Polymeric Waveguide Hologram Based 4-channel Coarse WDM for Satellite Optical Communications

Lanlan Gu, Feng Zhao, Zhong Shi, Jian Liu*, Ray T Chen, Fellow IEEE

Microelectronics Research Center, Department of Electrical and Computer Engineering, The University of Texas at Austin, Austin, TX 78758
*PolarOnyx, Inc., Sunnyvale, CA 94089

Summary

For data rates above 1Gbps, optical intersatellite links (ISLs) outperform conventional RF links in terms of high data rate, huge transmission capacity, low power consumption, small size and light weight. A lot of previous work was done based on 0.8 μm technology [1]. Current plans call for continuous investigations of medium bit rate (300 Mbps) systems using 0.8 μm technology and new investigations of high bit rate (1.2 Gbps) systems using 1.5 μm technology [2], [3]. Coarse wavelength-division multiplexing (CWDM) technology, which is developed for storage access networks (SANs), finds its great potential for applications in the space based optical communication system. In this paper, a coarse photopolymer grating-based WDM device is proposed and developed to work for a simple point-to-point data transfer between two satellites. The four-channel CWDM device reported herein provides two data streams at 0.83μm and 1.55μm, an inter-satellite tracking channel at 1.06μm, and an intra-satellite communication channel at 1.34μm. This device works properly in the current optical satellite medium bit rate system based on 0.8 μm technology and its performance can also be maintained in the future high bit rate system using 1.5 μm technology.

The schematic and the real device picture of the four-channel CWDM device using four photopolymer-based holographic gratings in conjunction with substrate-guided waves are shown in Fig. 1. An aluminum-coated beveled edge is used to couple optical signals into the wave-guiding plate with a bouncing angle larger than the critical angle of total internal reflection (TIR) of the glass substrate. Four volume holographic gratings are recorded to provide surface-normal fan outs for four different wavelengths, i.e. 0.83μm, 1.06μm, 1.34μm and 1.55μm. Independent zigzag guided beams of their designated wavelengths are selectively coupled out from one of the four outputs at their Bragg angles. The wavelength separation and channel spacing for our CWDM can be designed depending on different requirements to the targeted applications. In this work, a beveled edge is designed at the input end to maximize the coupling of the optical signal into the glass substrate. The beveled edge is coated with aluminum film with reflection efficiency higher than 99%. Wedge angle is designed at 22.5 ° to router normal incident signals into the wave-guiding plate shown in Fig. 1 (b) with a TIR bouncing angle at 45 °. In this work, 4 mm thick optically flat glass plate is used as the wave-guiding plate for all four wavelengths. To facilitate the output coupling and packaging, physical separation of the adjacent channels is designed to be 8mm. The total length of this device is 4cm. The light weight and small size of this device makes it promising for space-based application where a reduction in the mass and volume of the payload is always a concern.

Fig. 2(a) shows an experimental demonstration of a four-channel CWDM operating at 0.83μm, 1.06μm, 1.34μm and. 1.55μm. The image is taken by an infrared camera under the randomly polarized input optical signals. A TV lens with focal length of 25mm is used to enable the responding area of camera to accommodate all the four fan outs. It is seen from Fig. 2 (a) that four channels are completely separated while good mode qualities are maintained. Diffraction efficiency of each channel is measured, which is shown in Fig. 2 (b). This device is polarization sensitive. For TE wave, channel efficiencies at 0.83μm, 1.06μm, 1.34μm and 1.55μm are 55%, 40%, 35% and 45%, respectively. For TM wave, channel efficiencies are 45%, 30%, 25%, 30%, respectively. The polarization dependence of the diffraction beam is due to the different boundary conditions between the TE and TM waves, which can be analyzed in details by couple mode theory [4].
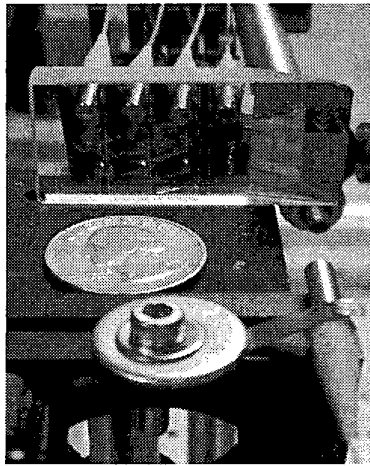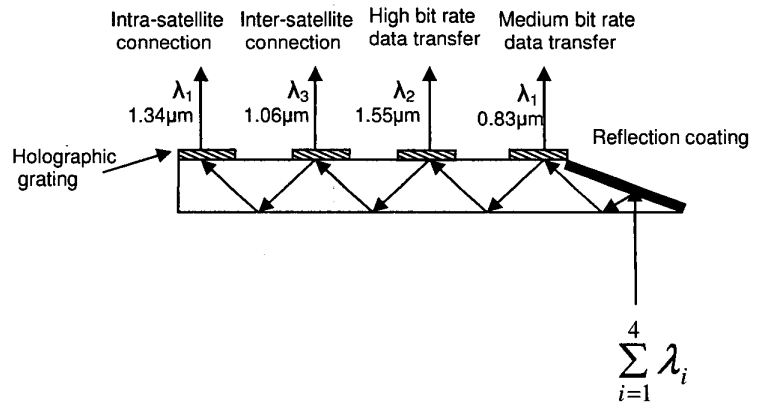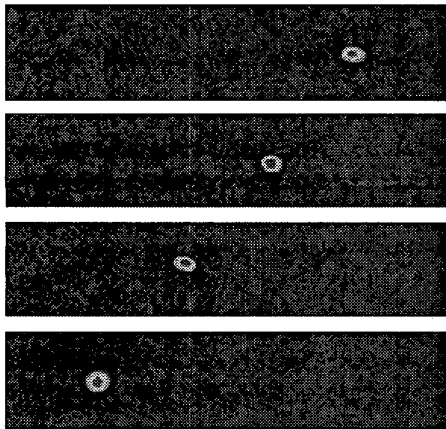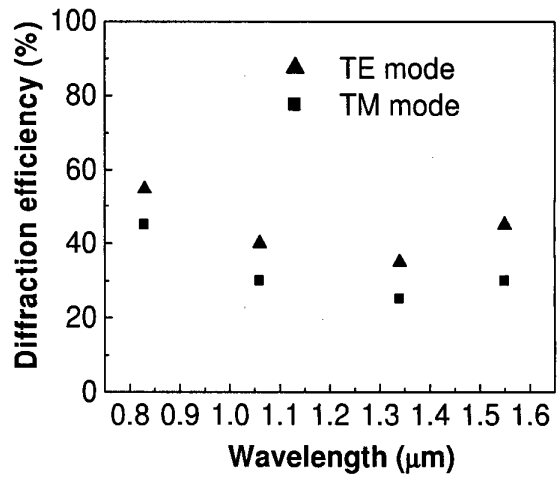
Fig. 1

Four–channel CWDM device using four photopolymer-based holographic gratings in conjunction with substrate-guide waves: (a) device picture; (b) geometric structure.

Fig. 2

(a) IR images of the light spots for CWDM working at 0.83μm, 1.06μm, 1.34μm and. 1.55μm; (b) measured diffraction efficiency of each channel for both the TE and TM waves.

References

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