Wavelength Division Demultiplexing in the Near Infrared using Holographically Processed Polymer Microstructure Waveguides

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Abstract

A five-channel wavelength division demultiplexer (WDDM), fabricated in polymer microstructure waveguides, and operating over a 100 nm bandwidth centered at 750 nm in the near infrared, is demonstrated. The device has a maximum diffraction efficiency of ~ 50% at 730 nm, a spectral bandwidth of ~ 15nm, and effectively utilizes the large optical transparency of the photo-lime gelatin polymer material at laser diode wavelengths.

2. Introduction

A technique for producing multiple phase gratings in locally sensitized photo-lime gelatin polymer waveguides for WDM applications, has recently been reported [1-4]. An efficient four-channel visible wavelength demultiplexer has also been demonstrated [3,4]. While the above device has demonstrated the feasibility of fabricating and processing locally sensitized polymer films into high density optical interconnection and signal processing elements, it fails to take advantage of the optical transparency and full transmission bandwidth (~ 2400 nm) available with the photo-lime gelatin polymer microstructure film. Herein, we report on the development of a new five-channel, planar polymer waveguide, wavelength division demultiplexer, for use in the near infrared wavelengths. The device, which selects out wavelengths from 730 nm to 810 nm, in 20 nm increments, shows the potential for high diffraction efficiency, low cross-talk, and compatibility with GaAs and AlGaAs laser diodes for use in signal processing and interconnection applications. The concepts presented herein should also make possible the development of WDM devices at the 1.3 and 1.55 um wavelengths for fiber-optic communication systems.

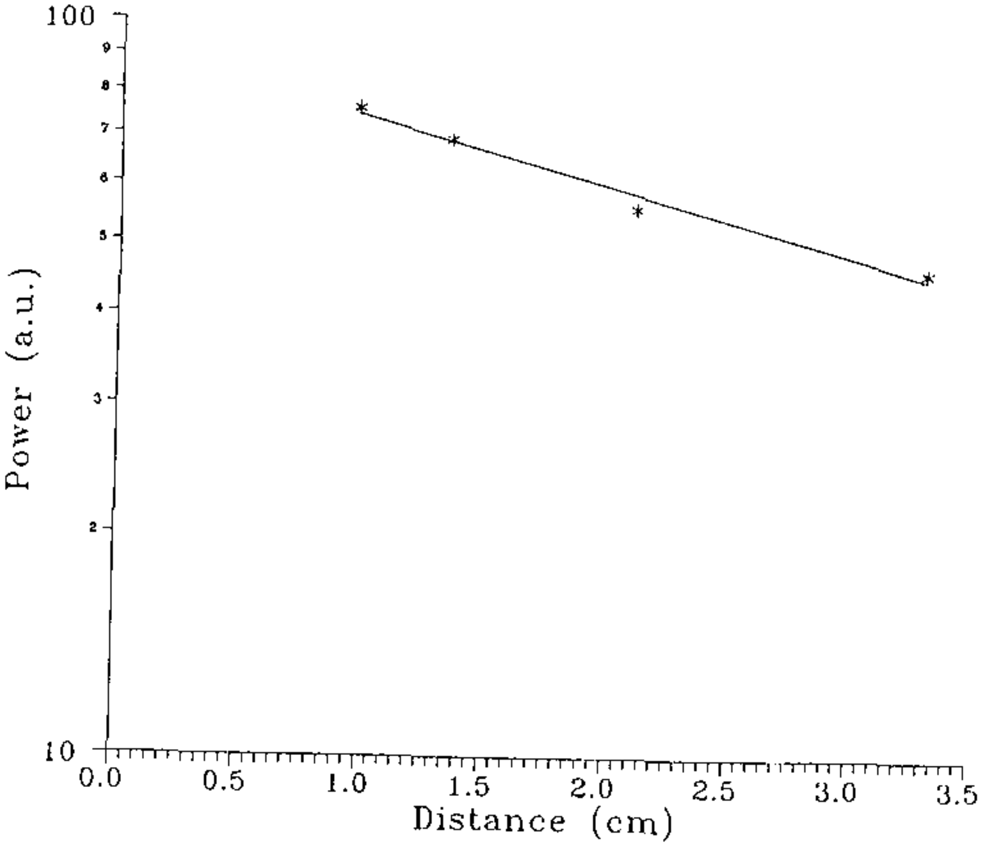
3. Experimental Techniques

The fabrication and processing procedure for producing a visible WDM device has been described in detail elsewhere [4], but is also applicable to demultiplexers which operate in the near-infrared and IR wavelengths. In essence, a thin-film polymer slab waveguide is formed, on an appropriate substrate, through a series of gelation, spin-coat, and slow-dry processing steps. The refractive index profile of the polymer waveguide is then tuned via a carefully controlled hydration and dehydration process using an alcohol immersion technique. A local sensitization process, consisting of polymer prehardening, ultraviolet exposure, and ammonimum dichromate polymer sensitization, is then used to sensitize selectively masked portions of the polymer waveguide. In this way, a single holographic phase grating, or multiply exposed phase gratings, having the proper Bragg diffraction angles, can be processed in the locally defined polymer film.

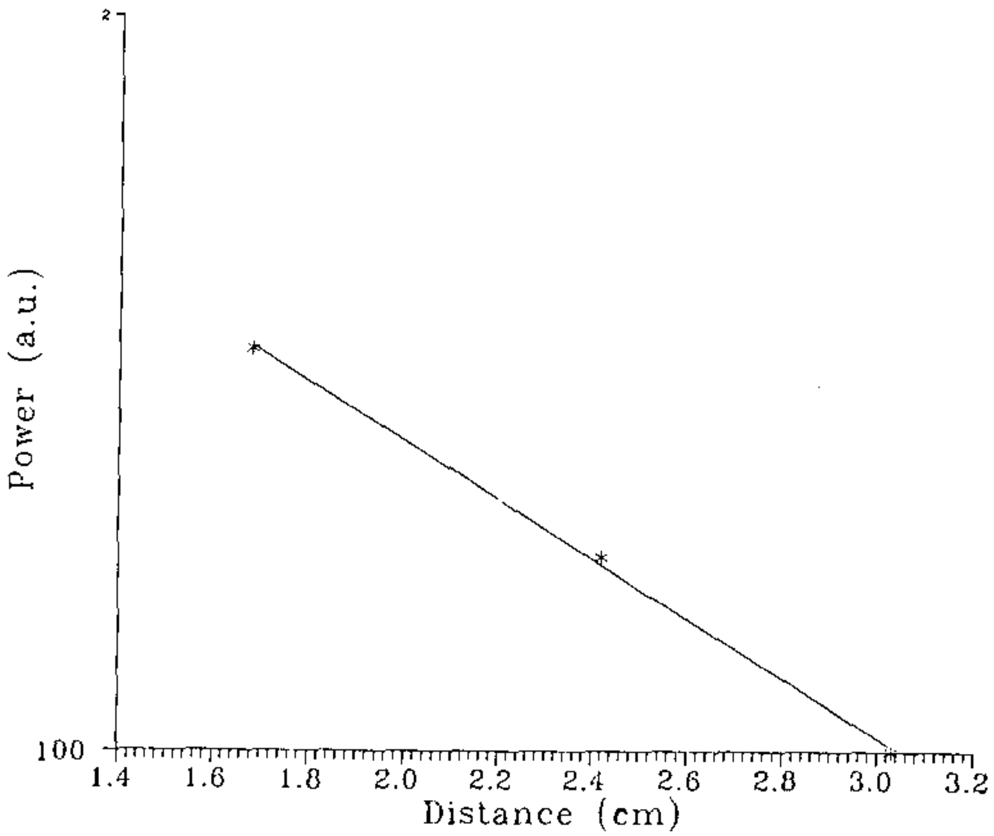
4. Experimental Results and Discussion

Using the prism coupling technique, the propagation losses for the polymer film were examined before, and after, refractive index profile tuning. The results for a typical polymer film are shown in Fig.2(a) and (b), respectively. We note that, prior to index tuning, the planar polymer film supported three slab modes, while only the fundamental TE_0 mode was observed subsequent to the tuning process. This behavior is commensurate with the conversion of the polymer step-index profile to that of a narrow graded-index core region, and the lowering of the surface refractive index, after successive profile tuning steps. From the logarithmic plots in Fig.2., it can be seen that the propagation loss increased slightly from ~ 0.94 dB/cm to ~ 1.22 dB/cm, as a result of further processing. The tuning process has been found to introduce some film defects that can, occasionally, result in larger losses. In general, however, only a small increase in loss has been consistently observed. The attenuation for the pre-processed TE_1 and TE_2 waveguide modes were found to be in the 1 - 2 dB/cm range.

The wavelength selectivity of each individual planar waveguide grating, as well as the multiplexed gratings in the WDDM device, is an important device parameter from which we can define the proper wavelength channel separation for a low crosstalk figure of merit. The demultiplexer diffraction efficiency, as a function of incident laser wavelength, is shown in Fig.3. For this measurement, the output prism coupler was placed ~ 2 - 4 mm away from the grating interaction region, so that a continuous wavelength scan for all five gratings could be



(a)



(b)

Fig.2. Propagation losses for the polymer microstructure waveguide, measured (a) before and (b) after refractive index profile tuning. Losses are 0.94 and 1.22 dB/cm, respectively.

obtained. The measurement of wavelength selectivity is performed by measuring the diffracted and undiffracted powers, I_D and I_U, respectively. The diffraction efficiency is then determined from the ratio $I_D/(I_D + I_U)$. This efficiency, measured around the center wavelengths of 750 and 770 nm are shown in Fig. 3. Here, the curves show the result of simultaneous diffraction by two channels as the incident laser wavelength is continuously scanned (upper plot), and when separate channels diffract, with alternate channel signals being blocked (lower plots).

From Fig.3, it can be seen that the diffraction at 33 degrees is maximum for the 750 nm wavelength, while the diffraction at 41 degrees is very small. This latter diffraction, produced by another grating, is seen to yield low crosstalk. When the center wavelength is tuned away from the 750 nm and towards 770 nm wavelength, the diffraction efficiency at the 33 dgreee Bragg angle is decreased, while the efficiency at the 41 degree angle is increased. Because some of the incident power is shared between the two gratings, the measured spectral bandwidth for each individual signal channel will, in fact, be wider than the actual single grating response. From the upper plot of Fig.3, it can be seen that an even broader spectral bandwidth is obtained, resulting from the summation of the two diffracted powers. Because of cross-coupling effects, a reliable measurement of spectral bandwidth cannot be obtained from this data. A single grating system, having the same grating parameters, diffraction angle, and interaction length, would be required to confirm these results. Similar results have been obtained at the other WDDM center wavelengths.

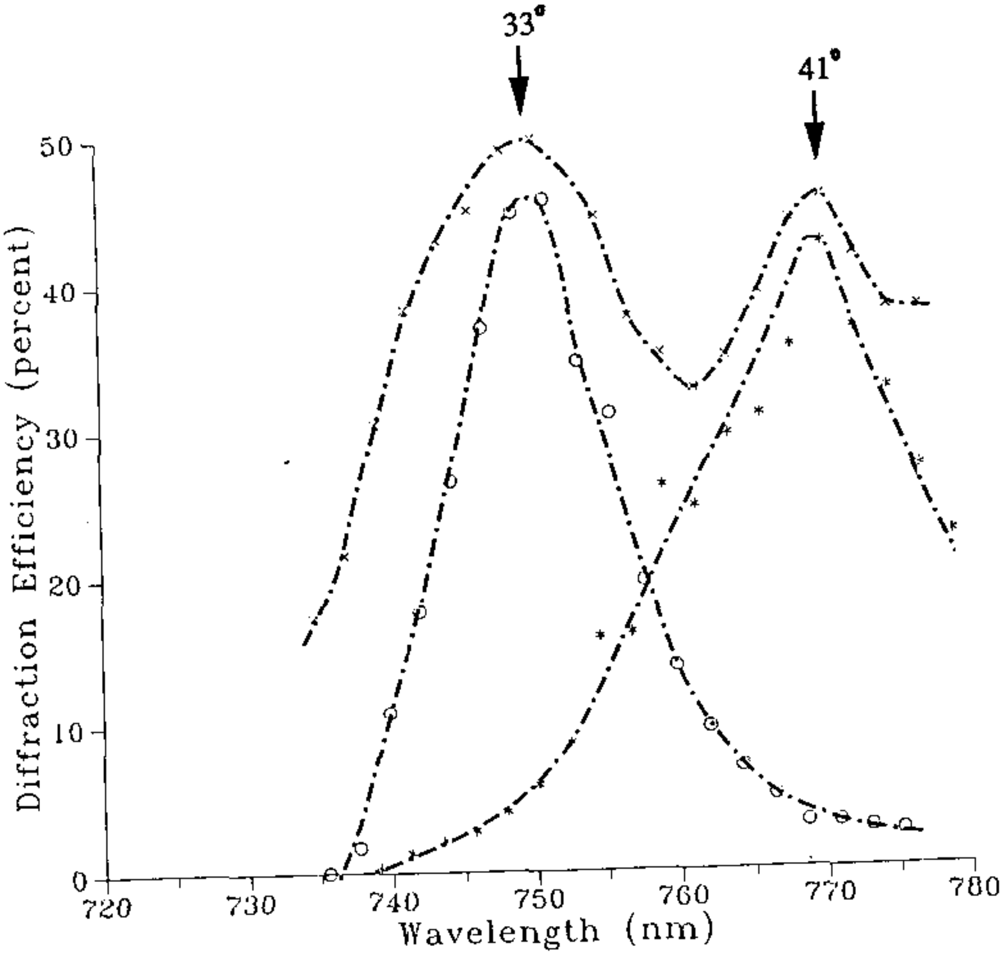


Fig.3. Diffraction efficiency, measured as a function of wavelength, around the center channel wavelengths of 750 and 770 nm, respectively. Curves represent a continuous laser scan of the two channels diffracting simultaneously (upper plot), and for separate channels, with alternate channel signals blocked (lower plots).

5. Conclusions

In conclusion, a five-channel WDDM device, operating in the near infrared, has been demonstrated in the newly developed polymer microstructure waveguide system. Based upon present results, the device described above has a spectral bandwidth of better than 15 nm. Better wavelength selectivity is expected, if the grating interaction length, and grating modulation parameters, can be optimized.

6. Acknowledgments

This work is currently sponsored by SDIO, Contract No. DASG60-90-C-0018.

7. References

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