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SINGLE MODE OPTICAL WAVEGUIDE DESIGN INVESTIGATION. (U)

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SINGLE MODE OPTICAL WAVEGUIDE
DESIGN INVESTIGATION

PROGRESS REPORT 2

Submitted to
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MAY 15 1981
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March 30, 1981

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1. Summary

- 1.1 Lateral and angular offset sensitivity test equipment has been designed and built.
- 1.2 Measurements of lateral offset sensitivity have been made on several fibers to determine reproducibility, and wavelength dependence. A modified expression for lateral offset loss which takes into account the important parameter of spot-size was studied.
- 1.3 Microbend sensitivity measurements were made using the linear pin array and compared with the random microbend test proposed in the Technical Proposal. The pin array is proving to be more reproducible and has thus been chosen for this contract.
- 1.4 Three fibers were determined to be within the fiber design matrix and have been chosen for study. The criteria for selecting a fiber was expanded to encompass "equivalent-step parameters" whereby refractive index profile shapes other than the ideal step profile are taken into account.

2. Details of Present Work

2.1 Lateral Offset Sensitivity Test

2.1.1 Equipment

The design and assembly of equipment are complete. A combination of rotary and translation stages were chosen for this test. The rotary stages allow one end of the fiber to be put into angular alignment with the other end about two perpendicular axes. A special translation stage was constructed consisting of a differential screw mechanism attached to a micrometer stage. Translation in 0.1 μm steps is accomplished under computer program control.

2.1.2 Measurements

Movement of the translation stage and data acquisition are performed under computer program control. Reproducibility studies were conducted on four fibers. At 800 nm the lateral offset measurement was shown to be reproducible to within 0.2 μm at that lateral offset value which results in a 1 dB loss. Figure 1 is a plot of loss (dB) versus offset (μm). This example shows two successive lateral offset sensitivity

measurements taken at 900 nm. Except for loss values less than ~0.3 dB the data for the two measurements are indistinguishable. The measurements will be taken at 6 different wavelengths to explore the V (normalized frequency) dependence. Wavelength dependent lateral offset data taken at 4 different wavelengths are shown in Figure 2 for a test fiber (#502607). The offset necessary to produce a 1 dB loss is noted to have increased by 70% corresponding to a wavelength change from 800 to 1300 nm.

2.1.3 Discussion

To develop the proper dependence of guide parameters on lateral offset sensitivity it was found that the important concept of spot size must be included. In Table I data is presented for 1 dB offset loss at 4 wavelengths for the test fiber #502607. The equivalent step parameters determined from refractive index profiles are $\Delta = 0.61$ and $\lambda_c = 870$ nm. Included are corresponding values of V, (w_0/a) , and $\delta/(w_0/a)$ where w_0 is the spot size, a is the core radius and δ is the offset. Values of (w_0/a) are determined from the literature.¹ It is noted that the term $\delta/(w_0/a)$ increases by approximately 14% from 800 to 1300 nm whereas the δ value increases by about 74%. It is concluded that the modified expression for lateral offset sensitivity should be:

$$\gamma = C_0 a^2 \Delta \left(\frac{\delta}{w_0} \right)^2.$$

With the determination of the physical size of the can and near-field measurements of the spot size the coefficient C_1 can be empirically determined.

Equipment has been assembled for the single mode near-field measurements.

TABLE 1

Lateral Offset Measurements and Analysis
Fiber #502607

λ (nm)	δ (μ m) for 1 dB loss	V	wo/a	$\frac{\delta}{(wo/a)}$ (μ m)
800	1.15	2.6	1.06	1.08
950	1.35	2.2	1.25	1.08
1100	1.50	1.9	1.30	1.15
1300	2.00	1.6	1.63	1.25

2.2 Angular Offset Sensitivity Test

2.2.1 Equipment

The angular offset test equipment is contained within the apparatus for the lateral offset test discussed in 2.1.1. One of the two rotary stages is used to set the angular offset, the other stage to adjust angular alignment along the perpendicular axis.

Angular positions are set manually and lateral adjustments made at each angular position to assure proper alignment. Performance tests on fibers are planned in the next several weeks.

2.3 Microbend Sensitivity Test

2.3.1 Results and Discussion

The linear pin array has been shown to give more repeatable and interpretable results than the random microbend test which presses the fiber between two sandpaper plates. The theory and initial results using the pin array were reported in Progress Report #1.

Three pin arrays were constructed with spacings of 3, 5, and 8 mm. Relative microbend tests have started which intercompares all fibers using the 3 arrays. Array lengths chosen which give reasonable losses within the dynamic range

of the detector are 3, 5, and 12 cm for the 3, 5, and 8 nm arrays, respectively.

Figure 3 shows the microbend loss versus wavelength for one of the fibers within the design matrix (Fiber #502905; see section 2.4). Data is shown for the 3 mm pin array spacing. Loss curves for both the LP_{11} and LP_{01} modes are evident. For this test the wavelength marking the onset of LP_{01} microbending loss, λ_{mb} , is ~ 1125 nm. As expected the reproducibilities of the loss curves and the values of λ_{mb} determined from the curves were significantly improved over those determined from the random microbend test using sandpaper plates.

The value of λ_{mb} is used to calculate V_{mb} , the normalized frequency. Values of V_{mb} determined from microbend tests using the 3 pin arrays are plotted versus the perturbation frequency and shown in Figure 4.

2.4 Fiber Fabrication

Three fibers were chosen which fit within the design matrix. Parameters and properties are listed in Table II.

TABLE II
Parameters of Selected Fibers

Fiber #	Cutoff Wavelength			Relative Index Difference		Attenuation		
	λ_c^{Multi}	$\lambda_c^{\text{EQ-ST}}$	λ_c^{RNF}	$\Delta^{\text{EQ-ST}}$	Δ^{RNF}	1060nm	1300nm	1550nm
502905	1060	1140	-	0.55%		1.55 dB/km	1.44	0.45
503103	1080	1150	-	0.5%		3.43	2.46	1.81
503403	1210	-	1382		0.81%	2.76	1.61	0.99

Multi: determined by ratioing the spectral attenuation curves of the single mode fiber to a multimode fiber.

EQ-ST: equivalent step determination.

RNF: refracted near-field technique.

3. Program

- 3.1 Evaluate existing fibers within design matrix for microbend, lateral offset, and angular offset sensitivities.
- 3.2 Fabricate and select additional fibers within design matrix.

References

- ¹ E. Brinkmeyer, Applied Optics 18, pp. 932-937 (1979).

Figure 1
Lateral Offset Sensitivity

FIBER NO. : 502607/ACR
DATE 800 NM

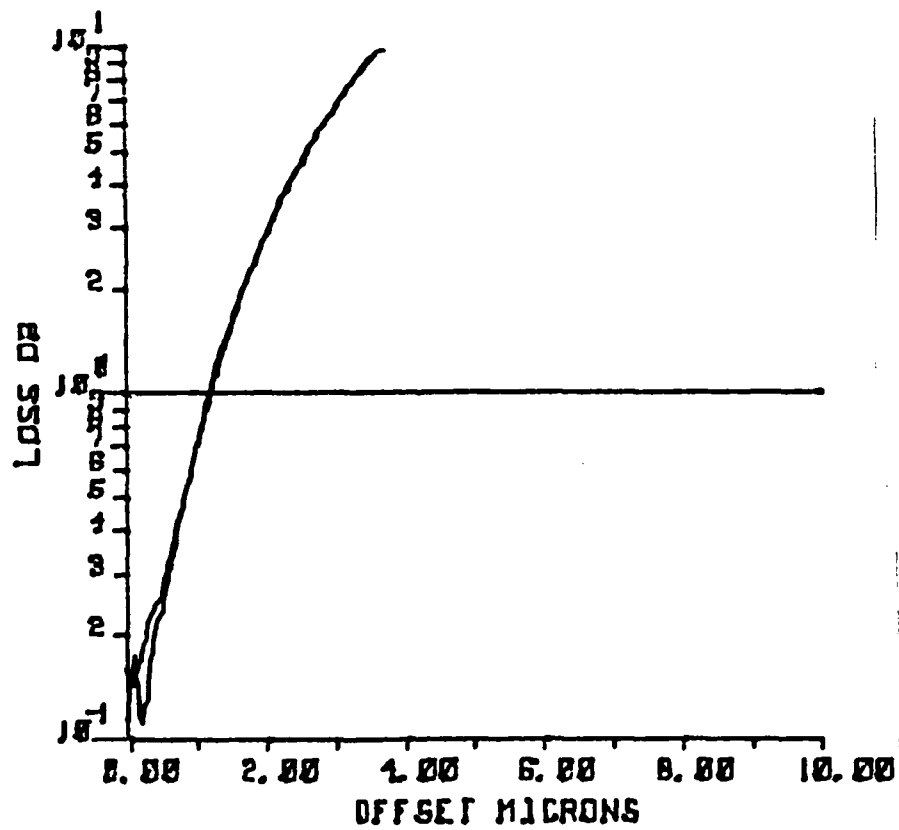


Figure 2

Wavelength Dependence of Lateral Offset Sensitivity

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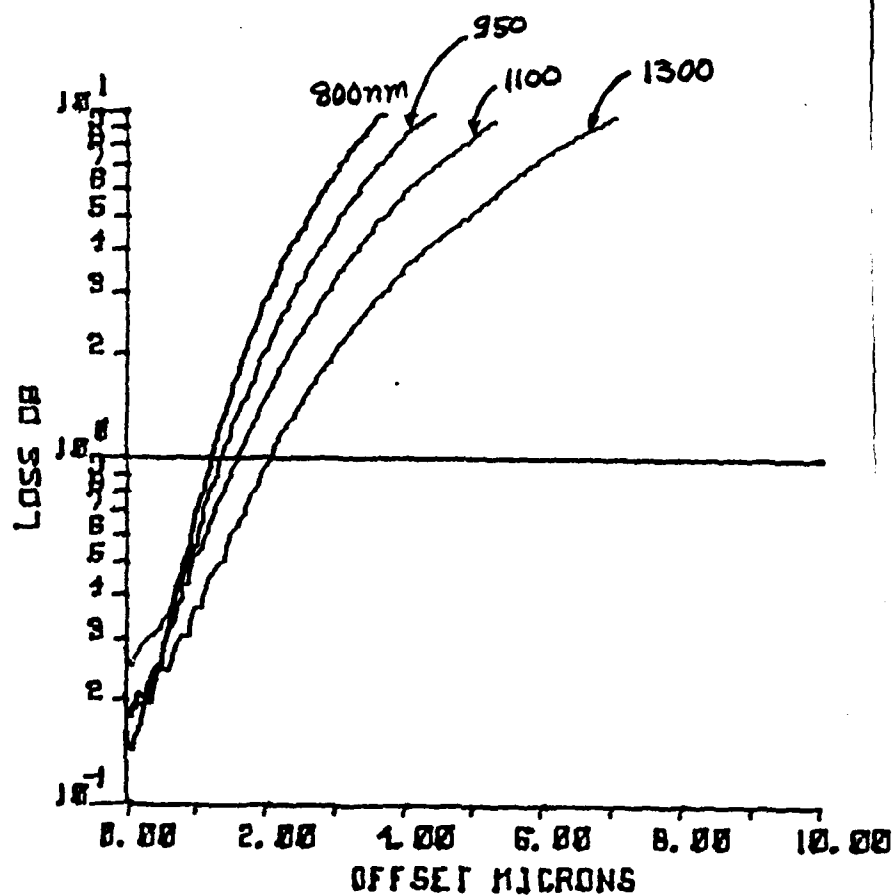


Figure 3

Microbend Loss vs Wavelength

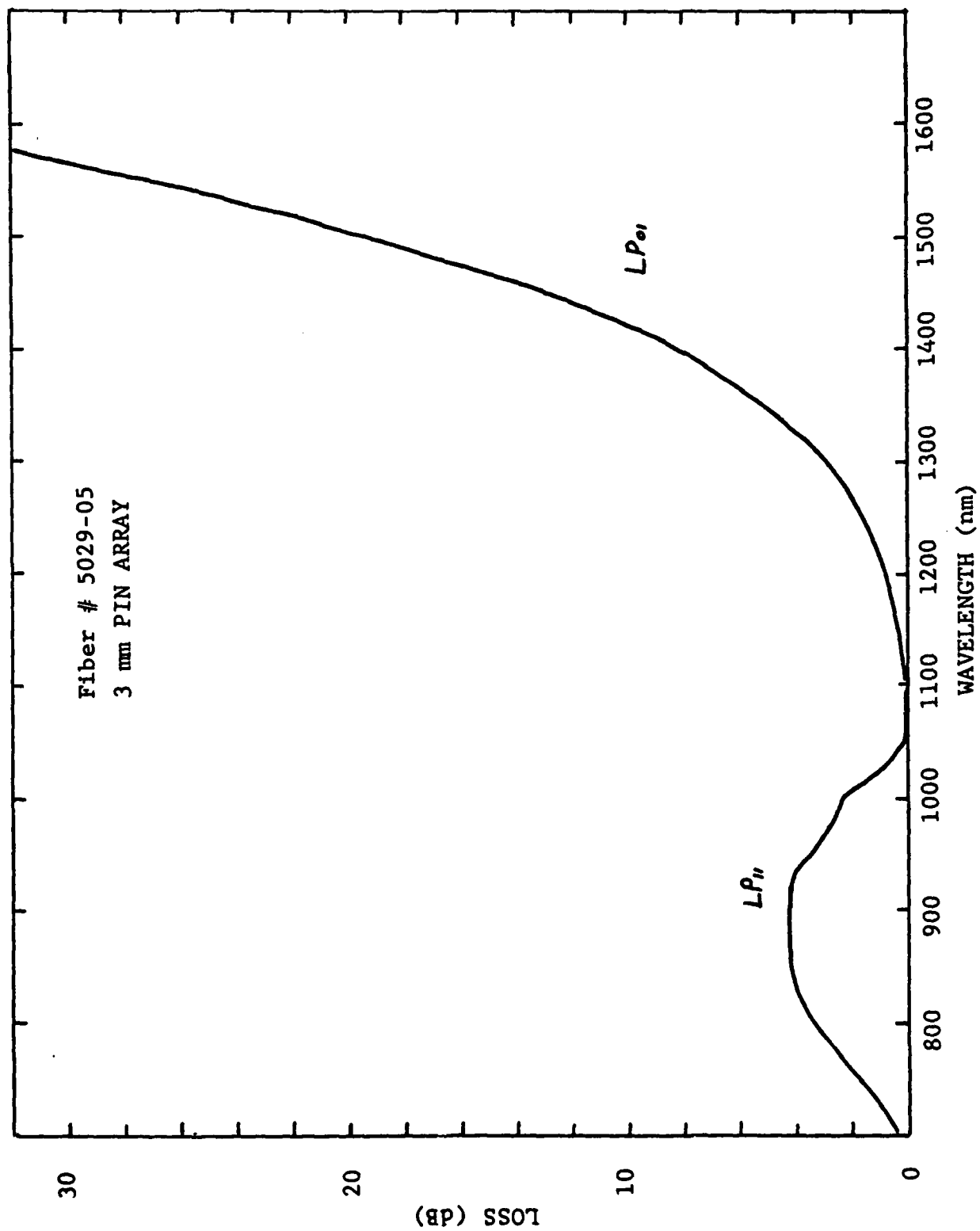
Fiber # 5029-05
3 mm PIN ARRAY

Figure 4

Microbend Sensitivity V_{mb} vs Perturbation Frequency

Figer # 502905

