National Institute of Standards and Technology

Certificate of Analysis

Standard Reference Material® 2520

Optical Fiber Diameter Standard

Serial No.

This Standard Reference Material (SRM) is intended for calibrating video microscopes or gray-scale systems used for fiber geometry measurements. Each SRM is individually calibrated and bears a serial number. The SRM consists of a short length of bare fiber in an aluminum housing. The end of each specimen has been carefully cleaved so that damage is minimal and the end is within approximately one-half wavelength of perpendicularity to the axis of the fiber. Also supplied for convenience is a 1-2 m pigtail that may be used for exciting the core of the fiber.

Table 1. Certified Diameters

Angle, in °	Diameter, in µm	Uncertainty, in nm (3σ)
0		± 42
45		± 42
90		± 42
135		± 42
mean		± 37

Expiration of Certification: The certification is valid indefinitely provided that the instructions for proper care and handling of the fiber have been adhered to and that the end face shows no sign of contamination, damage, or aging.

Housings were produced by Larsen Engineering, Boulder, CO and are based on a design provided by Photon Kinetics, Beaverton, OR. Fiber was contributed by Corning Inc., Optoelectronics Group, Corning, NY. Specimens were assembled by T. Drapela and S.E. Mechels of the NIST Optoelectronics Division.

The technical direction and physical measurements leading to certification were provided by M.Young with assistance from S.E. Mechels, P.D. Hale, T. Drapela, and D.L. Franzen of the NIST Optoelectronics Division.

Assistance with statistical analysis was provided by R.M. Judish of the NIST Electromagnetic Fields Division.

The technical and support aspects involved in the preparation, certification, and issuance of this SRM were coordinated through the Standard Reference Materials Program by N.M. Trahey and R.J. Gettings.

Gaithersburg, MD 20899
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(Revision of certificate dated 1-25-93)

Thomas E. Gills, Chief
Standard Reference Materials Program

Description of SRM: The specimen in the aluminum housing is a single-mode fiber that has been chosen especially to minimize noncircularity and fluctuations of diameter with length. The aluminum housing is marked so that the fiber may be held at several different angular orientations. Four diameters have been measured with a contact micrometer: these values, in addition to their mean, may be useful for calibrating a gray-scale system.

Determination of Optical Fiber Diameter: The diameter of the bare, cleaved end of the fiber has been measured approximately l mm from the end with a contact micrometer. Diameters have been measured at angles of 0°, 45°, 90°, and 135°, where the angles are defined in the instructions below. These four diameters and their mean are given in Table l. The noncircularity of the fiber may be estimated as the ratio of the largest diameter to the smallest diameter, minus l. No attempt has been made to locate the major and minor axes of the fiber. Provided that the fiber is approximately elliptical in cross section, the noncircularity estimated in this way is low by 0 % to 40 %, in addition to the uncertainty of measurement of the individual diameters. This SRM is not certified for noncircularity.

Discussion of Uncertainties: Uncertainties were calculated according to the procedures outlined in Ref. [1]. Measured (Type A) uncertainties were assumed to be Gaussian-distributed, whereas estimated or inferred (Type B) uncertainties were assumed to be described by a rectangular probability distribution function. The uncertainties were combined by adding their variances in quadrature, where the variance of a rectangular distribution is one-third the square of its half-width. Table 2 is a list of all the sources of uncertainty that could be identified. In (a), the measured standard deviations are listed, whereas in (b), the half-widths of the estimated uncertainties are listed.

Instructions for Use: Place the fiber housing in the set to be tested, with the magnetic stainless steel cover facing down. The front is the end from which the cleaved fiber end is pushed out; the rear is the end from which the brass barrel and fiber pigtail stick out. A line is scribed at the rear of the housing. The brass barrel has lines scribed on it at 45° intervals. There is a flat machined on the barrel. The fiber is defined to be in the 0° position when the line scribed on this flat aligns with the line on the rear of the housing. A 0° diameter measurement is defined to be a *horizontal* measurement when the fiber is in the 0° position. The 0° diameter, therefore, is measured in a plane parallel to the flat on the barrel. (These instructions assume that the user's gray-scale system is horizontal and that the image on the video screen is not inverted. If these conditions are not satisfied, the user may have to modify the angles accordingly.)

Place the housing in the gray-scale system with the flat on the barrel horizontal and facing upward, that is, in the 0° position. Micrometer measurements have been made at 0°, 45°, 90°, and 135°; that is, the fiber was rotated clockwise by those angles, as seen from the rear. Thus, with respect to the image on the monitor, the 0° diameter is horizontal and 90° diameter is vertical. The 45° diameter passes through the second and fourth quadrants, whereas the 135° diameter passes through the first and third quadrants. If a comparison of the NIST measurements of those four diameters with the edge table is desired, the fiber should be placed into the system in the 0° position. If the mean value of the four NIST diameter measurements is to be compared with the mean diameter, the specimen may be oriented in the system at any angle.

When ready to perform a measurement with the SRM, take the following steps to extend the fiber end from the housing:

Remove the housing and the pigtailed fiber from the recess in the SRM container. Remove the socket-head screw from the side of the housing. When in place, this screw keeps the barrel from moving forward, keeping the fiber retracted in the housing. This screw is just "finger-tight," simply unscrew it by hand. The barrel will now be able to move forward against slight resistance from the alignment spring. To extend the fiber end, push the barrel forward with a steady forward force. Be careful not to apply strong side forces while pushing or pulling the barrel, since the barrel could be forced out of its alignment and cause the fiber to hit the end of the housing or touch the side of the hole and break.

Following the instructions of the instrument manufacturer, insert the housing into the test set. It may be safest to have the fiber retracted when inserting the housing into the test set. Make sure that nothing is within l cm (0.4 in) of the front of the housing; then extend the fiber carefully. It will stick out roughly 0.57 cm (0.22 in) when fully extended.

Now rotate the barrel until the fiber is oriented at 0° (or at the desired angle), as defined above. While handling the barrel end, be careful not to bump or catch the exposed fiber pigtail. Secure the pigtail in a safe manner.

When launching light down the fiber, as with the gray-scale method, cleave the pigtailed end (opposite to the calibrated end). Cut away and strip as little fiber as possible, in order to ensure that there will be fiber left for future cleaving. Alternatively, it may be desirable to terminate the end of the pigtail with a connector.

Routine cleaning of the calibrated end of the fiber is not recommended. Rather, do the work in a clean environment and do not expose the fiber end more than necessary. If, however, the end becomes contaminated, clean it with an ultrasonic cleaner. This is the *only* method that is recommended for cleaning the calibrated end. Use either spectroscopic grade ethanol or acetone, preferably not reagent grade. Acetone may clean more stubborn contaminants. In either case, make sure that the fluid is fresh and clean. Then extend the fiber from the housing and dip it into the ultrasonic cleaning liquid for no more than a few seconds. Be careful not to bump the fiber end against the walls or floor of the cleaner. Do not immerse the housing itself in the fluid.

For calibrating the gray-scale system, simply follow the normal procedure and measure the diameter of the calibrated fiber. Calculate the mean value given on the certificate minus the measured value. This is the *additive correction.* Add the additive correction algebraically to the measured diameters to get the true diameters of the measured fibers. This procedure is most accurate for fibers that have nearly the same diameter as the calibrated fiber. Because of linear distortion or other factors in the gray-scale system, the additive correction may be less accurate if it is applied to fibers whose diameters differ greatly from the diameter of the calibrated fiber.

Storage and Handling: To store the fiber and housing, retract the fiber into the housing and replace the socket head screw into the side of the housing. Replace the housing into the recessed shipping container and screw the plastic top down. Store the entire assembly in a clean environment or put it into an airtight plastic bag. Do not expose the calibrated end or the housing more than is necessary.

Table 2. Tabulation of Uncertainties[a]		
Source of Uncertainty	Criterion	Uncertainty, in nm
(a) Measured Uncertainties		
Noise	Calculated standard deviation	8
Correction for deformation [2]	Standard deviation of calculated slope	3
(b) Inferred Uncertainties		
Correction for deformation [2]	Error of force equivalent to ½ g	10
Surface roughness	± ½ of correction	8
Burr on anvil	Control chart	10
Deformation or taper	Stress analysis & interference microscope	10
Cosine	0.2°	0.8
Abbe offset	1 μrad (0.2") x 2 mm offset	2
Wavelength	Fluorescence linewidth	0.3
Index of refraction of air under average conditions	Uncertainty of calculation	<0.1
Variation of Barometric pressure	± 4 kPa	1.25
Variation of Ambient temperature	± 5 K	0.5
Variation of Relative humidity	± 50 %	<0.1
Combined uncertainty	1σ	14
EXPANDED UNCERTAINTY	3σ	42

[a] Measured uncertainties are qualified as 1 standard deviation of the mean; inferred uncertainties are the estimated half-width of a rectangular distribution.

REFERENCES

[1] *Guide to the Expression of Uncertainty in Measurement*, ISBN 92-67-10188-9, lst Ed. ISO, Geneva, Switzerland, (1993).

[2] Young, M., Mechels, S.E., and Hale, P.D., "Optical Fiber Geometry: Accurate Measurement of Cladding Diameter," J. Res. Nat. Inst. Stands. Tech., Vol. **98**, No. 2, pp. 203-216, (1993).