An Ultra-compact Waveband Cross-connect Switch Module to Create Cost-effective Multi-degree Reconfigurable Optical Node

Kiyo Ishii[(1)], Hiroshi Hasegawa[(1)], Ken-ichi Sato[(1)], Masayuki Okuno[(2)], Shin Kamei[(3)], Hiroshi Takahashi[(3)]

[(1)] Nagoya University, Furo-cho, Chikusa-ku, Nagoya, 464-8603 Japan, k_isii@echo.nuee.nagoya-u.ac.jp
[(2)] NTT Electronics, [(3)] NTT Photonics Laboratories, Nippon Telegraph and Telephone Corporation

Abstract *We demonstrate a compact waveband cross-connect switch module that will be utilized for creating cost-effective multi-degree optical cross-connect nodes. Its measured performance confirms that it can be applied to metro-edge/metro-access networking in the future.*

Introduction

Video technologies including IP TV and high-definition and ultra-high-definition TV (72 Gbps, uncompressed) are advancing[1] and they will dramatically expand traffic in the near future; future communication network services will become video-centric. In order to support the expected traffic expansion, waveband path (bundles of wavelength paths) technologies have been developed[1]. A very efficient network design algorithm[2] that was recently developed offers extremely cost effective networking with wavebands; the optical port count of the Hierarchical Optical Cross-Connect (HOXC) switches was shown to be greatly reduced compared to that of single layer OXC. This is true for both HOXCs that adopt WSS and WBSS (Waveband Selective Switch) switches[3] and those that adopt matrix switches[4]. WSSs have been widely deployed since they can handle many wavelength channels and allow modular growth of the node scale. A WSS/WBSS consists of wavelength/waveband MUX(DEMUX) and optical switch functions. In WBSS, the number of wavebands to be handled is much smaller (a waveband is a bundle of wavelength paths), which necessitates small scale switches. If we can develop effective waveband MUX/DEMUX, the cost-effective WBSS can be realized. Based on these WBSS requirements, we have successfully developed a single chip WBSS using PLC technologies[5] that exploit cyclic AWGs for the waveband MUX/DEMUX. The device has no moving mechanical parts, requires no adjustment, and is very compact, which will lead to high reliability and low cost.

In this paper we introduce a very compact one box WBXC (Waveband Cross-Connect) module, which will be suitable for application to cost sensitive areas such as metro-edge and metro-access networks. The performance of an implemented module is presented for the first time.

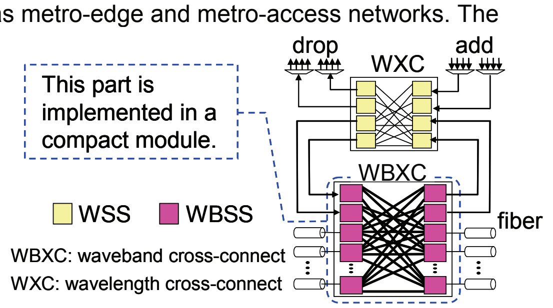


Fig. 1: HOXC node architecture that utilizes WSS/WBSS

HOXC switch architecture

Figure 1 depicts a basic architecture of a hierarchical optical path cross-connect. Wavelength paths are routed as much as possible by the WBXC part as a bundle, and when routing (glooming) or termination of each wavelength path is necessary, wavebands are demultiplexed and each wavelength path is routed or terminated through the WXC (Wavelength Cross-Connect) part.

Proposed WBXC

Figure 2 depicts our 5x5 WBXC architecture, which consists of five 1x5 WBSS and five 1x5 optical couplers (OC). At the input side of the WBXC, we introduced OCs instead of WBSSs, since the number of input/output ports is small (this means that the OCs have relatively small loss and are cost effective). The architecture allows optical multicasting which will be useful for video distribution. The WBXC is designed to accommodate five input fibers. Each fiber carries forty wavelengths (191.7 + 0.1xn [THz]; n=0-39) in five waveband; each waveband holds eight wavelengths. Figure 3 demonstrates the implemented ultra-compact WBXC switch module. The module size is 12.5 x 21 x 5 cm^3. The total throughput is 2 Tbit/s (10 Gbps x 40λs x 5 fibers). Combining two of the modules, their channel grid frequencies are offset by 50 GHz, and using 50-100 GHz interleavers, the system throughput

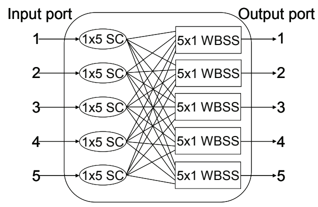


Fig. 2: WBXC architecture

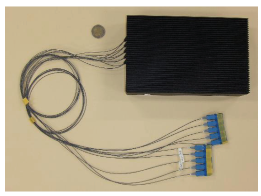


Fig. 3: WBXC module

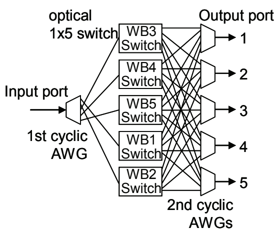


Fig. 4: WBSS architecture

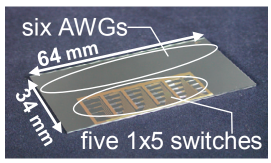


Fig. 5: WBSS chip

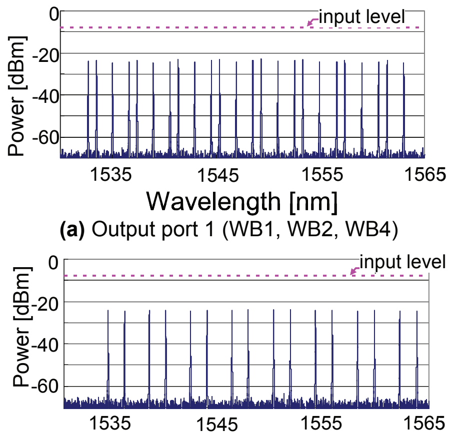
978-3-8007-3173-2

is easily upgraded to 4 Tbit/s.

The component 1x5 WBSS architecture[5] is shown in Figure 4. The interleaved waveband arrangement[5] was adopted; it allows cyclic AWGs to be used as waveband multiplexer/demultiplexers. The WBSS consists of six cyclic AWGs and five 1x5 thermo-optic switches; they are monolithically integrated on a 34x64 mm^2 chip as shown in Fig. 5. In order to compensate loss variations of the cyclic AWG output ports (waveband), a special connection arrangement between input and output AWGs was applied[5].

Experiments

Figure 6 shows an example of the output spectrum; WB1, WB2, and WB4 are routed to output port 1 and WB3 and WB5 are to output port 2 as intended. Figures 7 and 8 show the insertion loss and center wavelength error measured at each output port, respectively; input port 4 is used. Other major performance metrics of the developed WBXC switch module are summarized in Table 1. The average insertion loss was 15.2 dB, but it can be reduced by 2 dB when we use a 1x5 OC instead of the 1x8 OC that we used for this module. The experimental setup for bit error rate (BER) measurements is shown in Fig. 9. Figures 10 and 11 plot BER and power penalty



(b) Output port 2 (WB3, WB5)

Fig. 6: Output channel spectra (input port 1)

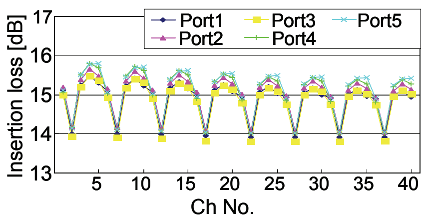


Fig. 7: Insertion loss of input port 4

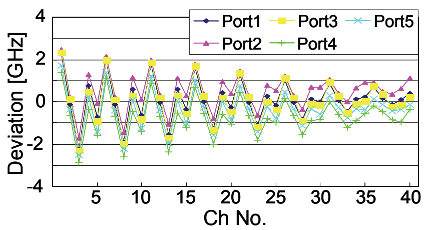


Fig. 8: Center wavelength error of input port 4

measurement results as gathered from multiple WBXC module transmission. After traversing 5 modules, the power penalty was about 0.2 dB.

Conclusion

We proposed a waveband cross-connect system that utilizes WBSSs, and realized a ultra-compact WBXC switch module with PLC technology for the first time. Its performance was tested and confirmed the suitability for application to metro-edge/metro-access networking.

Tab. 1: Transmission characteristics of fabricated WBXC

property	average	worst
insertion loss	15.2 dB	≦ 18.2 dB
PDL	0.35 dB	≦ 0.68 dB
1dB channel bandwidth	0.19 nm	≧ 0.13 nm
3dB channel bandwidth	0.35 nm	≧ 0.29 nm

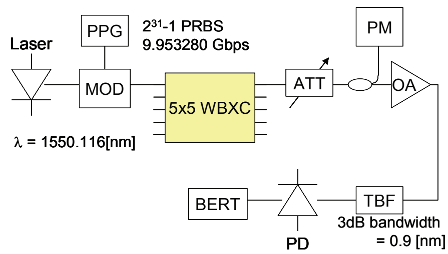


Fig. 9: Experimental setup for testing the WBXC

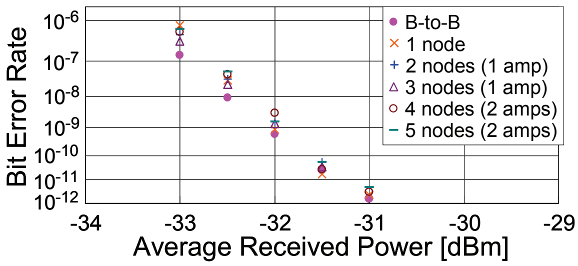


Fig. 10: BER measurements

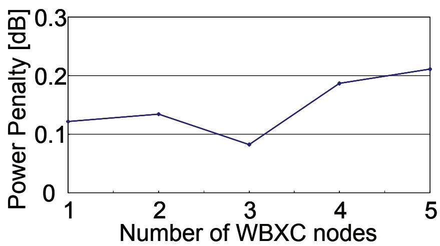


Fig. 11: Power penalty versus number of WBXCs traversed (at bit error rate of 10^{-9})

Acknowledgement: This work was partly supported by NICT and JST.

References

1 K. Sato et al., IEICE Trans. Commun. vol. E90-B(2007), pp. 1890-1902.

2 I. Yagyu et al.,J-SAC., vol. 26(2008), NO. 6, pp. 22-31.

3 S. Mitsui et al., Photonics in Switching 2008, paper S-04-1, Aug. 2008.

4 S. Kakehashi et al., IEICE Trans. Commun., vol. E91-B(2008), pp. 3174-4184.

5 K. Ishii et al., ECOC2008, paper Mo.4.C.4, Sept. 2008.

