Wavelength-tunable add-drop multiplexers using fiber Fabry-Pérot tunable filters for bidirectional wavelength-division multiplexing networks

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Abstract. A novel wavelength-tunable add-drop multiplexer (ADM) using fiber Fabry-Pérot tunable filters (FFP-TFs) for the bidirectional wavelength division multiplexing (WDM) network is proposed and demonstrated. The wide tuning range, low loss, and low polarization dependence properties of the FFP-TFs are used for the ADM operation. The experimental results show that the wavelength tuning range of this wavelength-tunable ADM can be up to 40 nm. The bit-error-rate performance of the dropped and pass-through channels for a 2.5 Gbit/s system shows the feasibility of ADM. [DOI: 10.1117/1.1787835]

Subject terms: wavelength-tunable add-drop multiplexer; fiber Fabry-Pérot tunable filter; wavelength division multiplexing.

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1 Introduction

The wavelength-tunable add-drop multiplexer (ADM) is one of the essential components for optical networks in wavelength-division multiplexing (WDM) systems, especially in a reconfigurable WDM network.[1–6] It is able to access all wavelengths from and to the WDM networks and provides the flexibility to satisfy the reconfiguration requirement and to enhance network survivability. In WDM networks, among desirable features for such components are wide tuning range, low insertion loss, narrow channel bandwidth, low electric power consumption, and polarization independence. Several different structures of wavelength-tunable ADMs have been reported using tunable fiber gratings[1–3] and integrated optic tunable filters.[4–6] However, it was difficult to achieve a wide tuning range and low insertion loss.

Bidirectional WDM networks attract a great deal of attention due to their cost-effectively enhanced capacity and possibility of self-healing functions.[7] In this paper, we proposed a novel wavelength-tunable ADM using fiber Fabry-Pérot tunable filters (FFP-TFs) for bidirectional WDM networks. The channel spacing and number of channels in the proposed ADM depend on the tunable range and bandwidth of the FFP-TF. The FFP-TF is an all-fiber device having[8,9] wide tunable range (>100 nm), low insertion loss (<2 dB), and low polarization dependence (0.1 dB). Furthermore, the FFP-TF provides a highly selective filter (1 MHz), which makes it very attractive for dense WDM networks.[10] In contrast with the conventional ADM, our scheme has a wide tunable range, narrow channel bandwidth, low insertion loss, and low electric power consumption. The principle and performance of the wavelength-tunable ADM operated in a WDM system are reported.

2 Experiments

Figure 1 shows a schematic diagram of the proposed wavelength-tunable ADM using FFP-TFs. It consists of two FFP-TFs, two 1×2 optical switches (SW), two four-port optical circulators (C), and two 1×2 couplers. First, multiplexed N wavelength ($\lambda_1\lambda_3,\ldots,\lambda_{2N+1}$) are led to the FFP-TF through the optical circulator. Then only the optical channel (λ_{2N+1}) can pass through the FFP-TF. The other optical channels are reflected by the FFP-TF and sent to the next port of the optical circulator. Optical channels leaving the optical circulator are sent to the 1×2 coupler and multiplexed with the added optical channel (λ_{2N+1}). Finally, optical channels leave the ADM through the other four-port optical circulator. To protect all optical channels operating at normal when the ADM breaks, the 1×2 optical switches are used to switch the wavelength-tunable ADM on and off.

Figure 2 shows the experimental setup. Since the configuration of the proposed wavelength-tunable ADM is symmetric and there is no interference between counter-propagating signals in the system, we perform experimental demonstration of only one side of the ADM. The central wavelength of the FFP-TF (Micron Optics, Inc.) is tuned by the voltage applied to the piezoelectric transducer. The FFP-TF operating voltage ranged from 0 to 11.2 V can select the tunable range from 0 to 49.8 nm. The insertion loss of the FFP-TF is 1.9 dB. The free spectral range and 3-dB bandwidth of the FFP-TF are 49.8 and 0.4 nm, as shown in Fig. 3. The tuning speed is about 5 ms, corresponding to 10 nm/ms. The polarization-dependent loss of the FFP-TF and the optical circulator are below 0.22 and 0.04 dB, respectively.

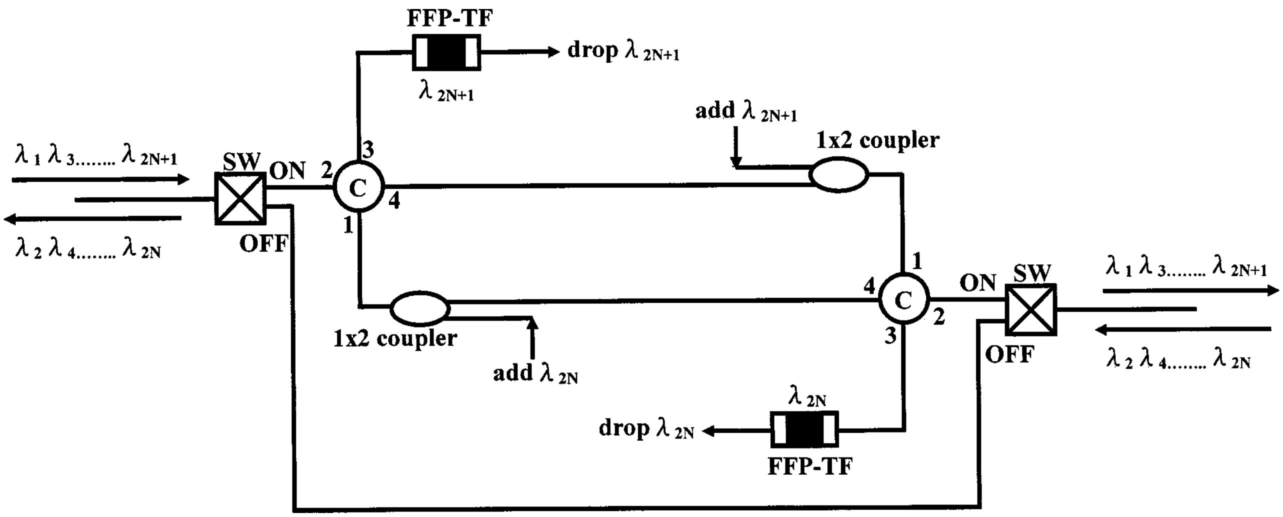

Fig. 1 Schematic diagram of the proposed wavelength-tunable ADM: C, optical circulator; SW, 1×2 optical switch; FFP-TF, fiber Fabry-Pérot tunable filter.

Four cw lasers operate at $\lambda_1 = 1520.05$ nm, $\lambda_2 = 1528.15$ nm, $\lambda_3 = 1552.45$ nm, and $\lambda_4 = 1560.05$ nm. The central wavelengths of the FFP-TF is tuned to 1520.05 and 1560.05 nm and the measured output spectra at different points are shown in Figs. 4 and 5, respectively. Figures 4(a) and 5(a) show the optical spectra obtained at the port IN. The input power of each optical channel is around -10 dBm. Figures 4(b) and 5(b) show the output spectra passing through the FFP-TF. The heterodyne crosstalk between the dropped channel and the other channels is up to -30 dB. Figures 4(c) and 5(c) show the optical spectra obtained at the port OUT. The average insertion loss of the passthrough channels is 2.1 dB. Furthermore, the minimum channel spacing in our ADM depends[10] on the finesse of the FFP-TP. We can select a different finesse of the FFP-TP for a practical application.

Figure 6(a) shows the experimental configuration of one channel drop/pass to demonstrate the system performance. A distributed feedback laser at 1552.45 nm is externally modulated by a 2.5-Gbit/s non-return-to-zero pseudorandom binary sequence (pattern length $2^{31}-1$). A 2.5-Gbit/s optical receiver is used to measure the system performance. Figure 6(b) shows the measured bit error rate of the ADM against the received power for the back-to-back, dropped channel, and passthrough channel, respectively. For the measurement of passthrough channel, the central wavelength of the FFP-TF is tuned 4.2 nm away from 1552.45 nm by applying voltage. The system performance confirms the feasibility of the ADM.

The demonstrated results are restricted by the FFP-TF of our laboratory. Nevertheless, narrower bandwidth and wider free spectral range of the FFP-TF also can[9,10] be selected for WDM systems. For long-term stability of the proposed ADM, an optical feedback system[2] can be adopted to monitor and control the central wavelength of the FFP-TF. The feedback system can improve the ADM for practical applications.

3 Conclusion

We demonstrated a novel and simple scheme to construct a wavelength-tunable ADM for bidirectional WDM networks. This wavelength-tunable ADM is implemented by using FFP-TFs with wide tunable ranges incorporated with optical circulators. The wavelength-tunable ADM is easily tuned dynamically. The tunable range of 40 nm was experimentally demonstrated. The bit-error-rate measurements show that our purposed ADM is suitable for a 2.5-Gbit/s system.

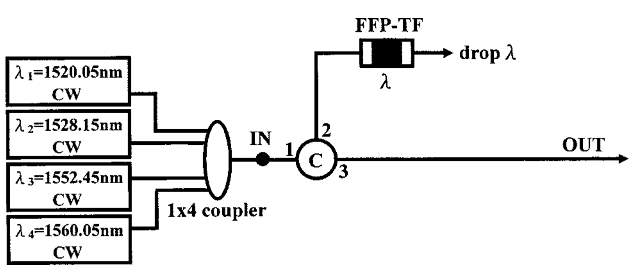

Fig. 2 Experimental setup of the wavelength-tunable ADM.

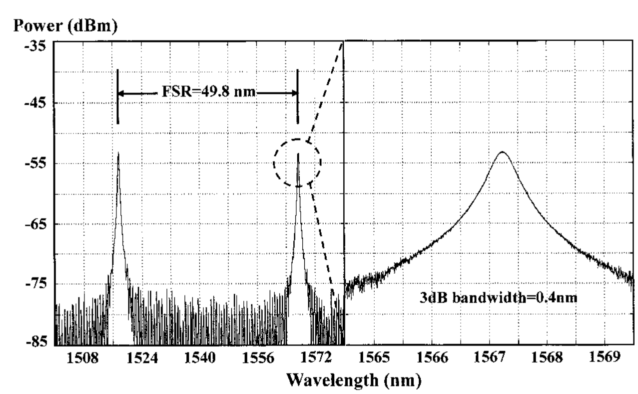

Fig. 3 Output spectra of the FFP-TF.

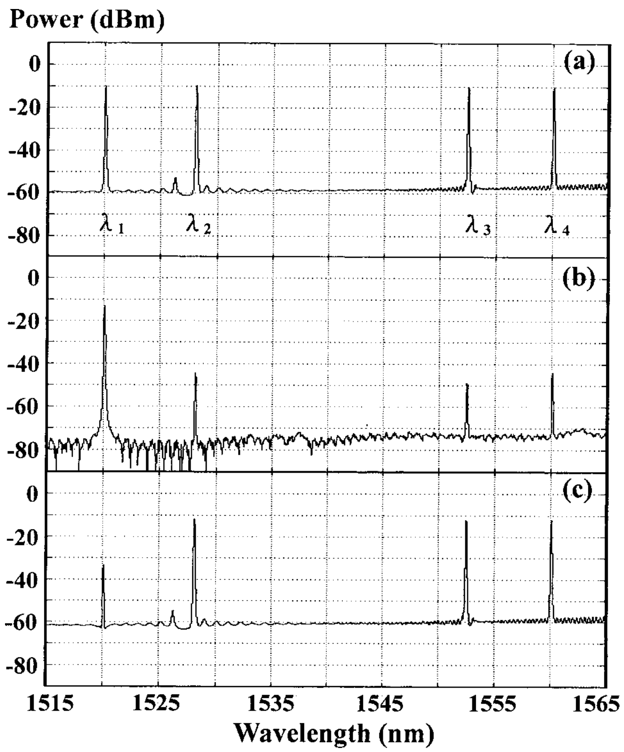

Fig. 4 Output spectra obtain at different points in Fig. 2: (a) at port IN (b) at the drop port when the optical channel λ_1 is dropped, and (c) at port OUT.

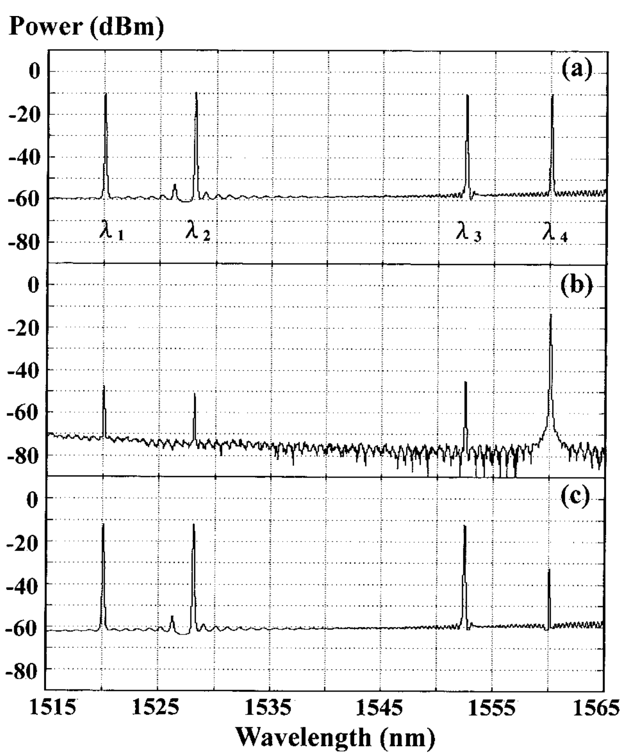

Fig. 5 Output spectra obtain at different points in Fig. 2: (a) at port IN, (b) at the drop port when the optical channel λ_4 is dropped, and (c) at port OUT.

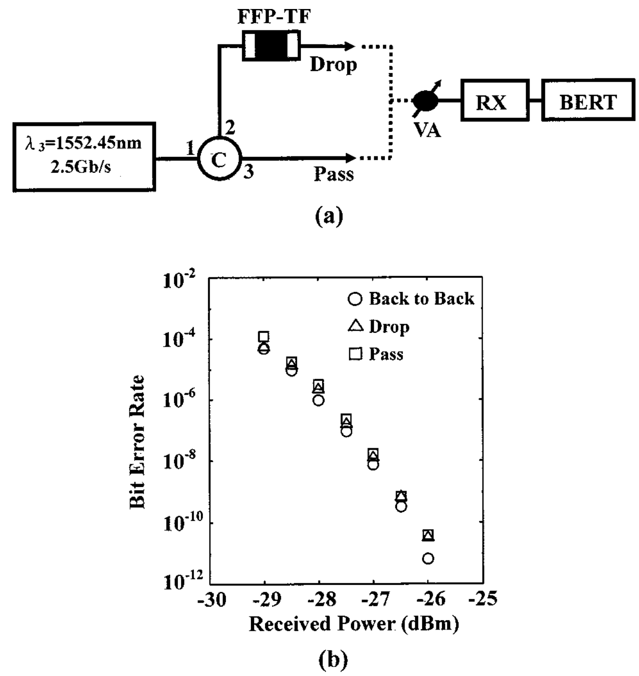

Fig. 6 (a) Experimental setup of bit-error-rate test and (b) measured bit error rate at 1552.45 nm in a 2.5-Gbit/s modulated system: VA, variable optical attenuator; RX, optical receiver; BERT, bit-error-rate test set.

Acknowledgments

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