National Institute of Standards & Technology

Certificate

Standard Reference Material® 2524

Optical Fiber Chromatic Dispersion Standard

Serial No.

This Standard Reference Material (SRM) is intended primarily to calibrate fiber dispersion measurement systems used to measure the zero-dispersion wavelength (λ_o) and the dispersion slope (S_o) at λ_o. Each SRM 2524 unit consists of an approximate 10 km length of dispersion-shifted fiber housed in an aluminum box containing foam insulation for thermal stability. Mounted on the front panel of the aluminum box are two bulkhead FC/PC type adapters for optical connection with the measurement system to be calibrated. Also supplied with the unit are two 1.5 m dispersion-shifted fiber jumpers with FC/PC connectors on one end and bare ends on the other. To minimize the likelihood of optical reflections, the FC/PC connectors on the fiber jumpers are from the same manufacturer as those internal to the SRM unit. The dispersion-shifted SRM fiber has a λ_o value in the 1550 nm region.

Table 1. Certified Values and Uncertainties at 23 °C

Certified Parameter	Certified Value	Uncertainty, 2σ
Zero-dispersion wavelength (λ_o)	nm	± 0.06 nm
Dispersion slope at λ_o (S_o)	ps/nm^2	± 0.008 ps/nm^2

The technical work and scientific research leading to certification were performed by S.E. Mechels, D.L. Franzen, and J.B. Schlager of the NIST Optoelectronics Division, with assistance from M. Young and P.A. Williams of the NIST Optoelectronics Division.

Statistical guidance was provided by C.-M. (J.) Wang of the NIST Statistical Engineering Division.

SRM production and certification measurements were performed by S.E. Mechels of the NIST Optoelectronics Division.

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

Gaithersburg, MD 20899
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Certified Values and Uncertainties: The uncertainties for λ_o and S_o were calculated according to the procedures outlined in Reference [1]. Measured (Type A) uncertainties were Gaussian-distributed and their widths were determined experimentally. The inferred (Type B) uncertainties were assumed to be Gaussian-distributed, and their widths were estimated. Both types of uncertainty were then added in quadrature to obtain the overall uncertainty. Tables 2 and 3 list all of the uncertainties that could be identified for λ_o and S_o.

Expiration of Certification: The certification of SRM 2524 is valid indefinitely, within the measurement uncertainties specified, provided that the SRM is handled and stored in accordance with the instructions given in this certificate (see Instructions for Use). This certification will be nullified if the SRM is damaged or modified.

The dispersion properties of typical SRM fibers including λ_o and S_o have been carefully studied for over a year, and values are stable with time. The λ_o and S_o values of the calibrated fiber are immune to hysteresis from temperature or strain and should be invariant over the life of the fiber.

Storage and Handling: Store the fiber SRM unit with dust caps (supplied with the unit) covering the FC/PC bulkhead adapters.

Instructions for Use: The bulkhead connectors on the SRM unit are the FC/PC type. When connecting the SRM to the dispersion test equipment to be calibrated, use high quality FC/PC connectors. Any type of connector necessary for interfacing with the user's system can be attached (by fusion splice, capillary tube, etc.) to the bare ends of the two jumper fibers supplied with the unit. Alternatively, if the measurement system to be calibrated already possesses FC/PC connectors of high quality (return loss $>$ 40 dB), they can be directly connected to the SRM unit.

In either case, the cleanliness of the connectors is of great importance. Accumulation of dust or dirt in the bulkhead adapter or on the connector ferrule endface can cause phase noise by optical feedback into the source laser. Use of a commercial fiber endface cleaner before every connection is recommended. If one is not available, then lens paper wetted with reagent grade ethyl alcohol can be used to wipe the ferrule endface. A dust-free and residue-free air source can then be used to dry the connector endface.

The SRM fiber must be in thermal equilibrium before proceeding with measurements. Group delay in an optical fiber has a strong temperature dependence; significant phase drift will occur during a measurement if the SRM fiber is not in thermal equilibrium. NIST recommends that the fiber be left for at least 12 hours at ambient room temperature before proceeding with measurements.

In dispersion-shifted optical fiber, λ_o has a temperature dependence of + 0.030 nm/°C. Therefore, it is important that users note the temperature at which their measurements are performed, so that useful comparisons with the NIST value can be made. All NIST calibrations were performed at 23 °C; if the temperature of the SRM user's laboratory is different, corrections to λ_o for the temperature difference may be necessary. The dispersion slope S_o does not have a significant temperature dependence.

The SRM unit has significant thermal inertia due to the foam insulation and to the thermal mass of the fiber itself. Thus, it may not be sufficient to measure a single laboratory temperature for the calibration process. If the temperature of the user's laboratory fluctuates significantly, the measured room temperature may be different than the actual fiber temperature. A temperature-controlled chamber will yield the best results, since the stable environment will enable the SRM fiber to come into equilibrium at a known temperature. If an actively controlled chamber is not available, the SRM unit may be placed inside a thermally insulating container.

If neither a room with well controlled temperature nor a temperature chamber is available, then use of the temperature probe port on the back of the SRM unit is recommended. The metal plug which covers the port can be easily removed by pulling it from the rubber grommet. Inside, a hole in the foam insulation leads to a milled out section in the center of the side foam piece. A temperature probe inserted into the hole will be able to directly measure the air temperature in the chamber containing the fiber. Although the hole in the foam runs parallel to the fiber specimen (rather than directly at it), a temperature probe should be inserted **no more than 10 cm** into the port as it may bend at a right angle and potentially damage the fiber.

Corrections for residual dispersion within the measurement system will need to be made. Residual dispersion will, if not corrected for, introduce an error in measurements of the SRM fiber and, therefore, in the calibration process. The procedure for making these corrections is discussed in Fiber Optic Test Procedures (FOTP) 169 and 175 [2,3].

Note: The SRM fiber length provided is an approximate length supplied by the manufacturer and rounded to the nearest 0.1 km. To express the dispersion slope with units of ps/(nm^2•km), divide the calibrated dispersion slope value by the approximate fiber length given. Note that this step is unnecessary for calibration of the dispersion slope.

Determination of the Zero Dispersion Wavelength and Dispersion Slope: The dispersion parameters, λ_o and S_o, of the SRM have been determined experimentally using a frequency domain phase shift technique [4]. To determine λ_o and S_o, the group delay (τ_g) of the fiber specimen was measured over a 30 nm wavelength interval, centered about λ_o, with data points being taken every 2.5 nm. Following the recommendations of FOTP-169 [2], the resultant group delay data are fitted to a quadratic equation

$$\tau(\lambda) = a\lambda^2 + b\lambda + c. \qquad \textbf{(1)}$$

The unknown variables a, b, and c are solved for by the method of least squares. To calculate the dispersion of the fiber specimen, the best fit group delay curve is differentiated with respect to wavelength. The dispersion coefficient

$$D = \frac{d\tau}{d\lambda} = 2a\lambda + b, \qquad \textbf{(2)}$$

has the units of ps/(nm•km) and is zero at a wavelength defined as λ_o. Using the calculated dispersion values, the dispersion slope (S) is calculated as

$$S = \frac{dD}{d\lambda}. \qquad \textbf{(3)}$$

The parameter S_o is defined as the dispersion slope evaluated at λ_o.

Table 2. Measurement Uncertainties in λ_o

Type A: Measured Uncertainties	Uncertainty (2σ), nm
Random noise	0.035
Correction for residual system dispersion	0.007
Type B: Inferred Uncertainties	Uncertainty (2σ), nm
Second order polarization mode dispersion (PMD)	0.040
Curve fitting	0.007
Wavelength	0.007
Chirp	negligible
Short term RF frequency stability	negligible
Temperature	0.025
Expanded uncertainty, 2σ	0.060

Table 3. Measurement Uncertainties in S_o

Type A: Measured Uncertainties	Uncertainty (2σ), ps/(nm^2)
Random noise	0.006
Type B: Inferred Uncertainties	Uncertainty (2σ), ps/(nm^2)
Curve fitting	0.005
Phase calibration error	negligible
Expanded uncertainty, 2σ	0.008

REFERENCES

[1] *Guide to the Expression of Uncertainty in Measurement*, ISBN 92-67-10188-9, 1st Ed. ISO, Geneva, Switzerland, (1993): see also Taylor, B.N. and Kuyatt, C.E., "Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results," NIST Technical Note 1297, U.S. Government Printing Office, Washington, DC, (1994).

[2] FOTP-169, "Chromatic Dispersion Measurement of Optical Fibers by the Phase-Shift Method," Telecommunications Industry Association, 2001 Pennsylvania Ave., N.W. Washington DC.

[3] FOTP-175, "Chromatic Dispersion Measurement of Optical Fibers by the Differential Phase Shift Method," Telecommunications Industry Association, 2001 Pennsylvania Ave., N.W. Washington DC.

[4] Mechels, S.E., Schlager, J.B., and Franzen, D.L., "Accurate Measurements of the Zero-Dispersion Wavelength in Optical Fibers," NIST Journal of Research, submitted (1996).