Optical Add/Drop Multiplexers based on X-crossing Vertical Coupler Filters

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Optical add/drop multiplexers (OADM) [1] are the key components for WDM systems to select and route different channels. Various OADM configurations have been investigated, including fiber or polymer gratings with circulators [2], Mach-Zehnder interferometer with gratings [3], cascaded unbalanced M-Z structures [4] and arrayed waveguides [5]. Although those structures have characteristics that can satisfy the requirements of WDM systems, complicated configuration and cost will be the main challenges for their applications. InGaAsP/InP vertical coupler filters as OADMs are of particular interest because of their inherent monolithic integration with other optoelectronic devices, simple configuration and large wavelength tunability. Although they have already been demonstrated long time ago[6, 7], some inherent obstacles are still limiting their applications. For fiber optic communication systems, these filters must be coupled to conventional fibers. However direct coupling is impossible since in traditional vertical coupler filters the spacing between the two waveguides is only about 1μm. To separate the two waveguides, a grating-assisted vertical coupler filter was proposed recently [8]. This required a complex regrowth. Another problem is a high sidelobe (-9dB) existing in conventional straight vertical coupler filters due to the uniform coupling along the length. To reduce the sidelobe the two waveguides should be gradual coupled. This is quite difficult to realize using conventional techniques. In this paper, a simple OADM based on X-crossing InP/InGaAsP vertical coupler filter is proposed and demonstrated. With X-crossing configuration, the two input and output waveguides can be laterally separated for direct coupling to fibers, and the side-lobe level is reduced to -26dB.

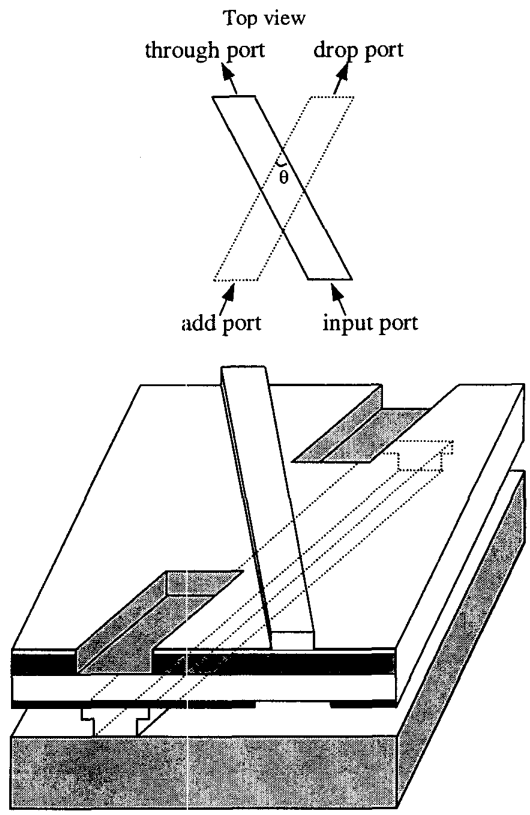

Figure 1. The schematic drawing of an OADM based on an X-crossing vertical coupler filter.

Figure 1 shows the schematic drawing of an OADM. The filter consists of two vertically stacked waveguides with different core region's quaternary compositions. The lower guiding layer is 0.21μm thick InGaAsP that has a bandgap at 1.41μm and the upper guiding layer is 1μm thick InGaAsP with bandgap at 1.1μm. X-crossing structure is fabricated by wafer bonding technique and double-sided wafer processing. Using wafer bonding, a conventionally processed epitaxial layer structure is inverted and bonded to a new host substrate. After removing the original substrate, the exposed backside of the epitaxial structure can be processed as well. This technique enables fabrication of 3D photonic integrated circuits.

The device structure was grown by metal organic chemical vapor deposit (MOCVD) on InP substrate. The detailed structure is shown in figure 2. First, the lower InGaAsP (λg=1.41μm) ridge waveguides are formed by RIE, the ridge height is 0.8μm and its width is 3μm. The 1.4μm quaternary layer below the top 1.1μm InGaAsP waveguides at two ends of the sample is removed by another chemical etching. Then the sample is inverted and bonded to a second InP substrate under pressure and H_2 atmosphere. After removing the original substrate, the upper 1.1μm quaternary waveguides are fabricated and the 1.1μm InGaAsP layer above the lower 1.4μm InGaAsP waveguide region is removed as before.

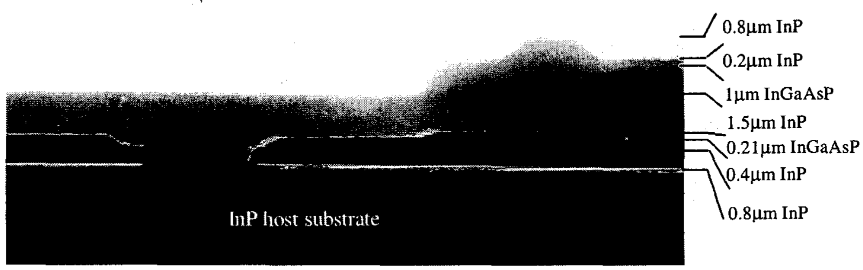

Figure 2. The SEM picture of the output facet

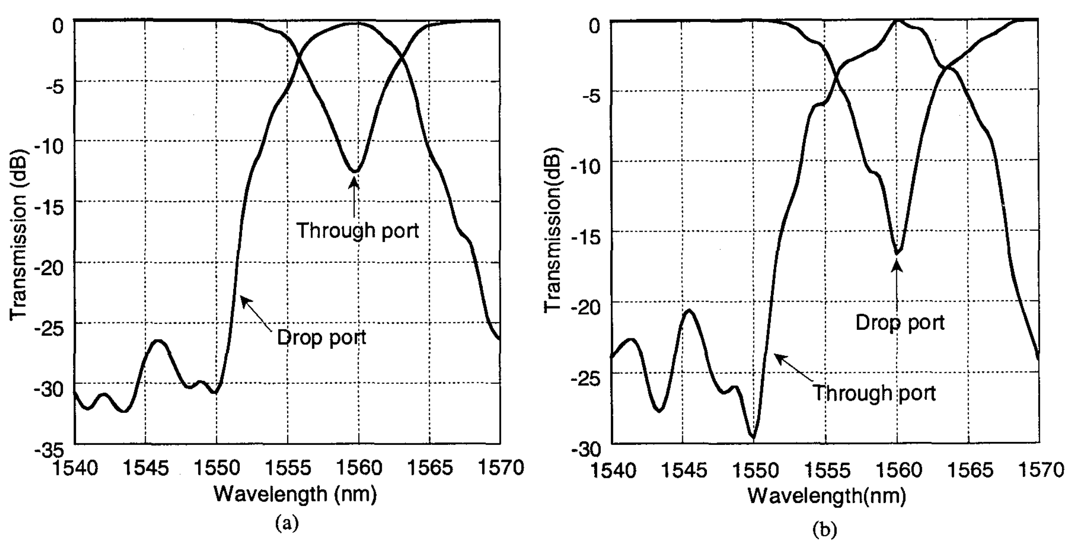

Figure 3. The transmission spectra of an OADM with X-crossing angle of 0.25°

(a) Input port to drop and through ports.
(b) Add port to through and drop ports.

Figure 2 shows the SEM picture of the output facet of an OADM with the crossing angle of θ=0.1°.

A tunable laser with a polarization controller was used as a light source to measure the performance of OADMs. Single mode fibers were butt-coupled to the input and output waveguides. Figure 3 (a) shows the transmission spectra from input port to drop and through ports of an OADM with the crossing angle of 0.25 °. The 3dB bandwidth is 6nm. The sidelobe level has been suppressed to below -25dB in this device. There is more than 16dB improvement compared to uniform coupling. Theoretical calculation predicts that the sidelobe level can be reduced to less than -40dB. The transmission spectra from add port to through and drop ports are also shown in figure 3(b). The coupling efficiency from add port to through port is above 97%, that strongly depends on the crossing angle. These OADMs are temperature tunable at a rate of 0.42nm/ °C.

In conclusion, a very simple OADM based on X-crossing InGaAsP/InP vertical coupler filters with laterally separated input and output waveguides has been successfully demonstrated. The sidelobe level has been reduced to -26dB and the coupling efficiency is above 97%. Compared to other OADM structures, X-crossing vertical coupler filters can avoid complicated material regrowth and grating fabrication. It is an attractive candidate as OADM in WDM networks.

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