A MULTI-HOP OPTICAL PACKET SWITCHING DEMONSTRATION EMPLOYING ALL-OPTICAL GRATING BASED HEADER GENERATION AND RECOGNITION

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Abstract *We present an optical packet switching system based on header recognition using 255 bit, 320 Gbit/s superstructured fiber Bragg gratings. Two hop operation, with header reuse, of a packet add/drop node that may be configured for packet relabeling is demonstrated.*

Introduction

There is an increasing need for communication networks that have a reconfigurable optical layer to provide a high-bandwidth flexible core. Optical packet switching is one such reconfigurable transport technology that is well matched to the bursty nature of IP traffic, enabling efficient utilisation of the available fiber bandwidth. Header generation, recognition and processing is a key feature of packet switched networks. To date most work has focused on performing such tasks in the electrical domain, however if such functions could be reliably achieved, wholly or at least in part, in the optical domain then this could eliminate the bottleneck imposed by electronic processing speeds, and should lead to both new and simplified architectures and protocols [1].

In this paper we demonstrate an optical add-drop packet switch network node based on all-optical header recognition and generation, and switching using lithium niobate electro-optic modulators. Optically coded packet switched systems based on optical encoding and decoding of the header using matched filtering in complementary tapped delay line filters, implemented in planar lightwave circuits (PLC), [2, 3] and multi-wavelength coding using fiber gratings have been recently demonstrated [4]. Here we outline an optical packet switching system based on optically decoding an encoded header, that is used to label the packets, using phase coded superstructured fiber Bragg gratings (SSFBG). Optical code division multiple access systems based on such gratings have been successfully demonstrated [5]. Phase coded grating encoders/decoders offer several advantages as they are readily scaled to long code sequences (255 bit OCDMA codes previously demonstrated in the laboratory [5]), low cost, compact and integrate easily with other fiberised network components.

Experimental Setup and Results

The functionality of our optical packet switching system, which incorporates a packet transmitter and two switching nodes, is shown in Fig.1, and the experimental configuration used to demonstrate it is shown in Fig.2.

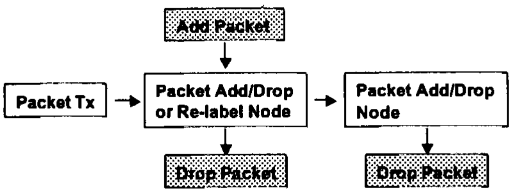

Fig. 1. Optical packet switching system

The packet transmitter generates optically coded header pulses that are inserted in front of the data payload to create a packet. The header pulses are generated by a regeneratively mode locked erbium fiber ring laser (EFRL) that produces pulses of 2.5 ps duration. These pulses are then optically encoded by reflection from an SSFBG. The SSFBGs used within this experiment contain coding information within their spatial refractive index profile that allow the generation of 255-Bit 320 GBit/s quaternary phase coded pulse sequences [5]. These codes have distinct well defined autocorrelation properties, and mutually low cross correlation properties allowing for at least 255 distinct headers for the given code length. The packet structure shown in Fig. 2 consists of the coded header followed by the data payload. The packet switching is transparent to the bit-rate and format of the data payload employed. In this experiment a 10 Gbit/s (PRBS 2^{31}-1) NRZ data payload that is 924 bits long is used. The header and the data payload are at the same wavelength, which allows for increased network capacity if WDM techniques are to be additionally employed. The packet switching transmitter presented here utilises two distinct data payloads, labeled P1 and P2, each with a unique header labeled H1 and H2 as shown at the transmitter output in Fig. 2.

At the add/drop node optical header recognition is performed in order to control the switching of the data. Part of the incoming packet stream is sent to the header decoder that consists of an array of fiber gratings H1*-Hn* whose codes are matched to the coding gratings in the transmitter. In this experiment decoding grating H1* is chosen using an optical switch in order to recognize packet 1. Header recognition is carried out by reflecting the packets off decoding grating H1* which results in a strong correlation peak H1:H1* arising from header H1, some residual background from the cross-correlation between header H2 and the decoding grating H1*, and a contribution from the reflected data payloads as shown in Fig. 2 (Decode output). In order to improve the extinction of the header recognition and to allow for the re-use of the header pulses, regeneration of the decoded header pulse is carried out in a NOLM [6]. Regeneration in the NOLM improved the header extinction to 18 dB and autocorrelation measurement (Fig.2(a)) show that the decoded header pulse is reshaped to a pulse of the original 2.5 ps duration and as such is suitable for re-encoding.

Fig. 2 (Dropped payload) shows the data payload dropped at the first node when the packet labeled by header H1 is recognized. The data payload P1 is clearly switched out as is shown by observing the signal before and after the switch Fig. 2 (Removed Packet). Once the payload P1 is removed a new packet can be added. A new packet is constructed at the node by recoding the reshaped header pulse using grating H3 and adding a new data payload P3. This packet is then inserted into the space vacated by the dropped packet as shown in Fig. 2 (Add Output). The add/drop node can also be used for packet re-labeling. In this application only the header corresponding to the recognized packet is dropped, and a re-encoded header is then inserted in its place at the add port of the node. A further packet drop operation at a second add/drop node is used to test the quality of the add and header re-encoding operations. At this node the decode grating H3*, corresponding to packet 3, is used to control the switch in order to drop the data payload P3 as shown in Fig. 2 (Dropped Payload P3). Note that in this instance we show that there is no requirement to use a NOLM to enhance the pattern recognition signature H1:H1* if no further processing other than electrical detection of the header is required. Fig. 2 also presents BER measurements performed on the dropped data which shows that there is no significant penalty when the switch is controlled by the decoded header (circles) after two hops.

Conclusion

An optical packet switching system based on optical header encoding and recognition using SSFBG has been demonstrated. Error-free operation of multiple cascaded add/drop nodes that utilise a recoded header pulse has been experimentally verified with no observed penalty. The reuse of the decoded header pulse after reshaping in the NOLM removes the need for an additional pulse source at each node. We consider that our results highlight both the capability and suitability of SSFBG technology for all-optical signal processing applications.

References

1 L. Rau et al,OFC'02, Postdeadline Paper FD2 (2002).
2 K. Kitayama et al, IEEE Photon. Technol. Lett., Vol. 11 (1999), pp.1689-1691.
3 N. Wada et al, ECOC'01 (2001), Postdeadline paper.
4 N. Wada et al, OFC'02, Paper WG3 (2002).
5 P. C. Teh et al, IEEE Photon. Technol. Lett., Vol. 14 (2002), pp.227-229.
6 J. H. Lee et al, J. Lightwave Technol., Vol. 20 (2002), pp. 36-46.

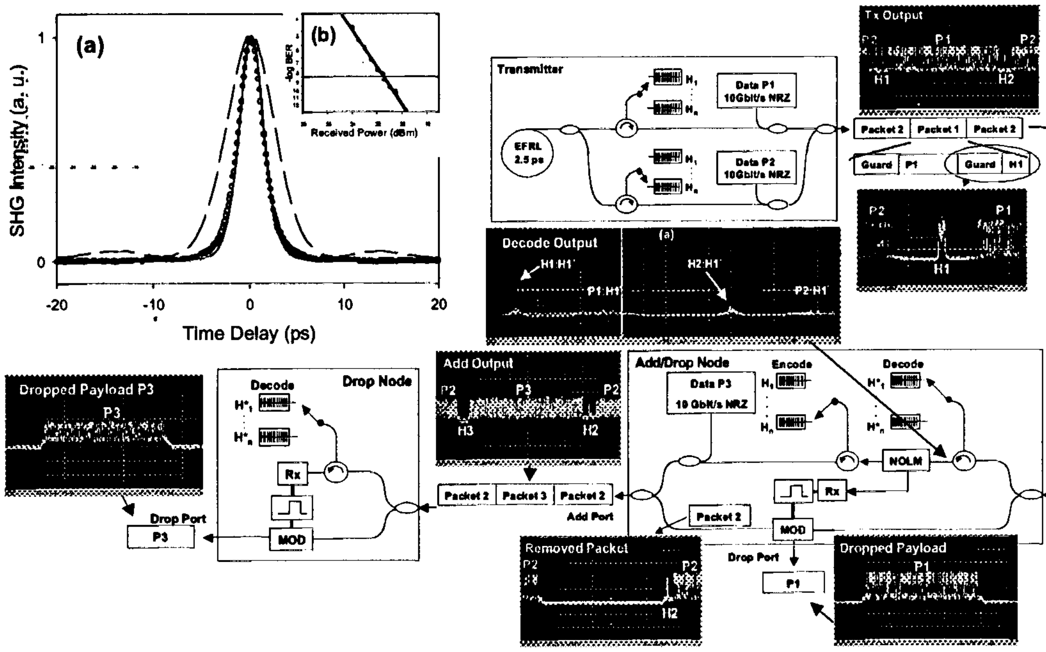

Fig. 2. Experimental optical packet switching system configuration and associated optical outputs. Insert (a). Autocorrelation measurements of the header pulse before encoding (solid), after decoding (dashed) and after reshaping in the NOLM (circles), (b) BERT measurement on dropped Packet 3 after two hops.