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Bimonthly Activity Report No. 1

Optical Fiber for Acoustic Sensor Applications

Prepared by
James R. Onstott
Principal Investigator

Prepared for the
Naval Research Laboratory
Contract No. N00014-89-C-2455

February, 1990

3M Fiber Optics Laboratory
3M Center
St. Paul, Minnesota 55144

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16. Abstract (Limit: 200 words)

Design of two single mode optical fibers for use in acoustic sensing systems is reported. One fiber design is optimized for use in optical coupler fabrication while the second design is optimized for use as an acoustic sensing fiber. The second fiber will be used as the basis for development of optimized coating for optical fiber acoustic sensor applications.

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Fibers
Optical Fiber
Sensor Fiber

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1.0 INTRODUCTION

This bimonthly activity report summarizes the research and development efforts performed to date by 3M on the development of optical fiber for acoustic sensor applications under Naval Research Contract Number N00014-89-C-2455.

2.0 PROGRAM OBJECTIVE

The objectives of this program are to develop long lengths of both acoustically sensitive and insensitive optical fibers that are environmentally stable, and to develop a fiber which is optimized for fused coupler fabrication During the first phase of this program, the development of optical fibers and organic fiber coatings specificaiiy optimized for acoustic sensing applications will be pursued.

3.0 PROGRAM ACTIVITIES

Fiber Design- Task One of the program statement of work requires the design and fabrication of two single mode fibers. Initial work has concentrated on the completion of this task. Current results for the two fiber designs are described below.

3.1 Sensor Fiber Design. Design of the fiber for sensor coating experiments has been completed. The design approach taken for the fiber is a high numerical aperture "depressed well" structure, where a low index fluorosilicate well surrounds a lightly doped germanium oxide core.This design approach allows the simultaneous minimization of intrinsic attenuation (Rayleigh scattering) and extrinsic attenuation (macro and micro bending). Target design specifications and measured results are listed in Table 1.

Table 1. Sensor Fiber Design Specifications and Results

	Target Specifications	Measured Results
Cladding Diameter	80um	80um
Numerical Aperture	0.16	0.160
Cutoff Wavelength	1250nm	1229nm
Attenuation	0.5 db/km	1.88 db/km

Measured results for this fiber (attenuation, mode field diameter, cutoff wavelength, ESI parameters, and concentricity) are shown in Figures 1 through 5 and Tables 3 and 4. All target specifications have been met with the exception of fiber attenuation. The unusually high attenuation is due to a 20 db -OH absorption peak at 1.38um. The -OH impurity level will be reduced in future preforms which will reduce the 1300nm attenuation to acceptable levels.

3.2 Coupler Fiber Design. This fiber is a high numerical aperture "matched index" structure which trades slightly higher attenuation for ease of coupler fabrication. Target design specifications and measured results are listed in Table 2.

Table 2. Coupler Fiber Design Specifications and Results

	Target Specifications	Measured Results
Cladding Diameter	80um	80um
Numerical Aperture	0.16	0.178
Cutoff Wavelength	1250nm	1249nm
Attenuation	2.0db	2.01db/km

Measured results for this fiber (attenuation, mode field diameter, cutoff wavelength, ESI parameters and concentricity) are shown in Figures 6 through 10 and Tables 5 and 6. All target specifications have been met with the exception of numerical aperture. One additional design iteration is needed to bring this parameter into specification.

4.0 DISCUSSION

Design of the two fibers is essentially complete. A major goal has been to match the mode field diameters so that splice loss would be minimized. Mode field diameter mismatch between the two fibers described above is 9%. Future design iterations will result in MFD mismatches of <5%. Refracted near field scans of the fibers are shown in Figures 5 and 10. The excellent concentricity of these fibers will result in low-loss splicing and connectorization.

5.0 FUTURE WORK

5.1 Completion of Fiber Design. Fiber design activities will be completed by the end of February, 1990. Two kilometers of coupler fiber will be delivered at this time. In addition, a sample of sensor fiber (acrylate coatings) will be delivered to NRL.

5.2 Coating Development. Subtask 2.0 of the program statement of work calls for the fabrication of silicone/Hytrel coated sensor fiber as the first stage of sensor fiber development. Delivery of this fiber to NRL is scheduled for March, 1990.

3M is currently evaluating the feasibility of thin (< 15um thickness), high adhesion fluoropolymer coatings as a primary buffer for sensor fiber applications. Preliminary results indicate that these coatings improve fiber strength in adverse environmental conditions. Delivery of sample fibers coated with these materials is scheduled for April, 1990. Further coating developments will occur after consultation with NRL personnel.

Table 3. Sensor Fiber Attenuation versus Wavelength

Spectral Attenuation
Fiber ID: 900131 SMDTN D434 8-Feb-90 08:49:28
Length: 1 km
File: 2424

Wavelength	Attenuation (dB/Km)	Wavelength	Attenuation (dB/Km)
650	11.89	1130	6.00
660	11.13	1140	5.90
670	9.93	1150	5.72
680	9.00	1160	5.54
690	8.60	1170	5.27
700	8.11	1180	5.04
710	7.62	1190	4.61
720	7.34	1200	4.19
730	7.22	1210	3.72
740	6.88	1220	3.14
750	6.26	1230	2.94
760	5.83	1240	3.13
770	5.48	1250	2.81
780	5.17	1260	2.14
790	5.04	1270	1.86
800	5.19	1280	1.79
810	5.50	1290	1.80
820	5.53	1300	1.88
830	5.40	1310	2.03
840	5.24	1320	2.31
850	5.04	1330	2.79
860	4.76	1340	3.42
870	4.26	1350	4.05
880	3.53	1360	5.03
890	2.81	1370	10.94
900	2.57	1380	23.29
910	2.49	1390	19.44
920	2.43	1400	12.38
930	2.42	1410	8.48
940	2.76	1420	6.24
950	2.61	1430	5.07
960	2.39	1440	4.51
970	2.28	1450	4.30
980	2.27	1460	4.32
990	2.39	1470	4.48
1000	2.64	1480	4.80
1010	3.03	1490	5.29
1020	3.65	1500	5.83
1030	4.43	1510	6.48
1040	5.26	1520	7.31
1050	5.84	1530	8.25
1060	6.15	1540	9.29
1070	6.23	1550	10.91
1080	6.25	1560	12.81
1090	6.21	1570	14.75
1100	6.16	1580	17.95
1110	6.11	1590	24.04
1120	6.08	1600	0.00

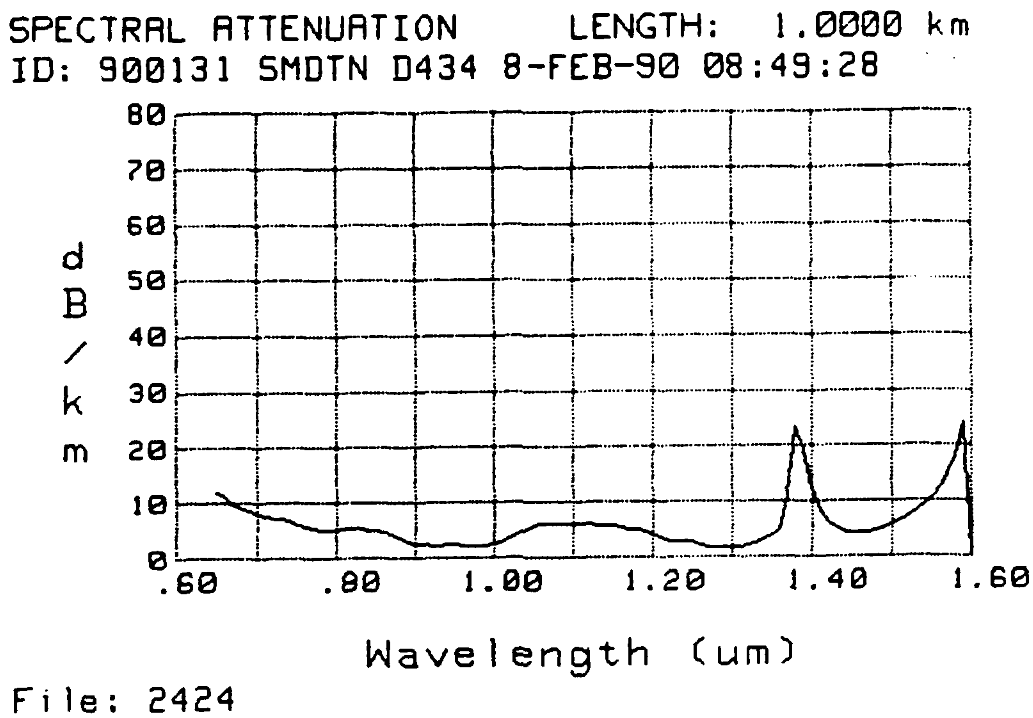


Figure 1
Sensor Fiber Attenuation versus Wavelength

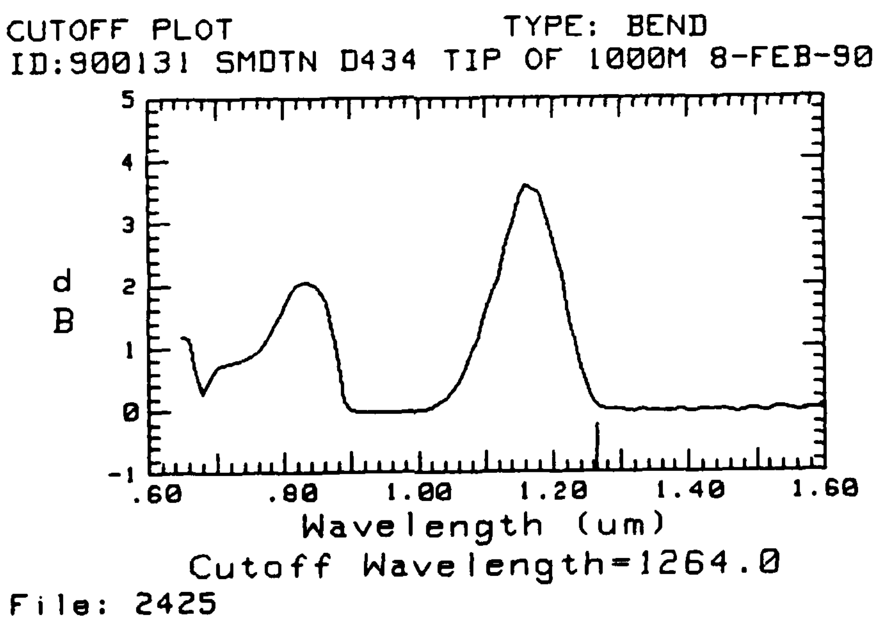


Figure 2
Sensor Fiber Cutoff Plot

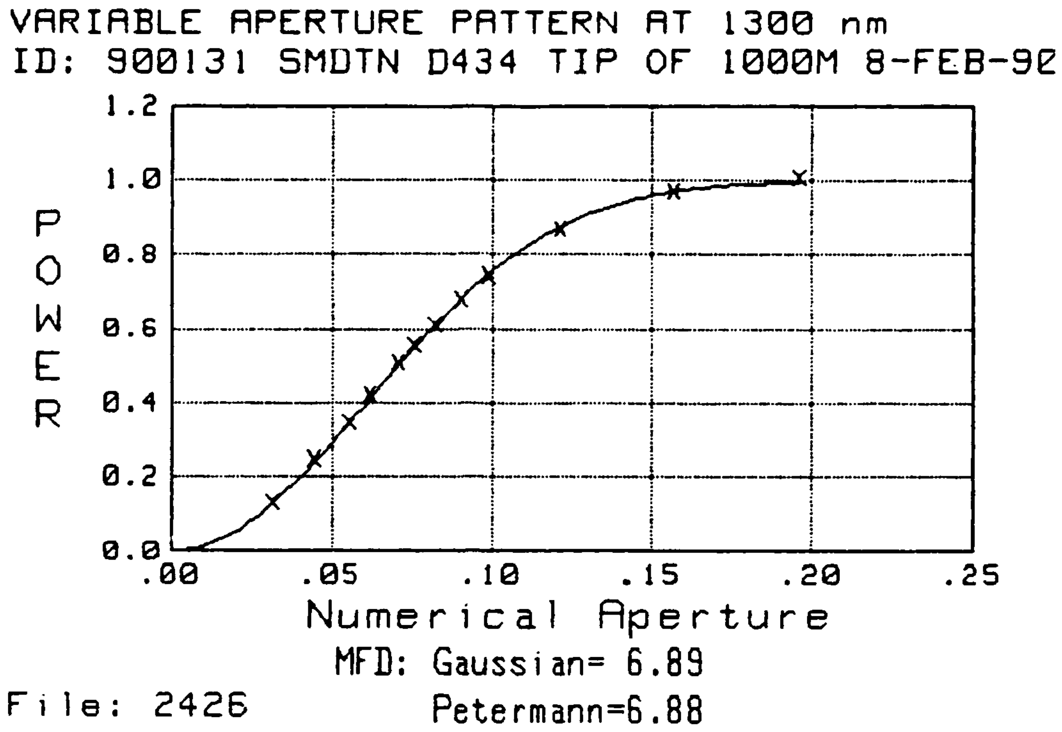


Figure 3
Sensor Fiber Numerical Aperture

Table 4. Sensor Fiber ESI Parameters

File:	2426	
Measurement Wavelength:	1300 nm	
Cutoff Wavelength:	1264 nm	
Conversion Factor:	1.120	
	Gaussian	Petermann
Spot Radius:	3.4229	3.4410 um
ESI Core Radius:	3.0731	3.0715 um
ESI Delta:	.0058	.0058
Nc-Ncl:	.0085	.0085
Numerical Aperture:	.1574	.1575

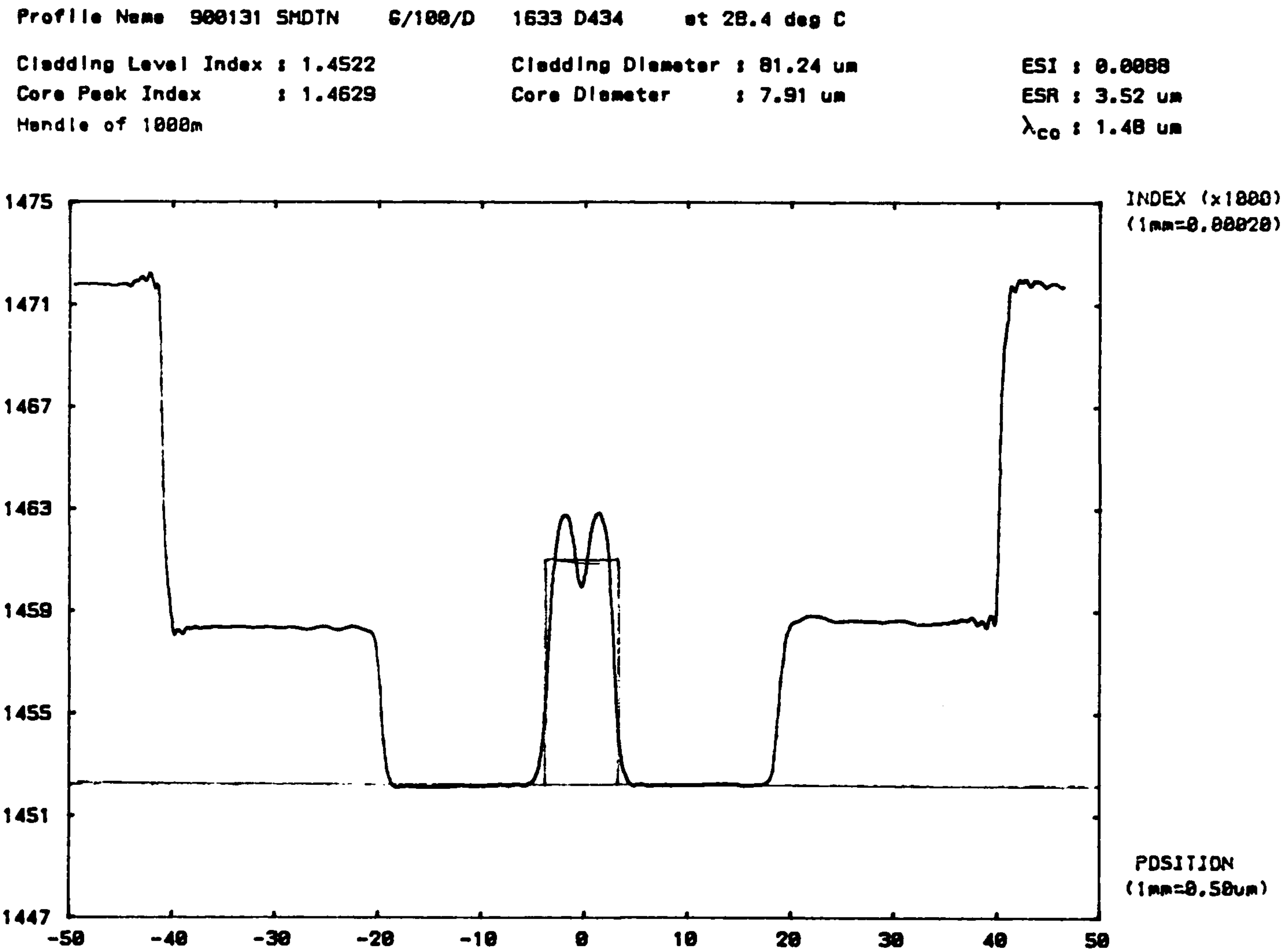
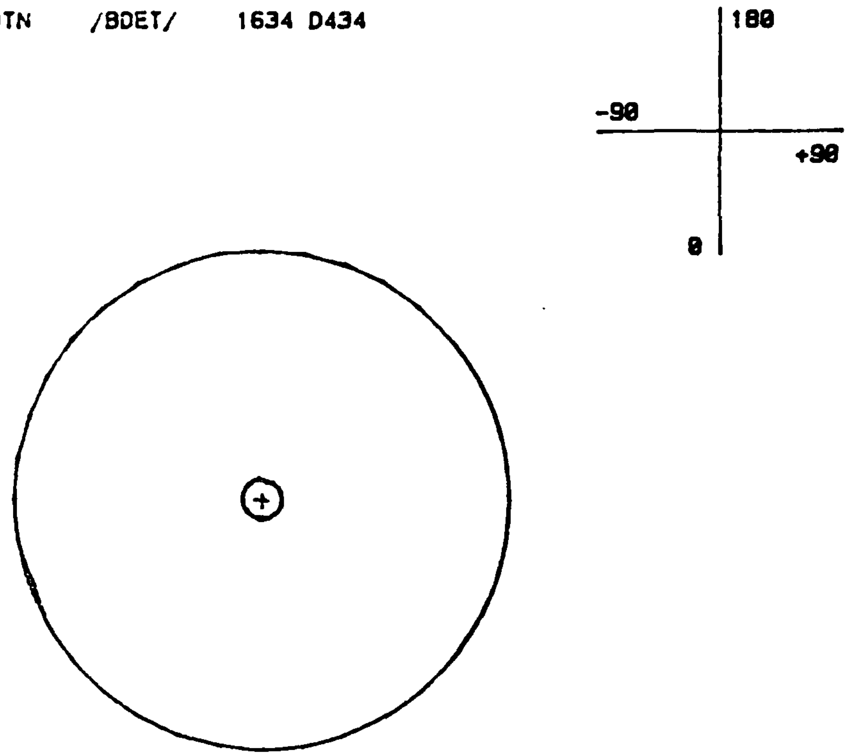


Figure 4
Sensor Fiber Refracted Near Field Scan

Fibre Name 900131 SMDTN /BDET/ 1634 D434



	Cladding	Core
Mean Diameter (um)	81.28	6.44
Maximum '' (um)	81.58	6.56
Minimum '' (um)	80.44	6.27
Non-Circularity (%)	1.4	4.6
Eccentricity	0.167 *	0.297
Major Axis Angle (deg)	6.8	77.7
Threshold Level (%)	50.0	50.0

Cladding Centre to Core Centre Distance 0.10 um

Concentricity Error 1.6 %

Figure 5
Sensor Fiber Geometry Report

Table 5. Coupler Fibers Attenuation versus Wavelength

Spectral Attenuation
Fiber ID: 900201 SMTN D435 As Drawn 8-Feb-90 12:42:29
Length: 1 km
File: 2429

Wavelength	Attenuation (dB/Km)	Wavelength	Attenuation (dB/Km)
650	18.49	1130	4.02
660	17.17	1140	5.13
670	16.29	1150	6.44
680	15.57	1160	7.03
690	14.75	1170	7.11
700	13.77	1180	7.06
710	12.58	1190	6.98
720	11.69	1200	6.87
730	11.06	1210	6.55
740	10.51	1220	6.03
750	10.00	1230	4.94
760	9.57	1240	3.36
770	9.51	1250	2.58
780	10.16	1260	2.31
790	10.24	1270	2.17
800	9.95	1280	2.11
810	9.27	1290	2.03
820	7.63	1300	2.01
830	7.08	1310	1.99
840	6.78	1320	2.03
850	6.53	1330	2.08
860	6.28	1340	2.18
870	6.04	1350	2.29
880	5.83	1360	2.51
890	5.61	1370	4.30
900	5.42	1380	7.51
910	5.25	1390	6.14
920	5.09	1400	4.76
930	4.95	1410	3.75
940	4.87	1420	2.83
950	4.69	1430	2.28
960	4.49	1440	1.97
970	4.31	1450	1.79
980	4.16	1460	1.63
990	4.02	1470	1.53
1000	3.89	1480	1.45
1010	3.75	1490	1.38
1020	3.63	1500	1.37
1030	3.51	1510	1.30
1040	3.41	1520	1.25
1050	3.31	1530	1.21
1060	3.22	1540	1.23
1070	3.13	1550	1.21
1080	3.08	1560	1.23
1090	3.04	1570	1.21
1100	3.05	1580	1.17
1110	3.15	1590	1.13
1120	3.42	1600	1.09

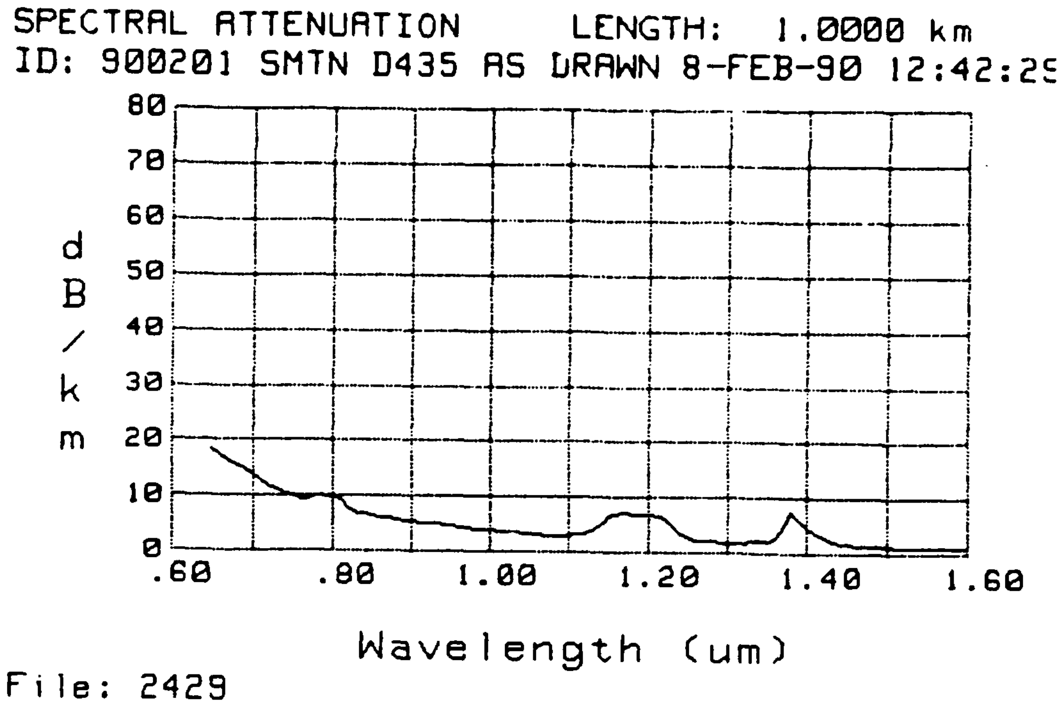


Figure 6
Coupler Fiber Attenuation versus Wavelength

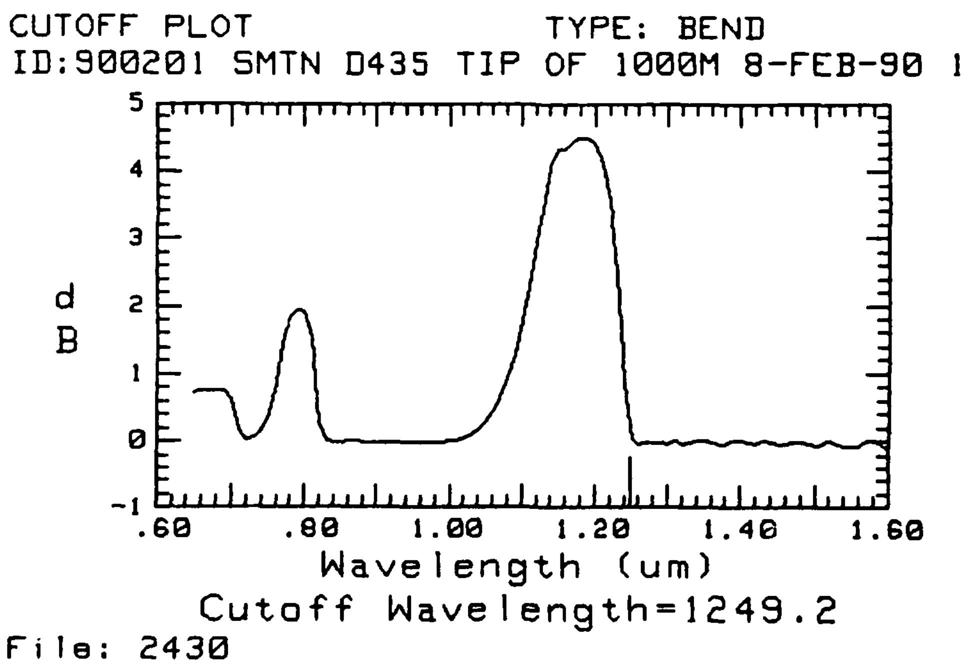


Figure 7
Coupler Fiber Cutoff

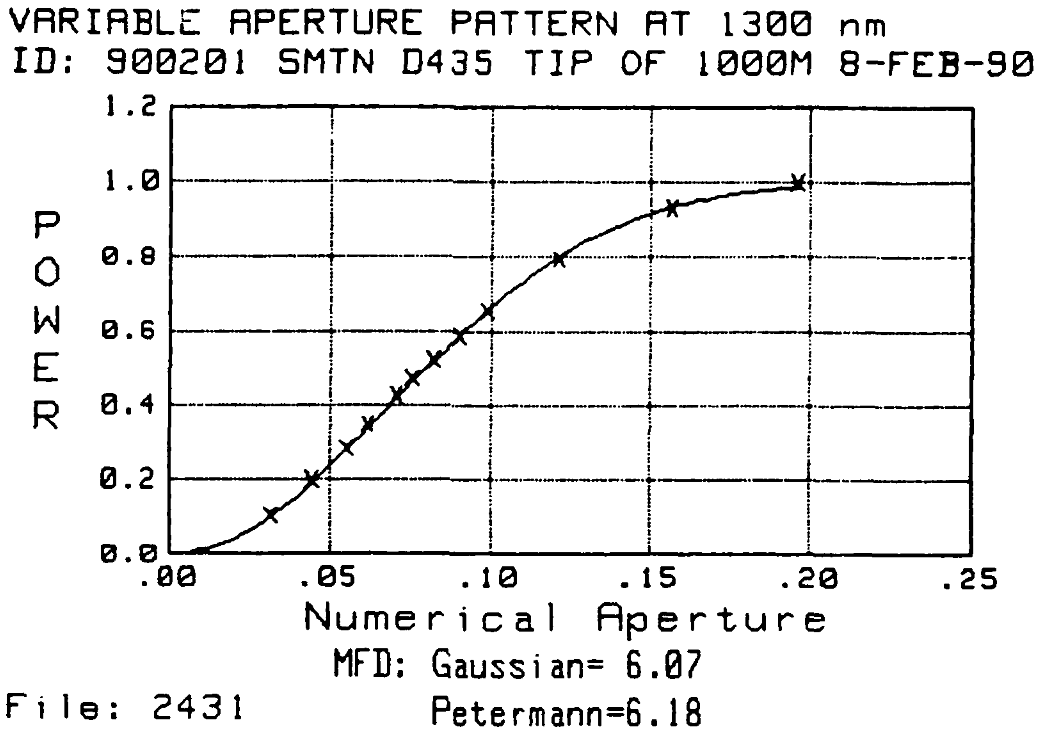


Figure 8
Coupler Fiber Numerical Aperture

Table 6. Coupler Fiber ESI Parameters

File:	2431	
Measurement Wavelength:	1300 nm	
Cutoff Wavelength:	1249 nm	
Conversion Factor:	1.130	
	Gaussian	Petermann
Spot Radius:	3.0355	3.0901 um
ESI Core Radius:	2.6868	2.7351 um
ESI Delta:	.0074	.0072
Nc-Ncl:	.0109	.0105
Numerical Aperture:	.1780	.1748

Profile Name 900201 SMTN 6/100/D 1624 D435 at 20.2 deg C

Cladding Level Index : 1.4527 Cladding Diameter : 81.71 um ESI : 0.0179

Core Peak Index : 1.4755 Core Diameter : 6.26 um ESR : 2.85 um

Tip of 1000m λ_{co} : 1.70 um

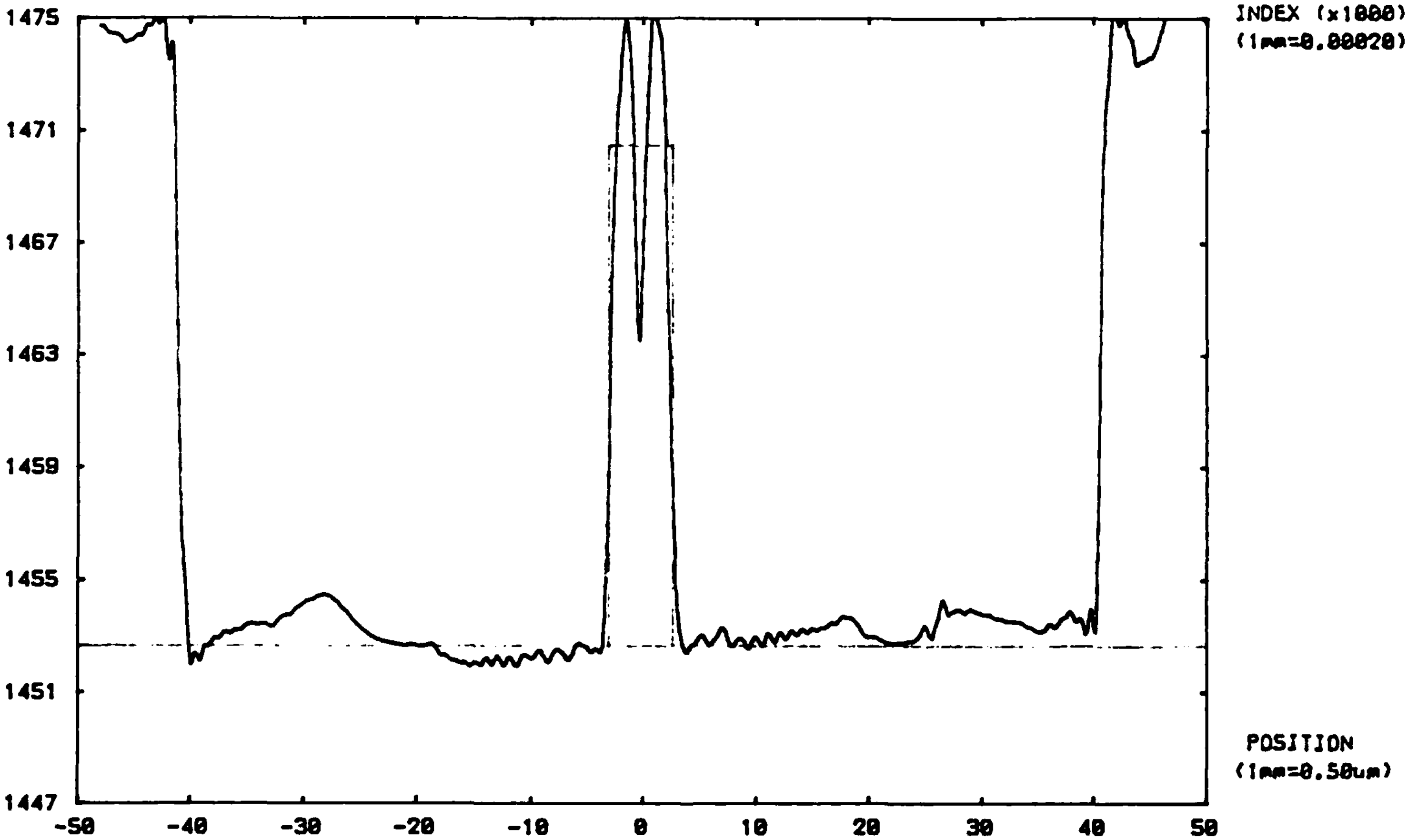
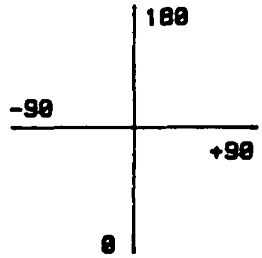
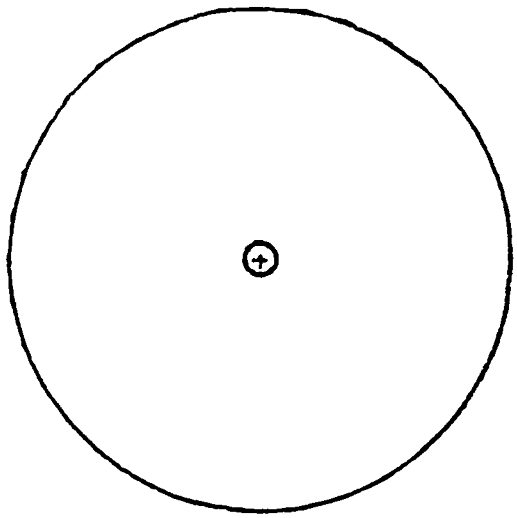


Figure 9
Coupler Fiber Refracted Near Field Scan

Fibre Name 900201 SMTN /BDET/ 1625 D435





	Cladding	Core
Mean Diameter (um)	81.93	5.27
Maximum " (um)	82.21	5.41
Minimum " (um)	81.40	5.17
Non-Circularity (%)	1.0	4.6
Eccentricity	0.140	0.295 *
Major Axis Angle (deg)	-28.3	50.3
Threshold Level (%)	50.0	50.0

Cladding Centre to Core Centre Distance 0.16 um

Concentricity Error 3.0 %

Figure 10
Coupler Fiber Geometry Report

Attachment A

Name of Contractor 3M

COST STATUS REPORT

For Period September 30 to January 31, 1989 Date: February 26, 1990

Contract No. N00014-89-C-2455

Period of Contract September 30, 1989 through September 29, 1990

Amount of Contract $198,906

Amount of Obligations and/or
Expenditures This Period $11,946

Amount of Obligations and/or
Expenditures To Date $11,946

Estimate of Funds to Complete: $186,960

Percentage of Funds Expended To Date: 6.00%

Percentage of Hours Expended To Date: 6.78%

Obligated Amount: $198,906

Percentage of Obligated Funds Expended To Date: 6.00%

All amounts shown must include overhead, G&A, handling charges, fees, etc.)

1. Is work on schedule? Yes (Attach sheets if necessary)
2. Can the contract be completed in the authorized time? Yes
3. Can the contract be completed with the authorized funds? Yes

Comments: (Attach sheets if necessary)

Technical Progress in Period: (Attach sheets if necessary)

Objective for the Next Period: (Attach sheets if necessary)

Submitted by
RCMcGraw