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The Leakages Analysis on Waveguide Based Optical Cross Add and Drop Multiplexer (OXADM)

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ABSTRACT

A wide application of planar waveguide Optical Cross Add Drop Multiplexing (OXADM) device has been designed and simulated successfully. The 6 µm width waveguide device has 1 input port, 2 add port, 1 output port, 2 drop port, 2 path exchange port. We introduced also a new feature which is path exchange to enable signal from the other waveguide to be multiplexed together with the local signal. In this paper, we are reporting the noise characteristic of OXADM by some parameters to prove the system feasibility such as Signal Distribution, Noise Distribution, Total Noise and Crosstalk. The result shows the values are is minimal and acceptable for the communication requirement. In this paper, the unwanted signal or leakage is considered noise in the system.

Key words:

Introduction

Upgrading telecommunication networks to increase their capacity is becoming increasingly important due to the rapid increase in network traffic. Wavelength division multiplexing (WDM) provides a new dimension for solving capacity and flexibility problems. Arrayed waveguide grating (AWG) is one of the most important components in WDM systems to split the wavelength to different unit. It has many advantages, including small size, high reliability, easy integration and low cost. AWGs can be used to realize multiple functions, such as wavelength multi/demultiplexers, wavelength routers, channel monitors, optical add/drop multiplexer (OADM), and optical cross connect (OXC). Ever since its invention in 1980s, AWG is being studied around the world(China Papers, 2010). The wavelength operational of OADM is depend to the type the types of AWG used. Instead of AWG, the demultiplexer based on the WDM coupler is also be used as the wavelength splitting element in the OADM. Here the coupled mode theory and evanescent field is important parameter in determining the efficiency of device that will be fabricated. The physical properties (length and width) of the device are also be influenced.

The term ‘mode coupling’ addresses one of at least three different means of power transfer. These include coupling modes of distinct waveguides by evanescent fields, coupling modes in the same waveguide by longitudinally homogeneous perturbations, and co- and contradirectional coupling by longitudinally inhomogeneous, usually periodical perturbations (Universitat Obnasbruck, 2008).

Coarse WDMs (CWDM) is the economical solution that is proposed after DWDM and WDM to reduce the standard of the previous system. The system is not requiring the high performance and very rigid specification such as super cooled laser source and super narrowband filter as the WDM requirement instead. CWDM perform two functions. First, they filter the light, ensuring only the desired wavelengths are used. Second, they multiplex or demultiplex multiple wavelengths, which are used on a single fiber link. The difference lies in the wavelengths, which are used. In CWDM space, the 1310-band and the 1550-band are divided into smaller bands, each only 20-nm wide. In the multiplex operation, the multiple wavelength bands are combined (i.e. multiplexed) onto a single fiber. In a demultiplex operation, the multiple wavelength bands are separated (i.e. demultiplexed) from a single fiber. The used wavelengths are defined by the International Telecommunications Union; reference ITU G.694.2 for the ITU CWDM Wavelength Grid. Note: as of June 2002, eighteen center wavelengths, from 1270 nm to 1610 nm, were listed (Fiberdyne, 2003; Rahman, M.S.A. and Sahbudin Shaari, 2005).

An optical add-drop multiplexer (OADM) is a device used in wavelength-division multiplexing systems for multiplexing and router different channels of light into or out of a single mode fiber (SMF). This is a type of
optical node, which is generally used for the construction of optical telecommunications networks. "Add" and "drop" here refer to the capability of the device to add one or more new wavelength channels to an existing multi-wavelength WDM signal, and/or to drop (remove) one or more channels, passing those signals to another network path. An OADM may be considered to be a specific type of optical cross-connect. A traditional OADM consists of three stages: an optical demultiplexer, an optical multiplexer, and between them a method of reconfiguring the paths between the optical demultiplexer, the optical multiplexer and a set of ports for adding and dropping signals. The optical demultiplexer separates wavelengths in an input fiber onto ports. The reconfiguration can be achieved by a fiber patch panel or by optical switches which direct the wavelengths to the optical multiplexer or to drop ports. The optical multiplexer multiplexes the wavelength channels that are to continue on from demultiplexer ports with those from the add ports, onto a single output fiber.

All the light paths that directly pass an OADM are termed cut-through lightpaths, while those that are added or dropped at the OADM node are termed added/dropped lightpaths. An OADM with remotely reconfigurable optical switches (for example 1×2) in the middle stage is called a reconfigurable OADM (ROADM). Ones without this feature are known as fixed OADMs. While the term OADM applies to both types, it is often used interchangeably with ROADM.

Physically, there are several ways to realize an OADM. There are a variety of demultiplexer and multiplexer technologies including thin film filters, fiber Bragg gratings with optical circulators, free space grating devices and integrated planar Arrayed waveguide gratings. The switching or reconfiguration functions range from the manual fiber patch panel to a variety of switching technologies including MEMS, Liquid crystal and thermo optic switches in planar waveguide circuits. Although both have add/drop functionality, OADMs are distinct from add-drop multiplexers. The former function in the photonic domain under wavelength-division multiplexing, while the latter are implicitly considered to function in the traditional SONET/SDH networks.

Optical cross add drop multiplexer (OXADM) is a newly invented device in optical networks. It is designed with a combined concept of optical cross connect (OXC) and optical add drop multiplexer (OADM) which is potentially used to increase efficiency and flexibility of optical network particularly in metropolitan ring and mesh configuration. OXADM has also widened its application to fiber to the home (FTTH) and network security system. The main function of OXADM is to reconfigure the optical channel path while implementing add and drop function simultaneously. The objective of this study is to propose the OXADM application aspects in optical network and to design a security system in ring network and in FTTH (Rahman, M.S.A., 2008; Rahman, M.S.A., S. Shaari, 2006; Rahman, M.S.A., S. Shaari, 2004; Rahman, M.S.A., 2008; Rahman, M.S.A., 2008).

The focus of this paper is the design, simulation and characterization of optical cross add drop multiplexers based on planar waveguide which operate in two CWDM wavelength. Fiber to the home (FTTH) has been developing rapidly in recent years and will become a major technology for next generation broadband access networks. An waveguide based OADM has many advantages including small size, high reliability and low cost. The commonly used wavelengths for CWDM have spacing of 20 nm. Because of the wide wavelength spacing, it is difficult to produce satisfactory results with a conventional AWG design.

Design:

The increase in capacity beyond than 10 Gbps of data transmission has been limiting the use of coaxial cable as a medium for data transmission. In this case, fiber-optic technology has become an option to meet the demand for broadband transmission. With the implementation of WDM in optical fiber technology has become a medium of transmission without the limit and offers many advantages including high capacity, high speed, long distance data transmission capabilities and the quality of the received signal is better. The information transmitted in the optical domain is transferred through the line point to point SONET equipment / SDH to form a ring and mesh networks topology.

In this network the needs of devices to implement add and drop function and path routing are performed by OADM and OXC devices respectively. Both devices have large applications in the optical world and have a similar basic structure, but both have different characteristics (Rahman, M.S.A. and S. Shaari, 2001). OADM control signals of different wavelengths at each base, while the OXC will operate the same wavelengths (Tzanakaki, A., 2003; Mutafungwa, E., 2000; Eldada, L. and J.V. Nunen, 2000). As a result, the devices are used at different locations with different functions. Device manufacturers conspired set used OADM in the ring network while OXC was used in the mesh network. However, the evolution of communication in the world today has directed two features of these devices be integrated together to form a hybrid device. Topology migration and network security issues in the ring network have inspired the existence of a device that can perform all the functions addresses by OADM and OXC called OXADM (Rahman, M.S.A., S. Shaari, 2004; Rahman, M.S.A., 2008; Rahman, M.S.A., 2008; Rahman, M.S.A., 2008; Rahman, M.S.A., S. Shaari, 2006). OXADM is the first in its class that combines the features of OADM and OXC devices. With the embedding of new features such as multiplexing and ‘U’ turn routing have extended the function and are not challenging by any existing devices yet. Moreover, all OXADM signal processing carried out in the optical domain.
The design of OADM is cascaded with multiplexer to perform the full OADM function. The basic block diagram of semi complete device is shown in Figure 1(a) and full complete OADM device is shown in Figure 1 (b). In actual application our proposed device will be cascaded with multiplexer to accumulate all signal in one output port.

Fig. 1: New OADM device (a) basic block diagram (b) complete design.

The Art of Design – Determination of Coupling Length:

Coupling Length is defined as the active area where the signals are alternately migrate from one waveguide to another waveguide. This can be achieved by designing a fundamental of coupling waveguide architecture as shown in Figure 2. Then the coupling length will determine according to the coupling profile that is generated automatically from the BPM software used. The detail of exact coupling length selection is shown in Figure 3.

Four wavelengths of CWDM are injected to the input port. Due to the evanescent field and two very closed waveguide the signal will be migrate to another waveguide alternately. Due to different of wavelength used, propagation constant and wave number has make the signal oscillation and distance of coupling has become different and finally the signal can be separated (Figure 4). In this case wavelength of 1510 nm and 1530 nm together exit at one particular output port while 1550 nm and 1570 nm exit at another output port. Thus the selection point of coupling length has been determined successfully (Rahman, M.S.A., 2006). However, the small portion of unselective wavelength is been detected in the particular port and this is considered leakage or noise. Crosstalk and Directivity is the respectively parameter used to determine the leakage affect in in-fiber and out-fiber (leakage to neighbors’ output port).

Fig. 2: (a) Designing a fundamental of coupling waveguide architecture to determine the split point.
**Result and Discussion**

The cascaded optical WDM couplers are translated to OXADM device with the support of Opti_BPM simulation tool. Figure 5 shows the simulation results of the OXADM waveguide based device achieved by using Opti_BPM simulator (a) Drop 1610 nm (b) Transmit 1610 nm (c) Exchange 1610 nm (d) Add 1610 nm (e) Drop 1590 nm (f) Transmit 1590 nm (g) Exchange 1590 nm (h) Add 1590 nm. Even the coupling length has been determined wisely and carefully but the leakages are still occurs for every function of OXADM. This is due to the small change of coupling length will change the amplitude of wavelength route. Figure 6 shows the measured power for each port for every function of OXADM. The significant differences for the signal and noise power showed the design is successfully rerouted the interested signal to the particular output port. The distribution of leakage powers for each port for every function of OXADM is shown in Figure 7.

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**Fig. 3:** The completed design of WDM coupler used to split wavelengths to different output ports.

**Fig. 4:** The selection point of exact coupling length used to separate two wavelength groups. However the leakage also emit out at the every output port further can be considered noise in the network system.

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**Fig. 5:** Simulation results of the OXADM waveguide based device achieved by using Opti_BPM simulator.

**Fig. 6:** Measured power for each port for every function of OXADM.

**Fig. 7:** Distribution of leakage powers for each port for every function of OXADM.
Fig. 5: The simulation results of the OXADM waveguide based device using Opti_BPM simulator (a) Drop 1610 nm (b) Transmit 1610 nm (c) Exchange 1610 nm (d) Add 1610 nm (e) Drop 1590 nm (f) Transmit 1590 nm (g) Exchange 1590 nm (h) Add 1590 nm.

Fig. 6: Power Amplitude measured at every port for every function of OXADM. The significant differences between signal and noise power showed the design is successfully rerouted the interested signal to the particular output port.

The time domain analysis is useful to examine the effect of noises to the data signal. The cumulative signal strike the photodetector will be considered to interfere the interested signal. Therefore it is useful to calculate the total noise that affects the performance of data signal. This is depicted in Figure 8. The overall performance of OXADM device is determined by Crosstalk as depicted in Figure 9 and Figure 10. The results show the amplitude of signal is higher as compare to noise power or leakage during the signal separation to the particular output port.
Fig. 7: The distribution of leakage powers at every port for every function of OXADM.

Fig. 8: The total noise detected at every OXADM output port.

Fig. 9: Significant different between signal and the highest neighbor noise power.
Fig. 10: The calculate crosstalk for every function of OXADM.

Reference


