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A Planarized Two-Dimensional Multi-Wavelength Routing Network with 1-to-many Cascaded Fanouts

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Wavelength-division (de)multiplexer (WD(D)M) is a pivotal bandwidth enhancement component in optical fiber communications and optical sensor systems. Various types of optical WD(D)M have been proposed and demonstrated.[1-13] When the WDDMs are applied to the fiber-to-home network[14] or multi-sensors system[15], it is nessecerry for them to be able to route seperate wavelength channels and to distribute each channel to many users. Photopolymer-based substrate guided wave optical interconnects, using photopolymer volume holograms combined with total internal reflection (TIR) in waveguiding substrates, have been demonstrated as efficient approaches for intra- and inter-module interconnections, optical clock distributions, optical backplane buses, and optical networks[16-18]. In this paper, a planarized two-dimensional (2-D) WDDM serving the functions of wavelength seperation and 1-to-many fanouts is demonstrated. In our design, stacked volume holograms are employed as the input couplers to steer input optical signals with different wavelengths to their desired directions, and then coupled-out by output HOE arrays. This two-dimensional network configuration having both the input and output HOEs integrated on one waveguiding plate fulfills simultaneously wavelength seperation, routing, and optical signal distribution. Experimental results of routing and distributing three optical channels at wavelengths of 760 nm, 790 nm, and 820 nm are presented.

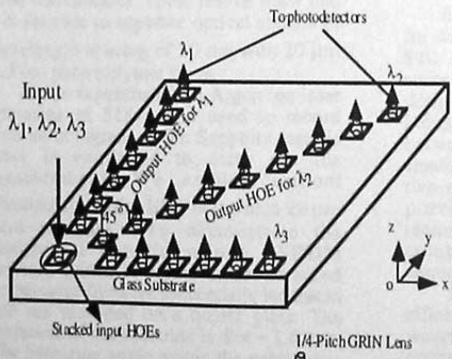

Fig. 1 Schematic diagram of a two-dimensional WDDM distributing network.

Figure 1 shows a schematic diagram for a planarized two-dimensional WDDM network. The input and the output volume holograms are integrated on the same waveguiding substrate at their designated positions. Three stacked volume holograms are used as the optical wavelength routing filters to couple three input optical signals λ_1, λ_2, and λ_3 into their designed routing directions with an angle of 45° between them in XY plane as indicated in Figure 1. The bouncing angle within the waveguiding substrate is 48°, greater than the critical angle of the substrate.The separated optical signals propagate within the waveguiding substrate with total internal reflection and are distributed to their respective destinations, and then coupled out surface-normally by the three arrays of cascaded volume holograms at the surface-normal direction. Many users may share the same source with this distributed 2-D WDDM.

For this substrate guided wave optical interconnect with the surface-normal configuration, the diffraction angle of the volume hologram is designed to be 48° in a quartz substrate while optical signal is incident from the surface-normal direction with $\theta = 0$. The deviation of operating wavelengths and the incident angle θ are evaluated using coupled wave theory[19]. The simulation results of diffraction efficiencies versus the wavelength deviation from central wavelength 760 nm, 790 nm, and 820 nm of an s-wave were done for DuPont photopolymer films HRF 600x001-20with refractive index n = 1.52. The film thickness is 20 μm. The refractive index modulation is $\Delta n = \sim 0.0166$ for the three wavelengths. These results show that it is feasible to seperate optical signals of wavelength spacing of 30 nm with 20 μm DuPont photopolymer films.

In our experiment, An Argon ion laser operating at 514 nm is used to record volume hologram. A Ti: Sapphire tunable laser is employed to carry out the measurement. We employ DuPont photopolymer film HRF 600 with a 20 μm film thickness. To demonstrate the conceptual two-dimensional WDDM network shown in Figure 1, three stacked holographic films are sequentially laminated and are recorded on a quartz plate. The thickness of the substrate is d' = ~ 1.6 mm. The bouncing angle within the substrate is 48°. The angle between the adjacent routing directions is designed to be 45°. Three arrays of output holographic grating couplers are fabricated along the desired routing direction for reconstruction wavelength at 760 nm, 790 nm and 820 nm, respectively. By taking advantage of the fact that the collimated laser beam is with a Gaussian intensity profile during hologram recording, we are able to record the output couplers with relatively uniform fanout distribution for both arrays.

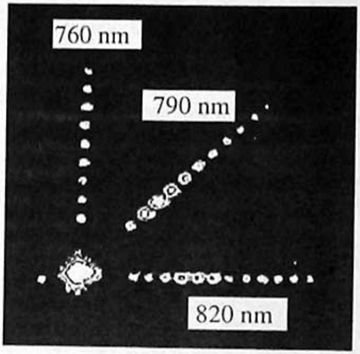

Figure 2 Experimental results of the two-dimensional WDDM device while operating at 760 nm 790 nm, and 820 nm.

Figure 2 shows the experimental results for device operates at 760 nm, 790 nm, and 820 nm. The three wavelengths are succesfully separated and directed to their designed directions by the three stacked input holographic grating coupler. The crosstalks between two channels are measured to be smaller than -20dB. It is obvious that this two-dimensional network configuration provides a robust, reliable, surface-mountable, and cost-efficient device with combined functions of wavelength demultiplexing and distributing.

In conclusion, we demonstated a cost-efficient and user-sharing two-dimensionanal wavelength demultiplexing and distributing optical network, with which optical signals at 760 nm, 790 nm, and 820 nm are seperated and diffracted into the waveguiding plate in three different routing directions by three stacked DuPont holographic gratings, distributed within the glass substrate with total internal reflection, and coupled out of the substrate to each user by output holographic grating. The crosstalks are measured to be <-20dB. The relatively uniform fanout energy distribution is pivotal to the integration with photodetector arrays for practical system designs. The monolithic integration of the input and output couplers on a waveguiding substrate provides a robust architecture against environmental and mechanical perturbations. Furthermore, it is possible to realize multi-wavelength channels routing and distribution involving 0.8 μm, 1.3 μm and 1.55 μm wavelengths. by stacking holographic gratings as input wavelength seperating and routing couplers and by integrating arrays of output couplers at desired wavelengths.

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