of the packet switching condition, the two pump wavelength was switched alternatively by additional intensity modulators (IMs). A 100GHz spacing AWG was set directly after the HNLF instead of the band pass filters (BPF) in the wavelength conversion block, and the IM for the gating was removed from the receiver block.

4. Results and discussion

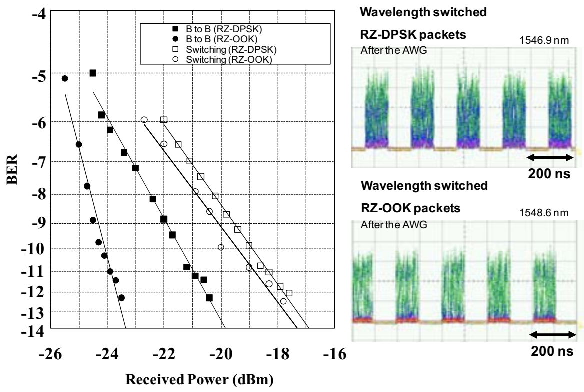
Figure 3 shows the BER results and observed packet waveforms. The performance of the multi-format packet wavelength conversion is shown in Fig. 4(a), and Fig. 4(b) shows the performance based on pump wavelength switching. Closed symbols show the back-to-back performance, and open symbols show the performance after the conversion. In the multi-format packet wavelength conversion experiment, we observed error-free performances for the RZ-OOK and RZ-DPSK formats, and a tendency towards a negative penalty from the back-to-back BER. This tendency is mainly a result of the signal amplification by the EDFA and the filtering effect on BPFs. On the pump source switching condition, error-free performance for both signal formats were observed, however the RZ-DPSK packet streams had a 4.2 dB penalty (at 10^{-9}) from the back-to-back condition. The penalty of the converted RZ-OOK packet was 2.5 dB. Future experiments will employ a balanced receiver for RZ-DPSK packets for reduced penalty.

5. Conclusion

We have investigated and demonstrated multi-format packet wavelength conversion of RZ-OOK and RZ-DPSK packets and wavelength switching based on FWM in a highly nonlinear fiber at 10 Gb/s. Error-free performance for each packet signal was achieved. This scheme is applicable to multi-format optical packet switching systems.



(a) Multi-format packet wavelength conversion



(b) Switched pump wavelength for packet switching

Fig. 3 : BER results and packet waveforms

6. Acknowledgment

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6. References

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