B. S. T. J. BRIEF

Effect of Ambient Temperature on Infrared Transmission Through a Glass Fiber

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Recent progress in reducing the losses in optical fibers[1] has increased the possibility that such fibers might be used as dielectric waveguides in future optical communication systems.[2] The loss properties of such fibers are therefore of interest. This note concerns the measured change in transmission loss of a glass fiber for an ambient temperature variation of $-196°C$ to $+200°C$. The results indicate that the loss in glass fibers varies only slightly with temperature.

The attenuation measurements were made on single fibers taken from a Corning type 5900 optical fiber bundle. These fibers were approximately 60 μm in diameter and had a very thin cladding with a refractive index about 10 percent below that of the core. The elevated temperature measurement was performed on a 39-meter length which was made up of three 10- to 20-meter lengths joined into a single piece by a low-loss fusing process.[3] The reduced-temperature tests were made with a 12-meter segment of this same fiber. The light source consisted of a 50-μm-diameter gallium arsenide light emitter diode (GaAs LED)[4] which was used to supply about 0.05 mW of power into the fiber at a wavelength of 0.9 μm. Detection was accomplished with a silicon PIN photodetector. The high-temperature test was carried out with the major portion of the fiber on a reel in an oven; for the low-temperature test, the fiber was coiled in a Dewar flask filled with liquid nitrogen. In both cases, the source and the detector were outside the test chamber in a room-temperature ambient.

Calibration and stability tests showed that no measurable change occurred in the LED output when the input current was maintained within ± 0.05 percent; that the optical power from the LED decreased 0.24 percent for a one-degree rise in the ambient temperature (near 25°C); and that there was no measurable change in the detector sensitivity for an ambient temperature variation of ±2°C. The recording voltmeter drifted less than 0.001 mV (the estimated reading accuracy) in a 5-hour period. The time of an individual run was less than one hour.

Results of the measurements are summarized in Table I. The absolute attenuation of the fiber at room temperature was determined by measuring the received power, first through the entire length, and then (after breaking the fiber near the source) through a very short length. The tabulated results include a correction for a 0.144-percent reduction in input power due to a 0.6°C increase in the ambient temperature near the LED during the course of the heating run. The ambient temperature near the detector changed less than one degree during both runs, and thus no correction was required. The difference in loss per unit length of the two sections of fiber listed in the table is typical, in our experience, of the variation in the infrared loss of different individual fibers from the same bundle.

On the assumption of a thermal expansion coefficient for the glass of approximately $1 \times 10^{-5}/°C$, the change in fiber length over these large temperature ranges is significant. The estimated increase was 7 cm for a temperature increase of 175°C, for example. While this expansion slightly changes the value of the fiber loss per unit length, it does not affect consideration of the total change in loss between two terminals connected by a specific fiber.

The small variation in transmission loss measured for rather extreme temperature changes indicates that glass or glass-like dielectric waveguides should have transmission characteristics essentially unaffected

TABLE I—MEASURED CHANGE IN OVERALL TRANSMITTED POWER THROUGH CORNING 5900 FIBER

Fiber Length @25°C (m)	Ambient Temp. (°C)	Received Power (dBm)	Fiber Loss (dB)	Change in Effective Attenuation Constant (%)
39.20	+25	−44.83	31.82†	
	+200	−44.78*	31.76‡	−0.19*
12.02	+25	−26.29	13.28†	
	−196	−26.41	13.42‡	+1.05

* Corrected for change in source output due to ambient-temperature change of source
† Measured
‡ Derived from change in received power

by ordinary ambient temperature changes. The measured value for this fiber, of the order of 0.001 percent per degree Centigrade above room temperature, would correspond to a variation of the order of 10^{-3} dB/°C between repeaters separated by a transmission line with an overall attenuation of 50–60 dB. Thus the complex active temperature compensation required by coaxial cable systems[5] probably would not be necessary in a system employing fiber transmission lines.

These results qualitatively confirm the expectation that the absorption characteristics of wide band-gap materials should change very little as a result of normal temperature fluctuations. Furthermore, the direction of the small but detectable changes measured here is consistent with an increase in the lower-energy-state population of the glass at lower temperatures.

REFERENCES

1. Kapron, F. P., Keck, D. B., and Maurer, R. D., Appl. Phys. Letters, *17*, (1970), p. 423.
2. Miller, S. E., "Integrated Optics: An Introduction," B.S.T.J., *48*, No. 7 (September 1969), pp. 2059–2069.
3. Bisbee, D. L., "Optical Fiber Joining Technique," B.S.T.J., *50*, No. 10 (December 1971), pp. 3153–3158.
4. Burrus, C. A., and Dawson, R. W., "Small-Area High-Current-Density GaAs Electroluminescent Diodes and a Method of Operation for Improved Degradation," Appl. Phys. Letters, *17*, No. 3 (August 1971).
5. Members of the Technical Staff—Bell Telephone Laboratories, *Transmission Systems for Communications*, Third Edition, Winston-Salem, N.C.: Western Electric Company, 1964, Chapter 14.