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Terabit Photonic Networks Using OADM and OXC Nodes

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Abstract

The photonic network will enable the construction of high-capacity and flexible optical communication systems for the future data-centric era. Optical add drop multiplexers (OADMs) and optical cross connects (OXCs) along with already mature DWDM systems are key technologies for photonic networking. In this paper, prototype systems of OADMs based on the acousto-optic tunable filter (AOTF) and OXCs based on PLC optical switches have been demonstrated.

1. Introduction

In the 21st century, there will be an explosive growth in the amount of information being transmitted by digital services such as electronic commerce, software distribution, and digital video/music distribution services. The capacity required to handle all this information will be provided using new communication technologies. Photonic networking is key-enablers for realizing terabit capacities and effective and reliable use of networks.

The introduction of an optical path layer with high bit rate TDM pipes multiplexed by DWDM which can be managed by Optical add drop multiplexers (OADMs) and optical cross connects (OXCs) OXC will be effective for overall network efficiency [1]. In addition, photonic networks based on OADMs and OXCs will provide openness and transparency in future networks to accommodate various client signals with different bit rates and formats (e.g., SONET, SDH, ATM, and IP) efficiently and to forward the client signals transparently to end users.

This paper provides a perspective of the latest optical path layer technologies based on terabit WDM technologies. Some key advancements in the OADM architectures using acousto-optic tunable filters (AOTF) will be described along with the concept of optical path protection. Also, optical path cross connect architectures will be discussed along with the key features required for practical use of this technology.

2. Optical Add Drop Multiplexer (OADM)

OADM can be introduced to make effective use of network capacity, network protection, wavelength routing, and many more features. OADM can be used in the static as well as dynamic mode. The dynamic OADM has advantages of better cost-effectiveness and flexibility than passive OADM because it can select any wavelength by provisioning on demand without its physical configuration.

We have developed a fully dynamic and reconfigurable OADM using AOTFs and compact wavelength-tunable LD module [2]. The AOTF with an integrated optical waveguide on a lithium niobate substrate is very useful as a wavelength selectable switch because of its multi-channel selectivity, no pssband narrowing due to its concatenation [3], and its compactness. By achieving both a low sidelobe and narrow bandwidth of AOTF [4][5], we succeeded in developing an AOTF applicable to sub-nanometer spaced OADM systems.

To add any wavelength at an OADM node, the wavelength-tunable LD with wide tuning ranges, easy controls, high wavelength accuracy and high output power is required. We developed a practical wavelength-tunable LD module by incorporating the wavelength stabilization scheme and integrated chip of an 8-DFB LD array as well as a semiconductor optical amplifier [6].

Figure 1 and 2 show the configuration and a photograph of an OADM. This system is composed of two shelves, such as an OADM and a Tributary. This system can handle 32 wavelengths with 0.8 nm channel spacing and be fully remotely operated via PC. The AOTF unit, which is carried on OADM shelves, acts as a multi-wavelength rejection filter. An AOTF can block all wavelengths at a rejection ratio of more than 42 dB. In this unit, two of the 3-satge AOTF are used. Each AOTF blocks an odd- or even-number channel. The channel spacing for each AOTF is dilated to realize even less coherent crosstalk. In the Tributary shelf, all wavelengths can be added and dropped. 4 drop units and 4 add units are installed in the Tributary shelf. A wavelength-tunable LD module is on a tunable transponder for wavelength conversion. This OADM system has a drop-and-continue (broadcast) function by dividing input WDM signals into a drop path and a through path using an optical coupler.

3. Optical Cross-Connect (OXC)

To realize efficiency and transparency in the optical network, wavelength grooming and routing functions for each client signal and optical path supervising functions such as performance monitoring and path tracking must be provided. The key element for providing these functions is the optical cross-connect (OXC) system. Some technical issues have to be considered in connection with the development of the OXC. The optical switch is a key element for realizing an OXC node. If the insertion loss of the optical switch is large, optical amplifiers must compensate for the loss inside the node. If the loss variation at each switch port is too large, the optical receivers (ORs) at the termination and regenerating nodes cannot receive the optical signals because the dynamic range of the ORs is exceeded. We have proposed a PI-LOSS (path-independent insertion loss) optical switch as a solution for these problems [7]. In the PI-LOSS switch architecture, all optical signals pass through the same number of switch elements, which means that the insertion loss is constant and is about half of the maximum loss of the conventional cross-bar switch. Figure 3 and 4 shows the configuration and photograph of the prototype OXC node [8]. The prototype system mainly consists of optical switches (OSWs), wavelength multiplexers (WMUXs) and demultiplexers (WDMXs), and optical pre-amplifiers (Pre-OAs) and post-amplifiers (Post-OAs). In this system, we used our proposed PI-LOSS switches for the OSWs. The PT senders were connected to the input intra-office ports, and the PT receivers were arranged at the output of the OSWs. The optical signals from each input port were routed by the OSWs to the appropriate output ports according to the control signal from the network element (NE) controller. We also monitored quality of service (QoS) factors such as the optical power, wavelengths, and optical SNR for each optical path at the input inter-office ports by using an optical spectrum analyzer. The performance information was sent to the NE controller.

4. Summary

We are just at the beginning of photonic networking, which will enable the transfer of extremely large amounts of traffic over optical fiber and provide the foundation for efficiency, flexibility, and reliability in the next-generation backbone networks. The key network elements of OADM and OXC using advanced optical devices such as the AOTF and PI-LOSS SW are now being made available to provide efficient management of the optical path layer.

References

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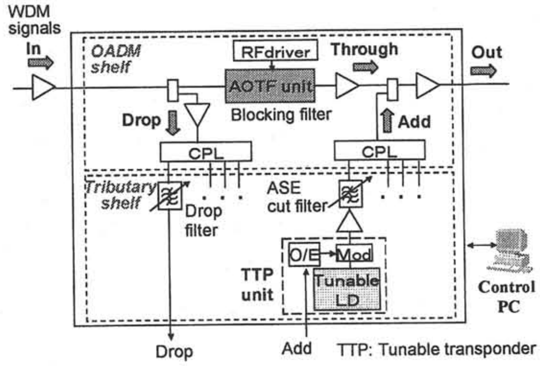

Figure 1 Configuration of OADM using AOTFs

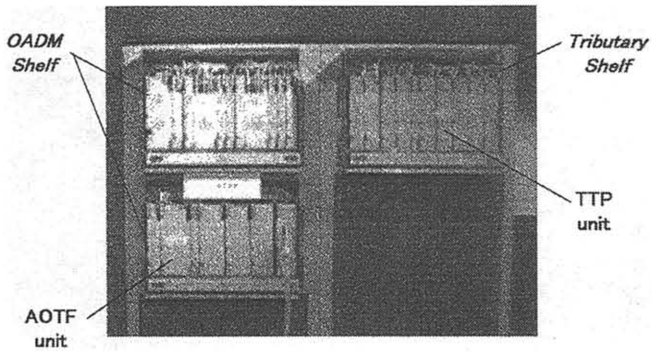

Figure 2 Photograph of prototype OADM

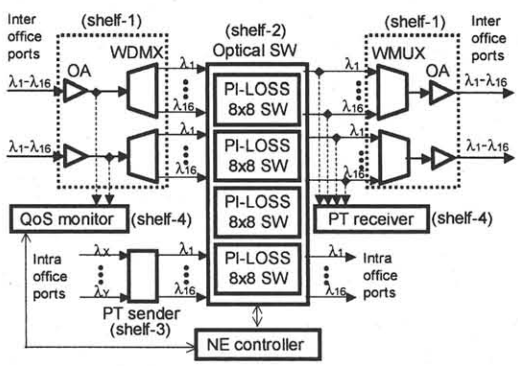

Figure 3 Configuration of OXC

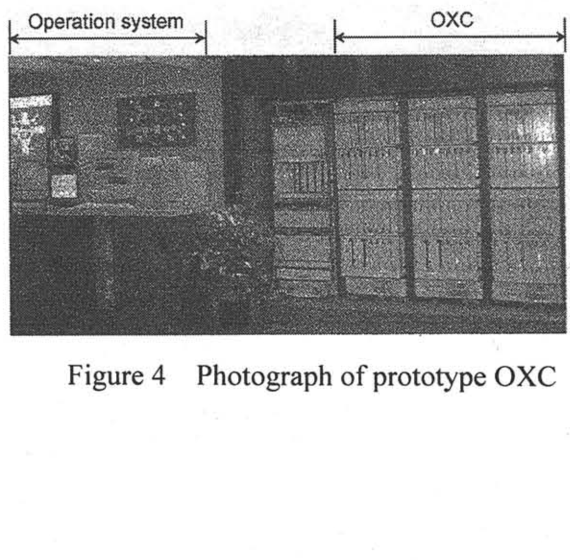

Figure 4 Photograph of prototype OXC