# Four Channel Multimode Wavelength Division Demultiplexer (WDM) System Based on Surface-normal Volume Holographic Gratings and Substrate-guided Waves

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## ABSTRACT

We demonstrate a four channel integrated wavelength division multiplexer (WDM) and demultiplexer(WDDM) based on volume holographic gratings and substrate-guided waves at near IR wavelengths. The four operating wavelengths are centered at 750, 780, 810 and 840 nm respectively. The WDM and WDDM are demonstrated using 50/125 multimode fibers. The channel-to-channel crosstalk level is measured to be less than -40 dB. The system insertion losses are -23dB, -21dB, -20dB, -22dB respectively for 750 nm, 780 nm, 810 nm and 840 nm.

## 1. SYSTEM DESCRIPTION

Wavelength division multiplexing (WDM) and demultiplexing (WDDM) techniques are the two key technologies for upgrading optical communication system bandwidth. The use of WDM technologies not only provides high speed optical communication links, but also provide advantages such as higher data rates, format transparency, and self-routing. Over the past twenty years, many kinds of WDDM device technologies have been developed and demonstrated [1-4]. WDDM devices using dispersive photopolymer or dichromated gelatin (DCG) volume holographic gratings have been recently reported [5-7]. In this paper, we report an integrated four-channel multimode fiber compatible WDDM system with four semiconductor lasers operating at 750, 780, 810 and 840 nm, respectively. The device is demonstrated using the combination of graded index (GRIN) lenses, photopolymer based holographic gratings and substrate-guided waves.

A four channel WDM/WDDM is designed for multimode fiber transmission systems. Multimode fibers are widely used in short haul optical communications. The schematic of a four channel wavelength division multiplexed and demultiplexed optical transmission system is shown in Fig. 1(a). The four discrete wavelengths are provided by semiconductor laser arrays. The four wavelengths are multiplexed into one 50 μm multimode fiber for transmission. At the receiving end, a wavelength division demultiplexer is used to separate the discrete wavelengths for O/E conversion. The integrated four channel polymer holographic grating based WDDM structure is shown in Fig. 1(b). At the input end, the surface-normal incoming multiple wavelength light is collimated by a quarter pitch GRIN lens and diffracted by the volume holographic grating into substrate guided waves. The input holographic grating is designed using the phase-matching principle. The volume holographic grating has slanted fringes induced by the refractive index modulation inside the photopolymeric film. Since the input holographic grating is dispersive, the input multiple wavelengths are diffracted into different bouncing angles. The substrate-guided lights are separated spatially as they propagate along the waveguiding plate. The device length should be long enough so that the output spots will not overlap each other[8]. The collimated spot size is determined by the numerical aperture of the fiber and the GRIN lens. At the output end, they are coupled out surface-normally by a holographic grating. The light can be detected with a photodiode array. Since the substrate-guided waves maintain the mode symmetry along the optical path, the output light spots can be efficiently coupled into fibers using focusing GRIN lenses at the output end. Due to the beam reversal principle, the reverse use of the WDDM device automatically results in a WDM device. The advantage of this device structure is the adjustability of channel wavelength separation. For any desired wavelength separation, we simply change the device length or the input hologram diffraction angle to achieve low crosstalk output light spots without changing device structure. The use of GRIN lenses and surface-normal coupling avoid pigtailing from waveguide edges and free space packaging, thus result in more rugged and reliable devices.

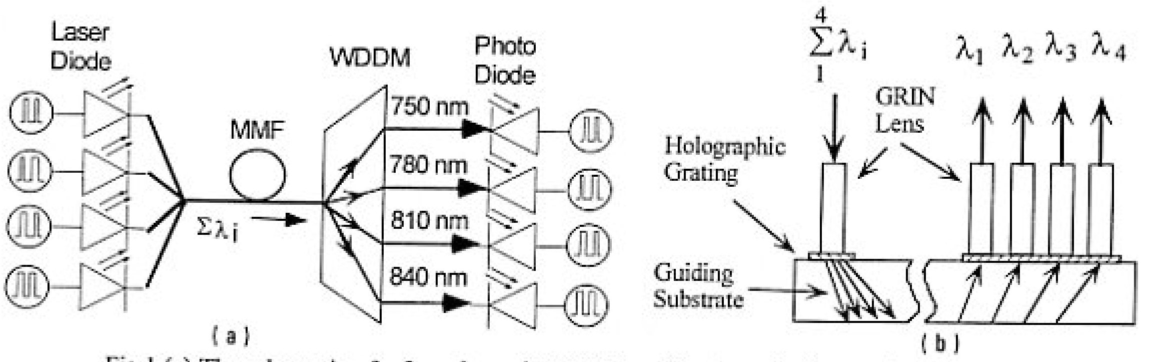

Fig.1 (a) The schematic of a four channel WDDM multimode optical transmission system,
(b) The WDDM based on GRIN lenses, holographic gratings and substrate-guided waves.

## 2. EXPERIMENTAL RESULTS

The WD(D)M devices demonstrated previously are mostly using tunable laser sources. In our experiment, the four discrete near IR wavelengths of 750 nm, 780 nm, 810 nm and 840 nm are provided by four SHARP LT series edge-emitting semiconductor lasers packaged with ST receptacles. A 30 nm wavelength separation is used to avoid crosstalk caused by temperature-induced wavelength changes. Each laser diode has a 3 mw output power rating. The light from each edge-emitting laser is lens-coupled into a multimode fiber. Due to the mode mismatch between the edge-emitting laser diode and the multimode fiber, 0.5mw is normally coupled into the 50/125 μm graded index multimode fiber from a laser. At the input end, four individual wavelengths are wavelength-division-multiplexed into a multimode fiber. A photo of the wavelength-division-multiplexing (WDM) module is shown in Fig. 2(a). The multiplexed light propagates through a spool of multimode fiber with 2km length. It is then connected to a fiber-pigtailed quarter pitch GRIN lens using an ST connector. The light is collimated by the quarter pitch GRIN lens with a diameter of 2 mm. The volume holographic grating is fabricated using 10 μm thick DuPont photopolymer films with a maximum refractive index modulation of up to 0.02. A 514 nm Argon Ion laser is used to crosslink the photopolymer film and the center replay wavelength is selected to be 795 nm. An average diffraction efficiency of 23%, 38%, 37% and 24% is experimentally confirmed for randomly polarized light operating at 750, 780, 810 and 840 nm channels separately. The four channel WDDM is integrated on a BK7 glass substrate glass with a thickness of 7 mm. A CCD-based image system is used to measure the output light parameter. A picture of the light output spots at device output length of 200 mm is shown in Fig. 2(b). The measured crosstalk is less than -40 dB. The system insertion losses are -23dB, -21dB, -20dB, -22dB respectively for 750 nm, 780 nm, 810 nm and 840 nm. We can see that mode symmetry is maintained, which promises a high coupling efficiency to a fiber by using a focusing GRIN lens. The symmetrical mode dot focused on the planar GRIN lens surface facilitates fiber end-face coupling. The optical spectrum of the four channel WDDM device used is shown in Fig. 2(c). The results show that the four channel WDDM system can be easily extended to more channels.

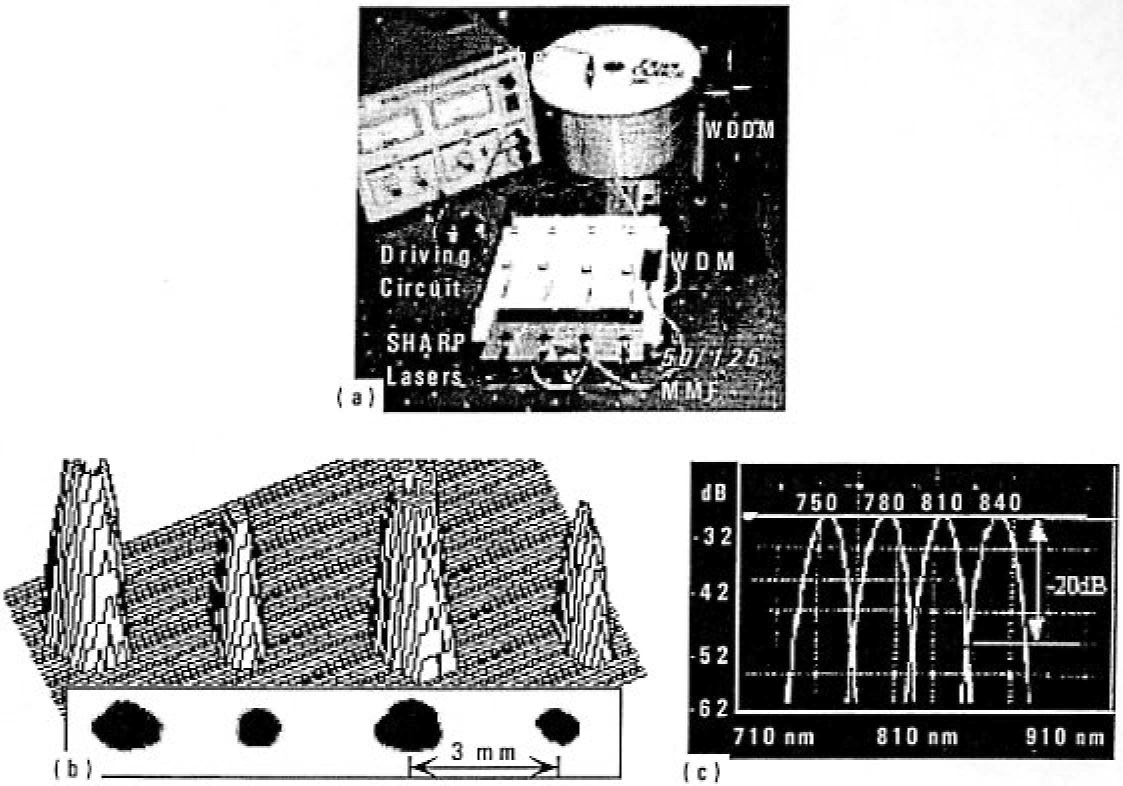

Fig.2 (a) The four channel WDM/WDDM light transmitting and receiving module picture,
(b) The four output spots of the four channel WDDM,
(c) The optical spectrum of the four wavelengths used in the WDM/WDDM system.

## 3. CONCLUSION

In summary, we have demonstrated an integrated four channel wavelength division demultiplexer using holographic gratings and substrate-guided waves. The WDDM is tested using multimode fiber input and near IR semiconductor laser sources. The crosstalk level is measured to be less than -40dB. The system insertion losses are -23dB, -21dB, -20dB, -22dB respectively for 750 nm, 780 nm, 810 nm and 840 nm. The wavelength adjustability, integrated packaging and multimode fiber compatibility features make it ideal for expanding local and wide area networks communication system bandwidth.

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## 4. REFERENCES

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