ACOUSTO OPTIC DEVICES IN ADD/DROP MULTIPLEXER NODES

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Abstract: Two advanced network demonstrators with OADM nodes integrating acousto optic devices are presented. Based on the obtained results, a new generation of acousto optic add/drop multiplexers for dense WDM networks has been developed.

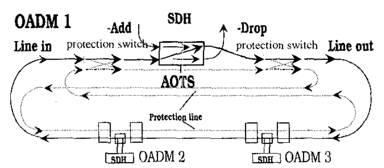
Introduction

Advanced high density WDM networks require a high degree of flexibility in wavelength routing and multiplexing. Acousto optic devices have been demonstrated to be key components to fulfill this needs, due to their tunable multi-wavelength functionality. They have been successfully applied already in the European RACE-project "MWTN" (1994, fully integrated polarization independent filters and 2###2 switches) and the North-American ARPA-funded project "MONET" (1995, hybrid devices). In this paper we present the latest fundamental progress in the development of acousto optic devices, based on the results obtained from the OADM nodes in the Italian PROMETEO field trial and the MOSAIC experimental network testbed.

The PROMETEO testbed

The PROMETEO WDM field trial has been started in 1996 to demonstrate a completely optical networking comprising network protection and flexible add/drop functions /1/. Different technologies supplied by various manufacturers have been integrated.

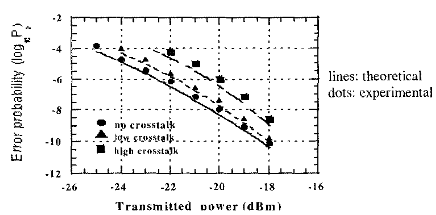
Fig 1: The PROMETEO Network Architecture



The network installed at Rome consists of a two fiber self healing ring with three OADM-nodes (Figure 1). The ring has been designed to carry at least four wavelengths (SDH-STM 16). Two 2###2 acousto optic switches (AOTS) of an early generation /2/ are forming the wavelength selective add/drop building block of the two flexible OADM nodes. The third node is a fixed OADM. The typical characteristics of the used apodized polarization independent AOTS are: Gaussian-like filter function with 2.1 nm FWHM; incoherent crosstalk: < 20 dB, extinction (coherent crosstalk): 18 dB; fiber-to-fiber loss < 6 dB.

In the standard operating condition the wavelength channels are fed from the working ring via the 2###2 protection switch to the 2###2 wavelength selective AOTS. The channels passing through the node are switched in the cross-state, whereas the dropped channels remain in the bar-state. The added channels are simultaneously inserted through the AOTS into the ring. Initial calibration of the wavelength corresponding driving frequencies is performed by sweeping the AOTS over the transmission channels and subsequently locking to the pilot tones. The filtering effect for the bypassed channels reduces the accumulation of ASE circulating in the network and hence improves significantly the signal-to-noise ratio. A gain in the power budget of at least 1 dB can be achieved using the multichannel filtering function. After initialization, the network has been operated for many days without any detected errors, hence the error probability can be estimated to be less than 10^{-14}. The good matching between the theoretical and experimental error probability in forced best- and worst-case crosstalk conditions is shown in Figure 2.

Fig. 2: Transmission characteristics under different crosstalk conditions



A 0.8 nm-misalignment of one of the transmission channels during the demonstration did not introduce any power penalty, showing the detuning tolerances of the AOTS.

The MOSAIC testbed

The MOSAIC Network Testbed has been under investigation since 1995 /3/. MOSAIC is an add/drop multiwavelength network that supports the optical layer of second generation optical networks. This testbed was designed to study the issues of scalability, cascadability, bit-rate transparency, the trade-offs between optical and electronic switching, and optoelectronic wavelength translation.

Two types of ADM nodes have been designed and implemented as shown in Figure 3. The Type I ADM can pass a lightpath from the input fiber to the output fiber or add/drop data between the network and a local host. The Type II ADM, in addition to performing the basic functions of a Type I ADM, can route a lightpath to another optical network or subnet. Type I and II ADMs support multiwavelength add/drop, regeneration and wavelength-translation.

In the network demonstration, multihop lightpaths are established giving an end-to-end bit error rate of better than

10^{-9} at 1.2 Gbit/s. The reconfigurable add/drop multiplexer, shown in Figure 4, is based on a novel dilated node architecture constructed from two cascaded 2 x 2 standard AOTS /4/. An analog opto-electronic crossconnect drives a 10 wavelength laser array transmitter up to 2.5 Gbit/s per wavelength. Both add/drop multiplexers support bit-rate transparent 2R optoelectronic regeneration as well as wavelength translation.

Fig. 3: MOSAIC Network Architecture

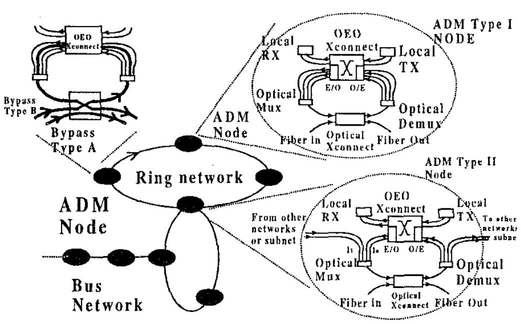
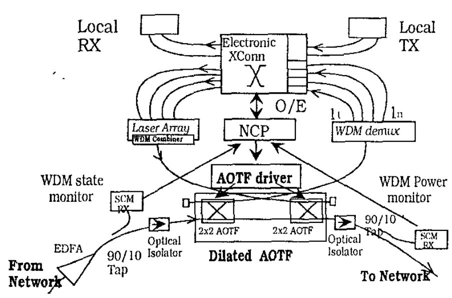


Fig. 4: The reconfigurable Add/Drop Multiplexer



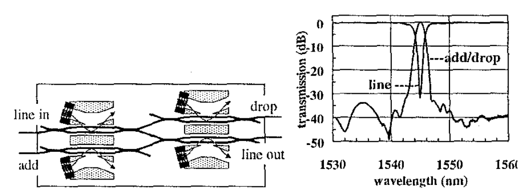
The first stage AOTS independently routes input wavelengths to the second stage or to the wavelength demultiplexer. The second stage AOTS is used to improve the signal extinction ratio, decrease inter- and intra-channel crosstalk from the first stage and to route wavelengths from the optoelectronic-optic crossconnect to the network. This configuration exhibited better than 30 dB rejection on the dropped channel and a suppression of more than 18 dB on the sidelobes at the drop port. This rejection is further improved by the WDM demux with a measured power penalty less than 0.3 dB at $P(e) = 10^{-9}$ for coherent and incoherent crosstalk. During multichannel operation, the switching performance will degrade due to the superposition of multiple acoustically induced traveling wave gratings inside the device. To measure the impact on lightpath performance, BER measurements on 2.5 Gbit/s On/Off keyed signals were made. A signal at $\lambda_0 = 1556.8$ nm was dropped by applying an RF signal at f_0 and adding a second RF signal at f_1. For $\Delta f = 400$ kHz ($\Delta\lambda = 3.3$ nm) the power penalty at BER equal to 10^{-9} is greater than 2 dB. The penalty reduces to below 0.3 dB for $\Delta f = 600$ kHz ($\Delta\lambda = 4.9$ nm) allowing alternate channels in a 3.2 nm system to be dropped simultaneously with acceptable BER. A simple readjustament of the drive frequencies allows to drop channels of 3.4 nm spacing without significant penalty.

Discussion

Dynamic optical channel power equalization, improved intra-band crosstalk rejection and agile wavelength selectivity have been found to be fundamental features of the AOTS based OADMs. A further interesting application is the possibility to perform drop- and pass-function simultaneously by reducing the conversion efficiency. In this condition the AOTS acts as a splitter with variable splitting ratio.

From various experiments performed in the ring fundamental specifications for a/o devices for current and future high density WDM networks have been obtained. Novel dilated integrated acousto optic add/drop multiplexers based on a double-y configuration are now available for 400 GHz channel spacing (Figure 5).

Fig. 5: Acousto Optic Add/Drop Multiplexer with enhanced Performance



Such devices provide 1.2 nm FWHM, more than 30 dB sidelobe suppression, 30 dB intra-band crosstalk rejection and even more than 30 dB inter-band crosstalk rejection. The small bandwith allows simultaneously dropping of channels spaced by at least 2.5 nm without introducing any penalty. The crosstalk between add- and drop port is negligible due to the spatial separation of the ports. Fiber-to-fiber insertion loss is less than 5 dB and polarization dependent loss is typically 0.3 dB. Such characteristics are more than sufficient for advanced network applications.

Conclusion

The experimental results obtained from two recent OADM network demonstrators allowed the realization of high performance dilated acousto optic add/drop multiplexers for 400 GHz channel spacings. 200 GHz devices are currently under development. Special techniques are under investigation to reduce further the channel spacing to 100 GHz and 50 GHz.

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