19940018758

N94-23231

1993 NASA/ASEE SUMMER FACULTY FELLOWSHIP PROGRAM

JOHN F. KENNEDY SPACE CENTER
UNIVERSITY OF CENTRAL FLORIDA

S1-32
197187
p. 25

WIDE BAND FIBER-OPTIC COMMUNICATIONS

PREPARED BY:	Dr. Harry E. Bates
ACADEMIC RANK:	Professor
UNIVERSITY AND DEPARTMENT:	Towson State University Department of Physics
NASA/KSC	
DIVISION:	Electronic Systems
BRANCH:	Communications
NASA COLLEAGUE:	Po T. Huang
DATE:	August 20, 1993
CONTRACT NUMBER:	University of Central Florida NASA-NGT-60002 Supplement: 11

ACKNOWLEDGEMENTS

This research effort would not have been possible with out the assistance, cooperation and careful planning of a number of people. Larry Hand and Po T. Huang suggested the problem and provided valuable support along the way. Po T. Huang was always available to answer questions and provide literature references He also gave guidance and support in more ways than can be described here. All levels of Engineering management above Po and Larry beginning with Perry Rodgers provided valuable assistance and showed genuine interest in the project. Everyone was willing to listen and suggest solutions to problems. Special thanks to Fred McKenzie for helping to provide computer support and introductions to people who could help with other problems. INET personnel were most helpful in the laboratory. Special thanks to F. Houston Galloway and Bob Swindle who worked closely in all laboratory phases of this project. Thanks to Tim Shepard, co-op student, who participated in a number of experiments and was always willing to lend an hand in the lab. Also, thanks to David Wedekine who helped with software problems on the Macintosh IIx. Last but not least I would like to thank Dr E. R. Hosler of UCF who managed the Summer Faculty Program and provided a great deal of support and assistance.

ABSTRACT

A number of optical communication lines are now in use at the Kennedy Space Center (KSC) for the transmission of voice, computer data and video signals. At the present time most of these channels utilize a single carrier wavelength centered near 1300 nm. As a result of previous work the bandwidth capacity of a number of these channels is being increased by transmitting another signal in the 1550 nm region on the same fiber. This is accomplished by means of wavelength division multiplexing (WDM). It is therefore important to understand the bandwidth properties of the installed fiber plant. This work developed new procedures for measuring the bandwidth of fibers in both the 1300nm and 1550nm region. In addition, a preliminary study of fiber links terminating in the Engineering Development Laboratory was completed.

SUMMARY

A number of multimode optical communication links are now in use at the Kennedy Space Center (KSC) for the transmission of voice, computer data and video signals. At the present time most of these channels utilize a single carrier wavelength centered near 1300 nm. As a result of previous work the bandwidth capacity of a number of these channels is being increased by transmitting another signal in the 1550 nm region on the same fiber. This is accomplished by means of wavelength division multiplexing (WDM).

The main goal of this experimental program was to characterize the bandwidth of the fibers used in these systems in the 1550 nm window.

During this project, new test procedure was developed to measure bandwidth using the HP 8702 Lightwave Component Analyzer System and associated components. The system was used to determine the bandwidth of a small number of fiber optics communications links terminating in the Engineering Development Laboratory at KSC.

Using the new test procedure, bandwidth measurements were accomplished on all multimode fiber test links terminating in the engineering development laboratory. These measurements showed that the 1550 LED bandwidth distance product of .42 ± .01 GHz*km.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

ABBREVIATIONS AND ACRONYMS LIST

CDSC	Communications Distribution and Switching Center
OSA	Optical Spectrum Analyzer
LED	Light Emitting Diode
KSC	Kennedy Space Center
WDM	Wavelength Division Multiplexer or Demultiplexer

I

INTRODUCTION

A number of multimode optical communication links are now in use at the Kennedy Space Center (KSC) for the transmission of voice, computer data and video signals. At the present time most of these channels utilize a single carrier wavelength centered near 1300 nm. As a result of previous work the bandwidth capacity of a number of these channels is being increased by transmitting another signal in the 1550 nm region on the same fiber. This is accomplished by means of wavelength division multiplexing (WDM).

The main goal of this experimental program was to characterize the bandwidth of the fibers used in these systems in the 1550 nm window.

Practical considerations such as modal dispersion, material (chromatic) dispersion, detector rise time, modulation limits of the receiver...etc. limit the usable bandwidth.[1] The fibers have the capability of transmitting a multiplicity of signals simultaneously in each of two separate bands (1300nm and 1550 nm)[2,3].
It is important to mention that this this study has not determined the properties of the overall fiber optic plant at KSC with any great statistical certainty.

II

ANALYSIS OF EXISTING DATA

2.1 SAMPLE OF DATA

A number of RF spectra were collected using the HP8702 Lightwave Component Analyzer. The experimental arrangement used is shown in Figure 2-1 and a sample of the spectra collected using a 1530nm LED as the E/O converter is shown in Figure 2-2. Four different E/O sources can be employed LEDs and lasers with output wavelengths in the 1.5 micrometer or 1.3 micrometer windows.

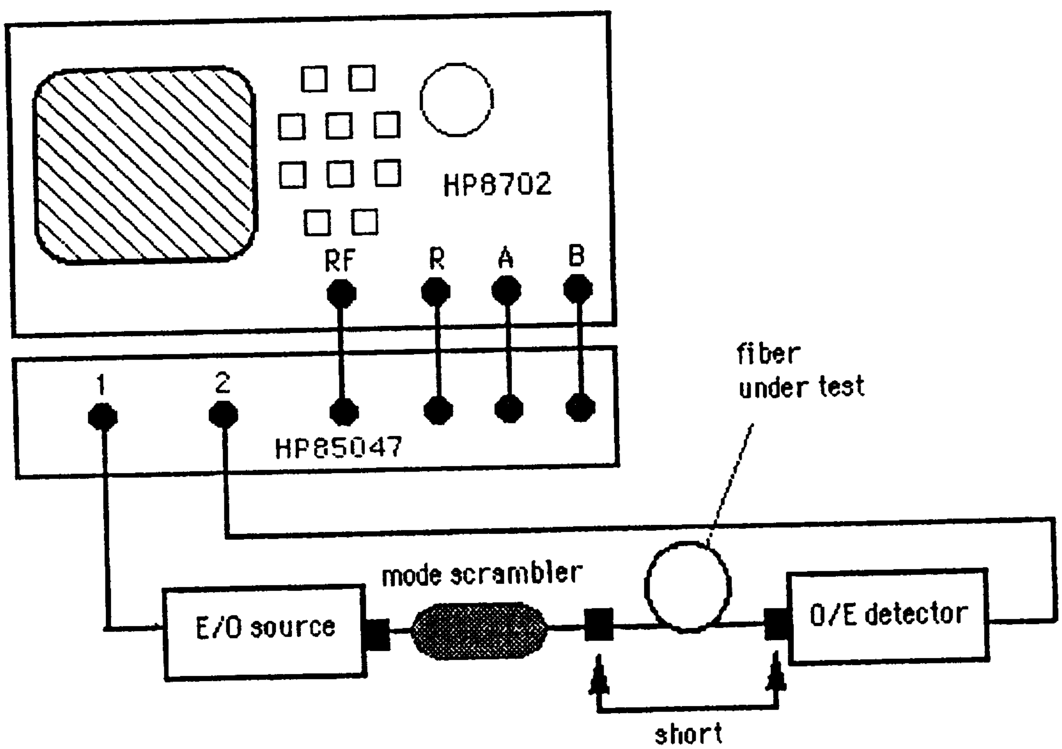

Figure 2-1. Lightwave Analyzer Setup Used to Collect Data

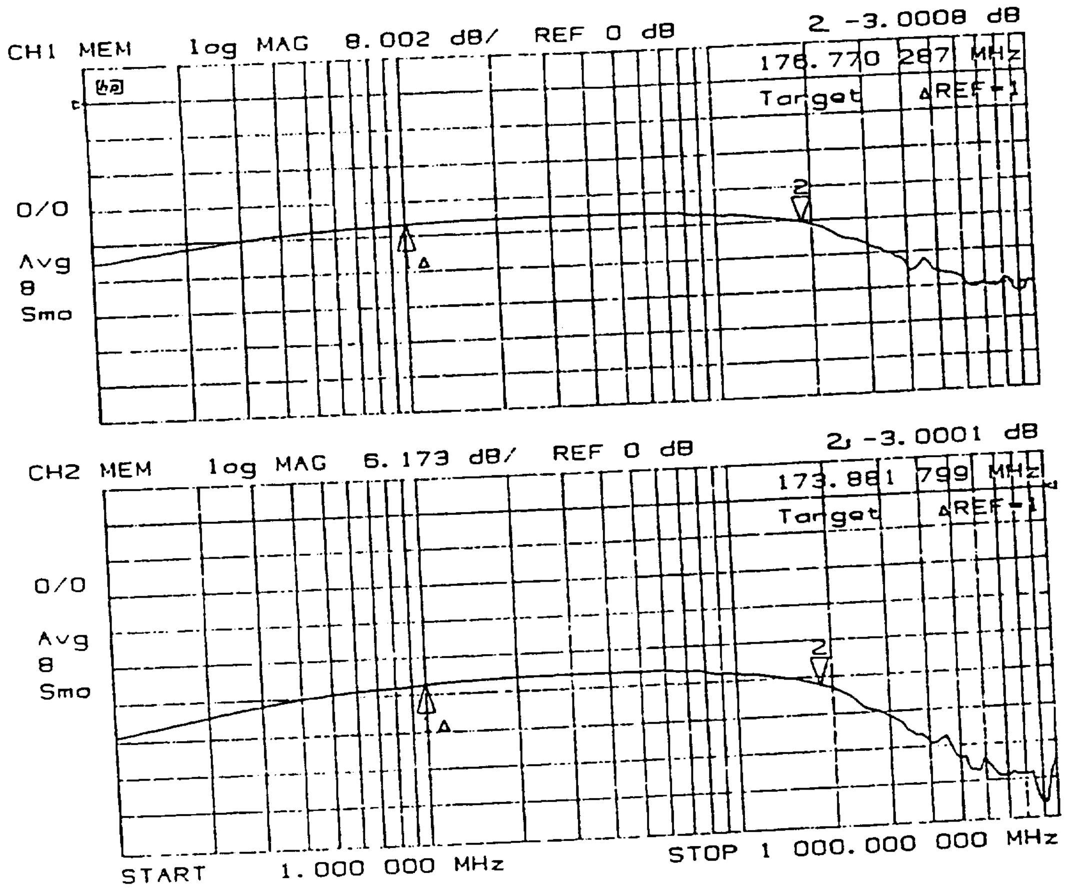

Figure 2-2. Spectrum of Link from CDSC to HQ using 1530 nm LED

A preliminary analysis of these results revealed fundamental problems with the data. Most spectra showed a 6 to 10 dB roll on in the low frequency region, a relatively flat area in the mid frequency range and a roll off at the high frequency end. There is no physical reason for the spectrum of an optical fiber link to roll on. A fiber acts like a low pass filter and should exhibit the best transmission at the lowest frequencies. Therefore an analysis of each element of the lightwave analyzer as well as test procedures was initiated.

III

LIGHTWAVE ANALYZER SYSTEM AND PROCEDURES ANALYSIS

3.1 Optical Spectra of E/O Converters

An Anaritsu optical spectrum analyzer was available in the laboratory to be used to perform spectral analysis of coherent and incoherent sources. This piece of test equipment was equipped with an IEEE 488 computer interface which provides for bidirectional computer communication. This equipment was interfaced with a Macintosh IIx computer to enable the efficient collection of spectral data in machine readable form during a project in the Summer of 1989. The analyzer was used to collect spectra of the E/O converters.

3.1.1 LED SPECTRA. The optical spectra of the LED-type E/O converters were collected. They are shown in Figures 3-1 and 3-2 below:

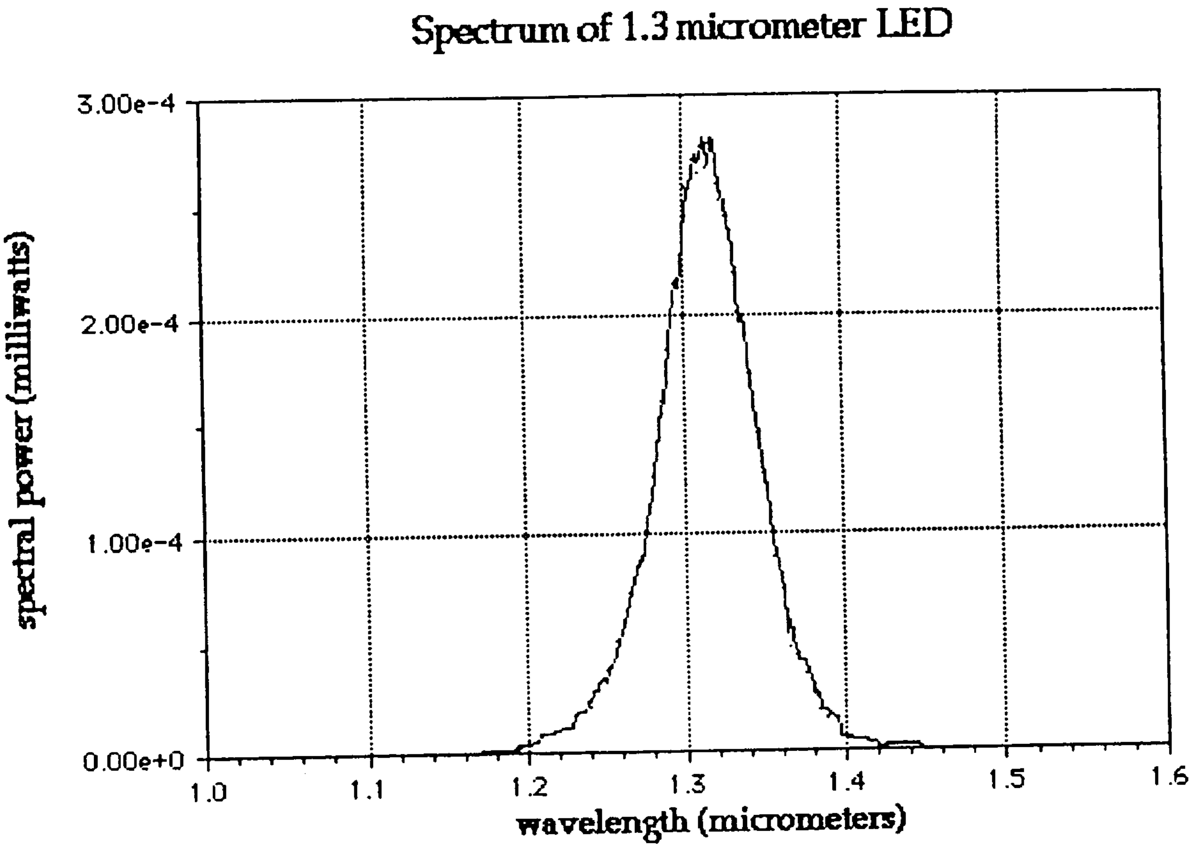

Figure 3-1. Optical spectrum of 1.3 micrometer LED E/O converter

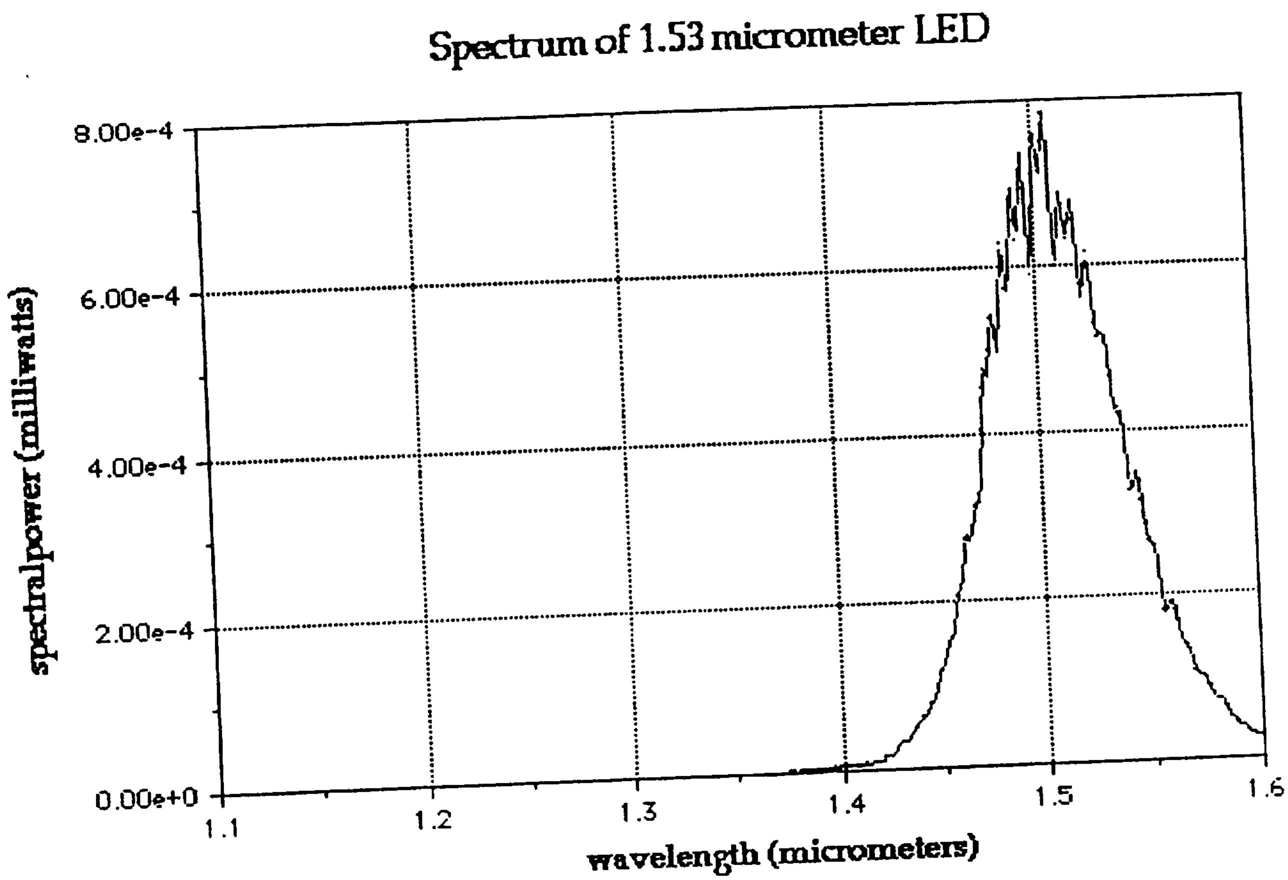

Figure 3-2. Optical spectrum of 1.5 micrometer LED E/O converter

3.1.2 LASER SPECTRA. The optical spectra of the LASER-type E/O converters were collected. They are shown in Figures 3-3 and 3-4 below:

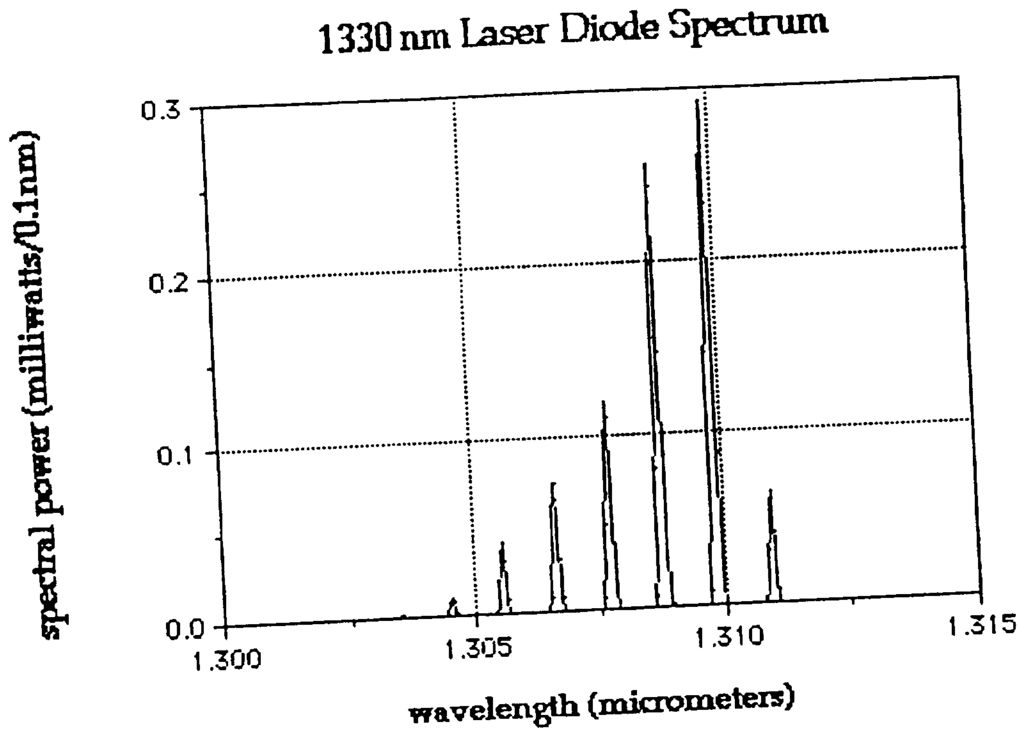

Figure 3-3. Optical spectrum of 1.3 micrometer Laser E/O converter

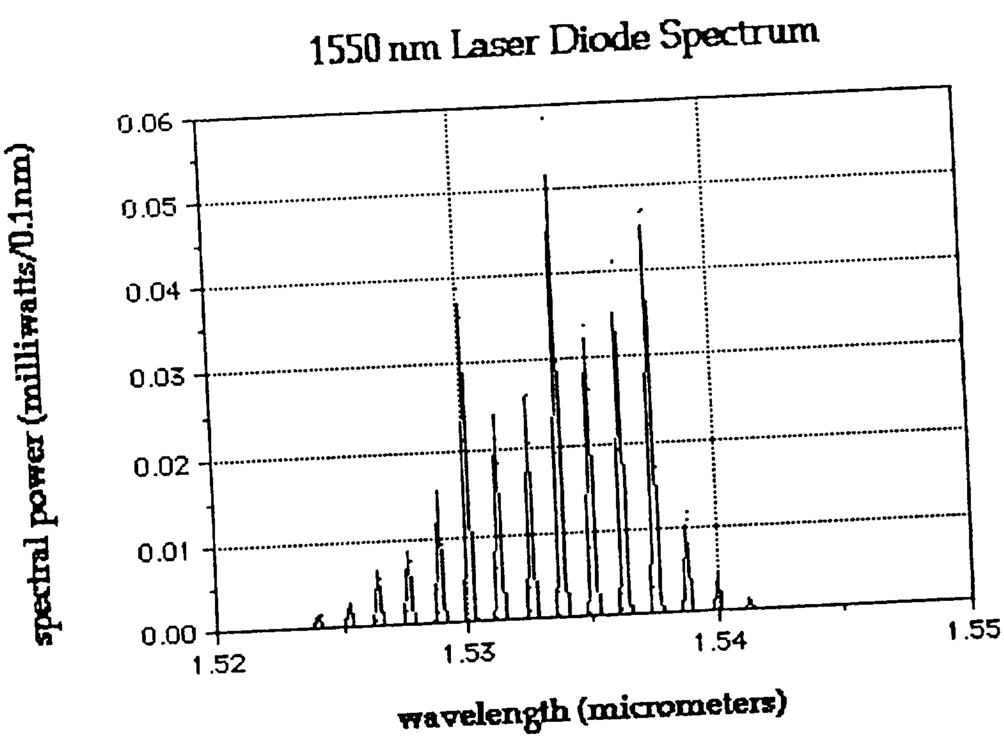

Figure 3-4. Optical spectrum of 1.5 micrometer Laser E/O converter

3.1.3 OPTICAL CALIBRATION CHECK OF SPECTRUM ANALYZER. The OSA was checked by using a HeNe laser source. A graph of the spectra of two LED's and the sharp peak of the 0.6328 micrometer laser is shown below. All spectra collected were normal.

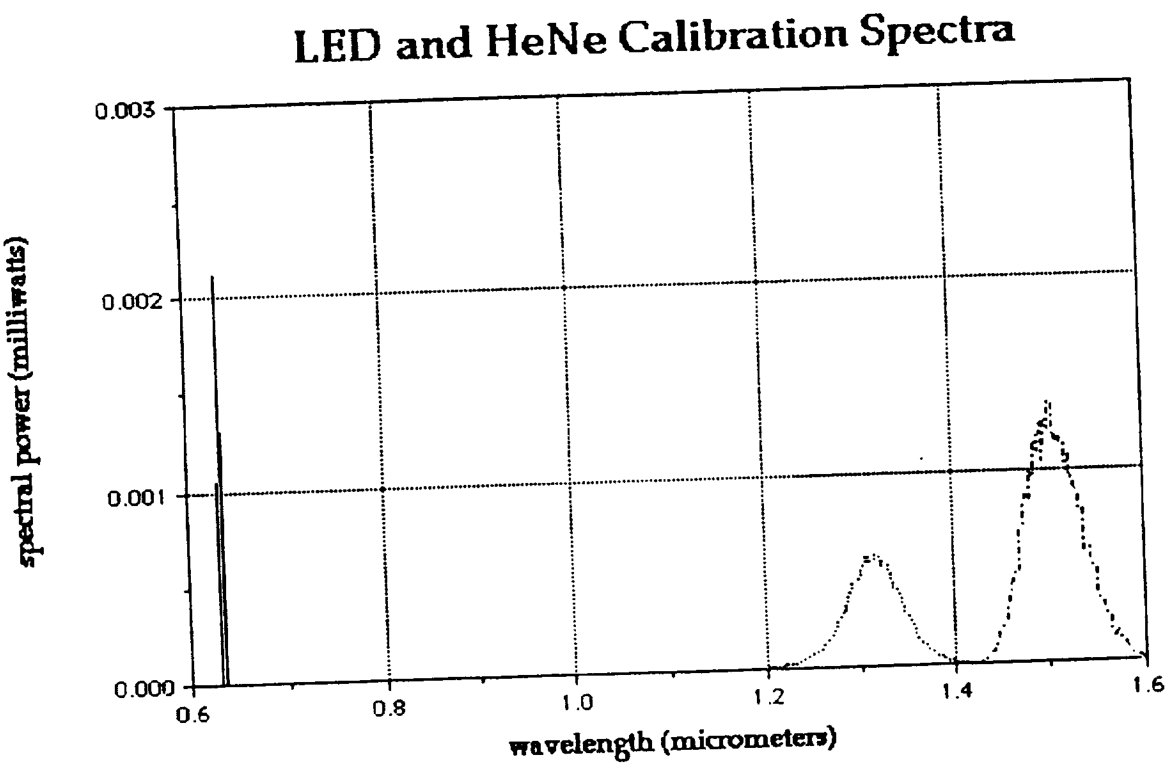

Figure 3-5. Optical calibration spectra

3.2 BANDWIDTH OF E/O O/E CONVERTERS

The bandwidth of the E/O - short fiber- O/E link was checked referenced to a short RF cable. Example RF spectra are shown for the 1.5 micrometer laser source and the 1.5 micrometer LED source in Figures 3-6 and 3-7 below. The lasers had the same general characteristics and the LEDs had the same general characteristics. The lasers generally had a low-pass filter type response and the LEDs showed a marked roll on at low frequencies and then a roll off at high frequencies.

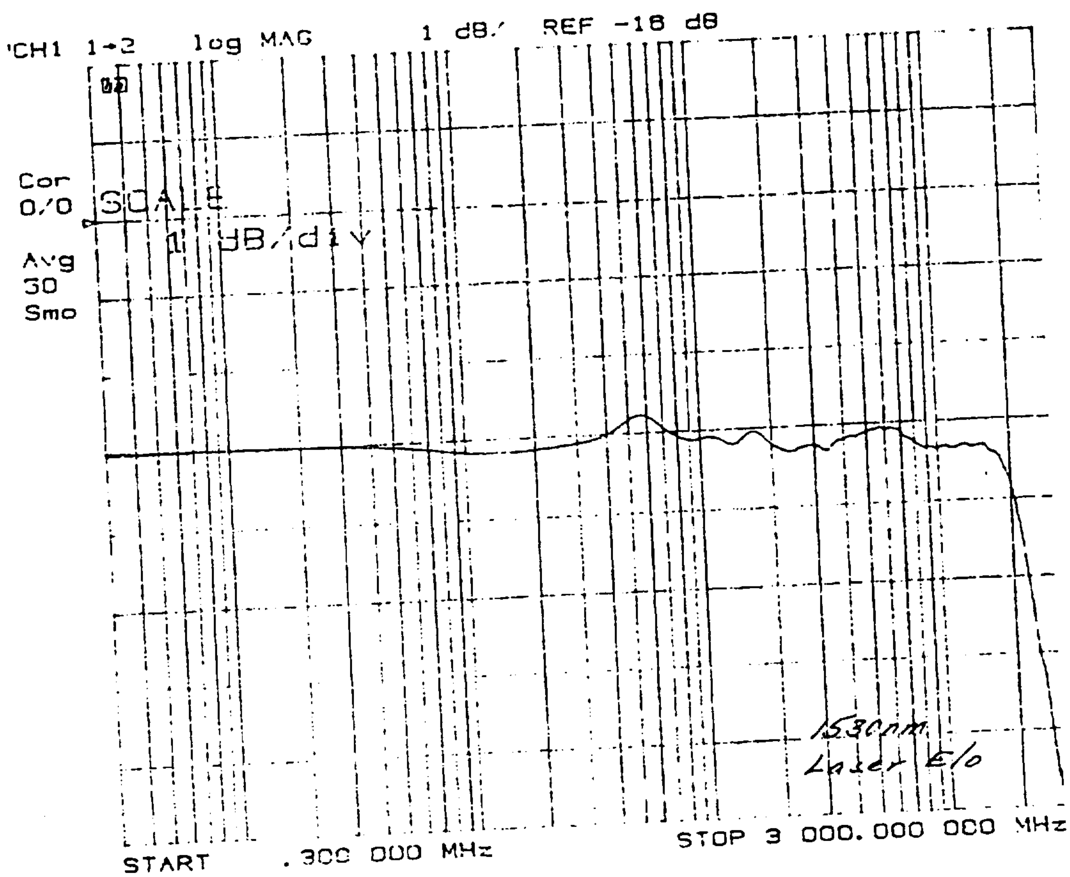

Figure 3-6. 1530 nm Laser E/O-Short Link-O/E Response Spectrum

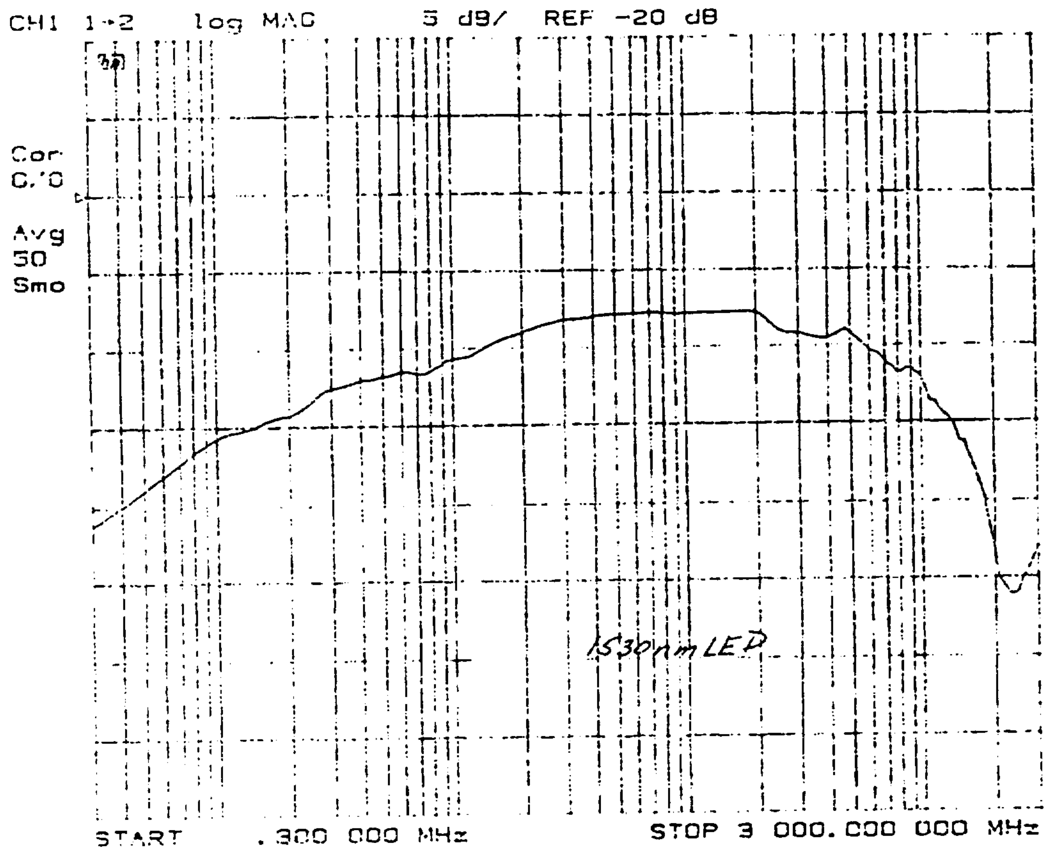

Figure 3-7. 1530 nm LED E/O-Short Link-O/E Response Spectrum

3.3 PROCEDURES ANALYSIS

The operating procedure and equipment setup used for collecting data was extensively analyzed. A number of problems were identified and corrected. Most of the problems could be traced to misleading equipment indications and poor human-machine interface software. Each item discovered together with the fix for the item is discussed in the paragraphs below:

3.3.1 DONE COMMAND USE AFTER CALIBRATION. The test procedure includes a step where a short fiber link is attached between the E/O - O/E system and a sequence of soft keys are depressed to memorize the thru response of the basic system elements. In the original procedure, the sequence of key strokes was **CAL**,CAL. MENU, RESPONSE, THRU. Then another key on the front panel was pushed. (Please note that labels in bold indicate front panel keys and small caps indicate soft key inputs). A sequence of soft keys appear on the right side of the CRT and get various screen labels depending on the mode of the analyzer. The DONE soft key at the bottom of the screen must be pressed in order for the instrument to accept and memorize the reference loop. Since this was not done in the collection of data, the spectra did not reflect just the response of the fiber, but also the response of other system elements that should have been compensated for. Therefore the original data is useless.

3.3.2 AVERAGING DURING DATA COLLECTION AND CALIBRATION. If data is to be collected using averaging, then the reference short loop response calibration should be done with the same level of averaging. If averaging is used, the DONE softkey must be pressed within one second of completing averaging or the instrument incorrectly restarts the calibration averaging procedure. This is a software flaw in the instrument.

3.3.3 USE OF PORT B FOR INPUT PORT. The diagram displayed by the instrument during the guided setup phase of operation is incorrect. The best dynamic range is obtained by utilizing port B as the input port from the network instead of port 2 as shown in the guided setup. This gives an improvement in dynamic range of about 10 dB. An improved equipment setup diagram is shown below in Figure 3-8:

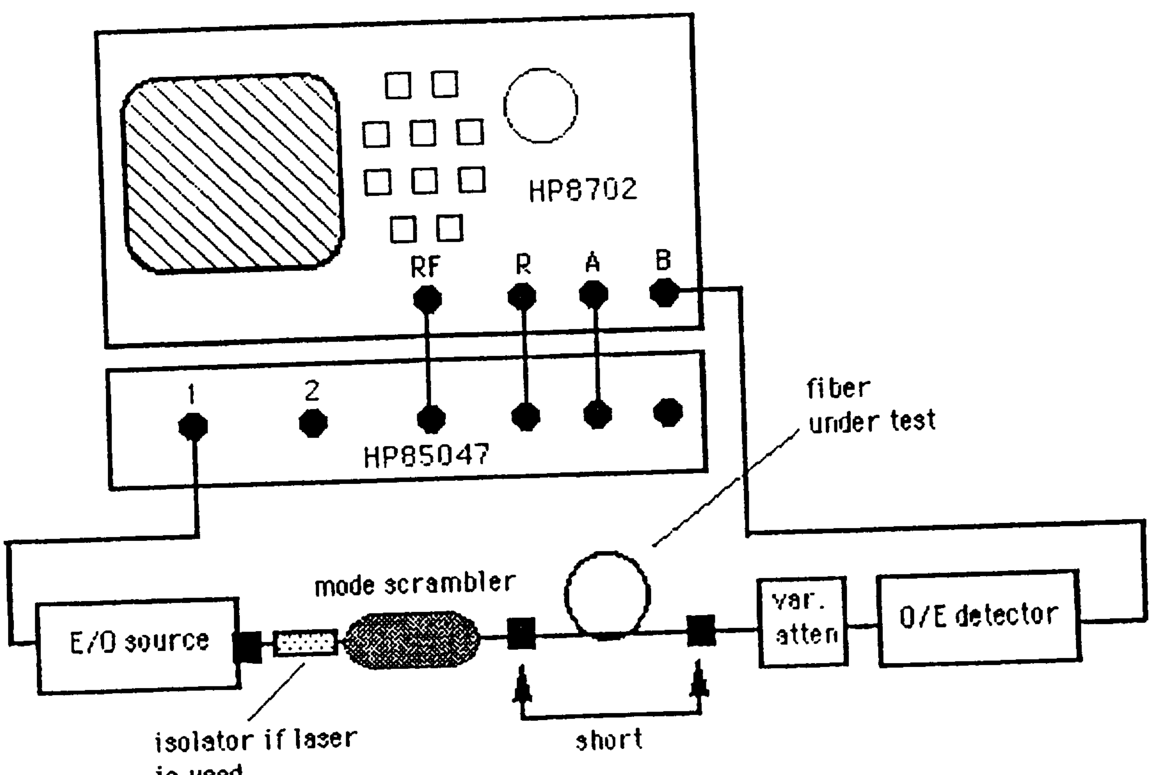

Figure 3-8. Improved equipment setup for bandwidth tests

3.3.4 SINGLE CHANNEL VS DUAL CHANNEL OPERATION. Improved graphs and more reliable operation can be obtained if single channel operation is used.

3.3.5 SIGNAL LEVEL TEST. With an averaging factor of 16, an acceptable signal level from the E/O converter thru the test fiber to the receiver is different for each different E/O converter. It is recommended that acceptable signal levels be established for each converter and wavelength region and that a test be made of the signal level thru the loop prior to making bandwidth measurements. If the signal level is not sufficient, bandwidth measurements should not be attempted. A conservative set of cutoff points is given in Table 3-1 below.

Table 3-1. Cutoff signal levels below which no measurement should be attempted without changing the procedure.

E/O Converter	MINIMUM SIGNAL LEVEL
1550 LED	-34 dBm
1550 LASER	-32 dBm
1300 LED	-26 dBm
1300 LASER	-33 dBm

3.3.6 INTEGER REFERENCE LEVEL CONTROL. Vertical reference level control should be set to integer values in order to make it easier to read the output graphs.

3.3.7 DB PER DIVISION FIXED VERTICAL SCALE. Vertical scale/div setting should be set to integer values in order to make it easier to read the output graphs. I recommend 1 dB/division.

IV

BANDWIDTH OF KSC MULTIMODE FIBER

4.1 TYPICAL FIBER TEST LINK

The Fiber Optics Laboratory in the EDL building has a series of multimode fiber optic links to the CDSC building. See Figure 4 -1 below for a diagram typical of any of the 2.4 km links marked (5-12). The bandwidth of pairs of these links was measured using the improved procedure discussed in the previous section. The bandwidth of the 6.3 km links (1-4) were also measured. They are routed from the EDL to the Bananna River Repeater Station.

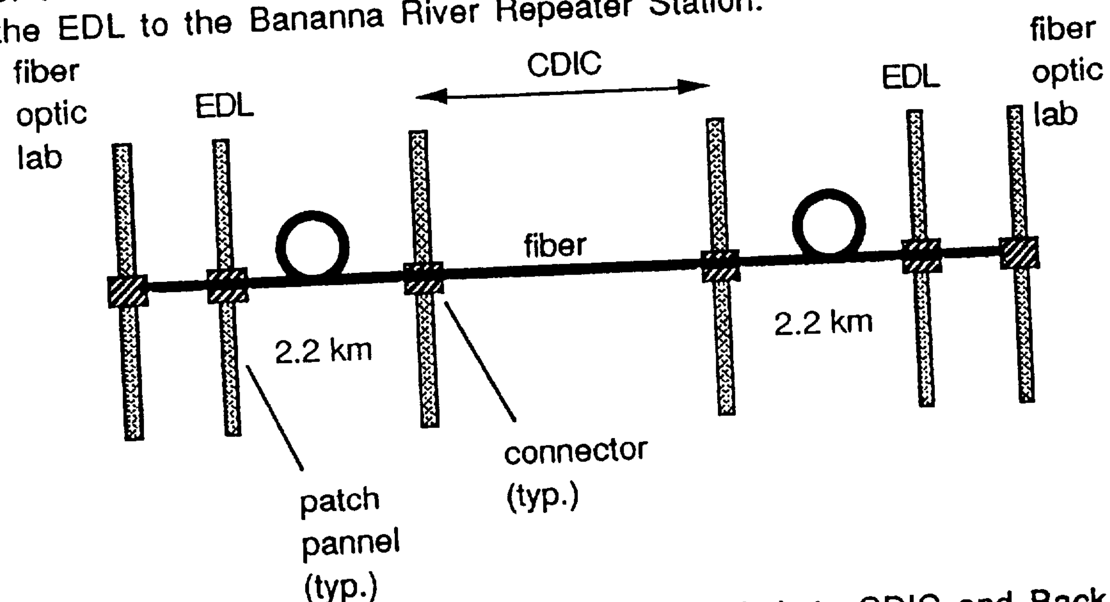

Figure 4-1 Typical Link from Fiber Optic Lab to CDIC and Back

Tables 4-1 thru 4-4 detail the results of the bandwidth measurements.

Table 4-1. Bandwidth measurements EDL links using 1300nm laser

	Length (km)	Forward (MHz)	Reverse (MHz)	Avg. (MHz)	BW*Dist. (GHz*km)
loop 1-2 to BRRS	12.6	369	414	391.5	4.93
loop 3-4 to BRRS	12.6	230	241	235.5	2.97
loop 5-6 to CDSC	4.8	640	653	646.5	3.10
loop 7-8 to CDSC	4.8	399	459	429	2.06
loop 9-10 to CDSC	4.8	494	509	501.5	2.41
loop 11-12 to CDSC	4.8	344	336	340	1.63

Table 4-2. Bandwidth measurements EDL links using 1550nm laser

	Length (km)	Forward (MHz)	Reverse (MHz)	Avg. (MHz)	BW*Dist. (GHz*km)
loop 1-2 to BRRS	12.6	could not measure------			
loop 3-4 to BRRS	12.6	97	102	99.5	1.25
loop 5-6 to CDSC	4.8	275	260	267.5	1.28
loop 7-8 to CDSC	4.8	181	261	221	1.06
loop 9-10 to CDSC	4.8	262	198	230	1.10
loop 11-12 to CDSC	4.8	179	169	174	0.84

Table 4-3. Bandwidth measurements EDL links using 1300nm LED

	Length (km)	Forward (MHz)	Reverse (MHz)	Avg. (MHz)	BW*Dist. (GHz*km)
loop 1-2 to BRRS	12.6	252	242	247	3.11
loop 3-4 to BRRS	12.6	198	196	197	2.48
loop 5-6 to CDSC	4.8	470	479	474.5	2.28
loop 7-8 to CDSC	4.8	345	330	337.5	1.62
loop 9-10 to CDSC	4.8	384	371	377.5	1.81
loop 11-12 to CDSC	4.8	281	273	277	1.33

Table 4-4. Bandwidth measurements EDL links using 1550nm LED

	Length (km)	Forward (MHz)	Reverse (MHz)	Avg. (MHz)	BW*Dist. (GHz*km)
loop 1-2 to BRRS	12.6	34.1	33.6	33.85	0.43
loop 3-4 to BRRS	12.6	34.2	34.1	34.15	0.43
loop 5-6 to CDSC	4.8	89	89.7	89.35	0.43
loop 7-8 to CDSC	4.8	86.6	89.2	87.9	0.42
loop 9-10 to CDSC	4.8	91.3	91.2	91.25	0.44
loop 11-12 to CDSC	4.8	82.9	82.7	82.8	0.40

An example spectrum collected using the 1550nm LED E/O source for loop 7-8 is shown in Figure 4-2 below.

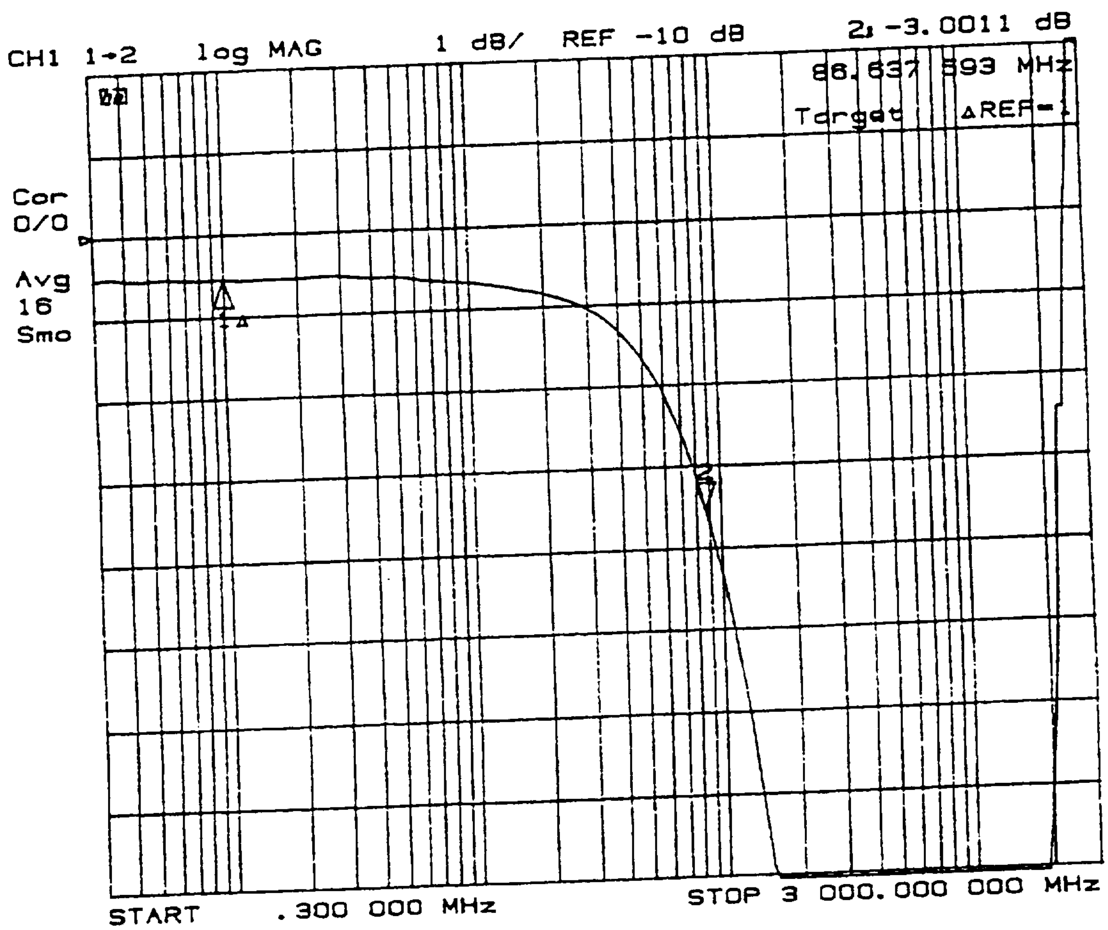

Figure 4-2. Sample Spectrum EDL Loop 7-8 1550nm LED E/O source

V

CONCLUSIONS

Significant results were achieved. The original data to be analyzed was found to be unusable. The test procedure was updated and refined. Using this new procedure, bandwidth measurements were accomplished on all multimode fiber test links terminating in the engineering development laboratory. These measurements show that the 1550 LED bandwidth distance product is .42 ± .01 Ghz*km.

Further work should be done to sample bandwidth of the multimode fiber links in the 1550 nm window of the rest of the fiber plant at KSC using the new test procedure.

REFERENCES

[1]Winzer and Reichelt. "Wavelength Division Multiplex Transmission over Multimode Optical Fibers: Comparison of Multiplexing Principles" Siemens Forsch.vol 9, number 4 (1980)

[2]N. A. Olsen et al., 68.3 km Transmission With 1.37 Tbit Capacity using Wavelength Division Multiplexing of Ten Single Frequency Lasers at 1.5 micrometers", Electronics Letters Vol. 21, Number 3 (January 1985)

[3]J. M. Senior et al. "Devices for wavelength multiplexing and demultiplexing", IEE Proceedings, Vol. 136, No. 3 (June 1989)