for these purposes) and the instrument should be current with respect to the required calibration date.

Measurements of the optical power emitted from the end of an optical fiber should ensure that all optical power is collected, not just the power within the angle defining the numerical aperture. A variety of specialized OFCS power meters have been developed and are commercially available. Optical power measurements for hazard classification for the purposes of this standard require the collection of total power (optical flux) within the defining aperture placed at the defined distance from the fiber tip (or FSOS aperture) as specified in Table 4c.

10. Revision of Standards and Codes Referred to in this Document

When any of the following American National Standards referred to in this document is superseded by a revision approved by the American National Standards Institute, Inc., the revision shall apply:

10.1 ANSI Standards

American National Standard for Safe Use of Lasers, ANSI Z136.1.

American National Standard for Safe Use of Lasers Outdoors, ANSI Z136.6.

American National Standard Fundamentals Governing the Design and Operation of Local Exhaust Ventilation Systems, ANSI/AIHA Z9.2.

American National Standard Recommended Practice for Laser Safety Measurements for Hazard Evaluation, ANSI Z136.4.

American National Standard Safety Requirements for Workplace Walking/Working Surfaces and Their Access; Workplace Floor, Wall and Roof Openings; Stairs and Guardrail Systems, ANSI A1264.1.

10.2 Other Standards and Codes

ACGIH, Handbook of Ventilation for Contaminant Control.

FDA/CDRH Federal Laser Product Performance Standard (FLPPS), 21CFR Part 1040.

FDA/CDRH Laser Products – Conformance with IEC 60825-1 and IEC 60601-2-22; (Laser Notice No. 50).

IEC 60825 Safety of Laser Products – Part 1: Equipment Classification, Requirements, and User's Guide.

IEC 60825 Safety of Laser Products – Part 2, Safety of Optical Communication Systems.

IEC 60825 Safety of Laser Products –Part 12: Safety of Free Space Optical Communication Systems used for Transmission of Information.

IEEE Standard for Safety Levels with Respect to Human Exposure to Electromagnetic Fields, 0 to 3 kHz, IEEE C95.6-2002.

NFPA 115 Standard for Laser fire Protection.

OSHA Occupational Safety and Health Standards for General Industry, 29 CFR

1910.147 The Control of Hazardous Energy (lockout/tagout)

1910.268 Telecommunications

Table 1 – Accessible Emission Limits for Class 1 and Class 1M OCS Laser Products

Wavelength (µm)	Exposure Duration (s)	Radiant Energy (J)	Radiant Power (W)	Radiant Exposure ($J \cdot cm^2$)	Irradiance ($W \cdot cm^2$)
0.600 to 0.700	1×10^{-3} to 10	$7 \times 10^{-4}\, t^{0.75}\, C_E$			
0.600 to 0.700	10 to T_2	$7 \times 10^{-4}\, t^{0.75}\, C_E$			
0.600 to 0.700 [a]	T_2 to 3×10^4		$3.9 \times 10^{-4} C_E$		
0.600 to 0.700 [b]	T_2 to 3×10^4		$7 \times 10^{-4}\, T_2^{-0.25}\, C_E$		
0.700 to 1.050	1×10^{-3} to 10	$7 \times 10^{-4}\, t^{0.75}\, C_A C_E$			
0.700 to 1.050	10 to T_2	$7 \times 10^{-4}\, t^{0.75}\, C_A C_C C_E$			
0.700 to 1.050 [a]	T_2 to 3×10^4		$3.9 \times 10^{-4}\, C_A C_E$		
0.700 to 1.050 [b]	T_2 to 3×10^4		$7 \times 10^{-4}\, T_2^{-0.25}\, C_A C_C C_E$		
1.050 to 1.400	1×10^{-3} to 10	$3.5 \times 10^{-3}\, t^{0.75} C_C C_E$			
1.050 to 1.400	10 to T_2	$7 \times 10^{-4}\, t^{0.75}\, C_A C_C C_E$			
1.050 to 1.400 [a]	T_2 to 3×10^4		$3.9 \times 10^{-4}\, C_A C_E$		
1.050 to 1.400 [b]	T_2 to 3×10^4		$7 \times 10^{-4}\, T_2^{-0.25}\, C_A C_C C_E$		
1.400 to 1.500	0.1 to 0.35	$4.4 \times 10^{-3}\, t^{0.25}$			
1.400 to 1.500	0.35 to 10	$10^{-2}\, t$			
1.400 to 1.500	10 to 3×10^4		10^{-2}		
1.500 to 1.800	0.1 to 0.35	8×10^{-3}			
1.500 to 1.800	0.35 to 10	$1.8 \times 10^{-2}\, t^{0.75}$			
1.500 to 1.800	10 to 3×10^4		10^{-2}		
1.800 to 4.000	0.1 to 0.35	$4.4 \times 10^{-3}\, t^{0.25}$			
1.800 to 4.000	0.35 to 10	$10^{-2}\, t$			
1.800 to 4.000	10 to 3×10^4		10^{-2}		
4.000 to 10^3	0.1 to 10			$0.56\, t^{0.25}$	
4.000 to 10^3	10 to 3×10^4				0.1

NOTE 1—See Table 7 for correction factors C_A, C_C, C_E and T_2.

NOTE 2—The hazard levels and access levels in this standard are analogous to the hazard Classes, 1, 1M, 2, 2M, 3R and 3B. This approach is consistent with that of ANSI Z136.1-2007, IEC 60825-2 (2004), and IEC 60825-12 (2004).

NOTE 3—Accessible Emission Limits (AELs) are used to determine hazard classification, hazard levels, and access levels. This level of power or energy entering the eye is not expected to cause injury. For clarification of the terms access level and hazard level as used in this standard, see Appendix D.

NOTE 4—The values shown in Tables 1-5b represent selected values commonly used with OCS laser systems. To determine values for other laser systems, refer to ANSI Z136.1 or IEC 60825-1.

NOTE 5—The wavelength region λ_1 to λ_2 means $\lambda_1 \leq \lambda < \lambda_2$, e.g., 315 to 400 nm means $315 \leq \lambda < 400$ nm.

[a] $\alpha \leq 1.5$ mrad

[b] $\alpha > 1.5$ mrad

Table 2 – Accessible Emission Limits for Class 2 and Class 2M OCS Laser Products

Wavelength (µm)	Exposure Duration (s)	Radiant Energy (J)	Radiant Power (W)
0.600 to 0.700	$t < 0.25$	$7 \times 10^{-4}\, t^{\,0.75}\, C_E$	
	$t \geq 0.25$		$C_C \times 10^{-3}$

NOTE—The wavelength region λ_1 to λ_2 means $\lambda_1 \leq \lambda < \lambda_2$.

Table 3a – Accessible Emission Limits for Class 3R OCS Laser Products

Wavelength (µm)	Exposure Duration (s)	Radiant Energy (J)	Radiant Power (W)	Radiant Exposure ($J \cdot cm^{2}$)	Irradiance ($W \cdot cm^{2}$)
0.600 to 0.700	1×10^{-3} to 0.25	$3.5 \times 10^{-3}\, t^{\,0.25} C_E$			
0.600 to 0.700	$t \geq 0.25$ to 3×10^{4}		$5.0 \times 10^{-3} C_E$		
0.700 to 1.050	1×10^{-3} to 10	$3.5 \times 10^{-3}\, t^{\,0.75} C_A C_E$			
0.700 to 1.050	10 to T_2	$3.5 \times 10^{-3}\, t^{\,0.75} C_A C_C C_E$			
0.700 to 1.050 [a]	T_2 to 3×10^{4}		$2.0 \times 10^{-3}\, C_A C_E$		
0.700 to 1.050 [b]	T_2 to 3×10^{4}		$3.5 \times 10^{-3} C_A C_C C_E T_2^{\,-0.25}$		
1.050 to 1.400	1×10^{-3} to 10	$1.8 \times 10^{-2}\, t^{\,0.75} C_A C_E$			
1.050 to 1.400	10 to t T_2	$3.5 \times 10^{-3}\, t^{\,0.75} C_A C_C C_E$			
1.050 to 1.400	T_2 to 3×10^{4}		$2.0 \times 10^{-3}\, C_A C_E$		
1.050 to 1.400	T_2 to 3×10^{4}		$3.5 \times 10^{-3} C_A C_C C_E T_2^{\,-0.25}$		
1.400 to 1.500	1×10^{-3} to 0.35	$2.2 \times 10^{-2}\, t^{\,0.25}$			
1.400 to 1.500	0.35 to 10	$5 \times 10^{-2}\, t$			
1.400 to 1.500	10 to 3×10^{4}		5×10^{-2}		
1.500 to 1.800	1×10^{-3} to 0.35	4×10^{-2}			
1.500 to 1.800	0.35 to 10	$9 \times 10^{-2}\, t^{\,0.75}$			
1.500 to 1.800	10 to 3×10^{4}		5×10^{-2}		
1.800 to 4.000	1×10^{-3} to 0.35	$2.2 \times 10^{-2}\, t^{\,0.25}$			
1.800 to 4.000	0.35 to 10	$5 \times 10^{-2}\, t$			
1.800 to 4.000	10 to 3×10^{4}		5×10^{-2}		
4.000 to 10^{3}	1×10^{-3} to 10			$2.8\, t^{\,0.25}$	
4.000 to 10^{3}	10 to 3×10^{4}				0.5

NOTE 1—See Table 7 for correction factors C_A, C_C, C_E, and T_2.

NOTE 2—The wavelength region λ_1 to λ_2 means $\lambda_1 \leq \lambda < \lambda_2$.

[a] $\alpha \leq 1.5$ mrad

[b] $\alpha > 1.5$ mrad

Table 3b – Accessible Emission Limits for Class 3B OCS Laser Products

Wavelength (µm)	Exposure Duration (s)	Radiant Energy (J)	Radiant Power (W)
0.600 to 0.700	1×10^{-3} to $t < 0.06$	0.03	
0.600 to 0.700	$0.06 \leq t \leq 3 \times 10^{4}$		0.5
0.700 to 1.050	1×10^{-3} to $t < 0.06\ C_A$	$0.03\ C_A$	
0.700 to 1.050	$0.06\ C_A \leq t \leq 3 \times 10^{4}$		0.5
1.050 to 1.400	1×10^{-3} to 0.25	0.15	
1.050 to 1.400	0.25 to 3×10^{4}		0.5
1.400 to 10^{3}	1×10^{-3} to 0.25	0.125	
1.400 to 10^{3}	0.25 to 3×10^{4}		0.5

NOTE 1—See Table 7 for correction factor C_A.

NOTE 2—The wavelength region λ_1 to λ_2 means $\lambda_1 \leq \lambda < \lambda_2$.

NOTE 3—The exposure duration t_1 to t_2 means $t_1 \leq t < t_2$.

Table 4a – Limiting Apertures (Irradiance and Radiant Exposure) for General Hazard Evaluation and the Determination of Access Levels (FSOCS)

Wavelength (µm)	Duration (s)	Aperture diameter (mm)	
		Eye	Skin
0.600 to 1.400	10^{-3} to 3×10^{4}	7.0	3.5
1.400 to 10^{2}	10^{-3} to 0.3 [a]	1.0	3.5
	0.3 to 10 [a]	$1.5\ t^{0.375}$	3.5
	10 to 3×10^{4}	3.5	3.5
10^{2} to 10^{3}	10^{-3} to 3×10^{4}	11.0	11.0

NOTE 1—The wavelength region λ_1 to λ_2 means $\lambda_1 \leq \lambda < \lambda_2$.

NOTE 2—The exposure duration t_1 to t_2 means $t_1 \leq t < t_2$.

[a] Under normal conditions these exposure durations would not be used for hazard evaluation. Although optical signals used with telecommunications systems are modulated, the modulating frequencies are usually greater than 1 MHz and CW conditions apply. For systems that are modulated at lower frequencies, see Z136.1. (See Table 4c for measurement conditions.)

Table 4b – Limiting Apertures for General Hazard Evaluation and the Determination of Hazard Levels (OFCS) [a]

Wavelength (µm)	Duration (s)	Measurement Condition	
		Aperture diameter (mm)	Measurement Distance (mm) [b]
0.600 to 1.400	10^{-3} to 3×10^4	7.0	70
1.400 to 10^2	10^{-3} to 0.3	1.0	28
	0.3 to 10 [c]	$1.5\ t^{0.375}$	28
	10 to 3×10^4	3.5	28
10^2 to 10^3	10^{-3} to 3×10^4	11.0	28

NOTE 1—The wavelength region λ_1 to λ_2 means $\lambda_1 \leq \lambda < \lambda_2$.

NOTE 2—The exposure duration t_1 to t_2 means $t_1 \leq t < t_2$.

[a] Hazard levels should not be confused with the classification of the laser product. See Appendix D for clarification.

[b] From the closest point of human access to the active end of the fiber, and if the emitting fiber tip is recessed, at that point of human access.

[c] Under normal conditions these exposure durations would not be used for hazard evaluation. Although optical signals used with telecommunications systems are modulated, the modulating frequencies are usually greater than 1 MHz and CW conditions apply. For systems that are modulated at lower frequencies, see Z136.1. (See Table 4c for measurement conditions.)

Table 4c – Summary of Measurement Conditions for Classification

	For AELs expressed in power (W) or energy (J)				For AELs expressed as irradiance (W/cm²) or radiant exposure (J/cm²)	
Wavelength (µm)	**Condition 1 Low divergence (for binoculars – FSOCS) [a]**		**Condition 2 High divergence (for eye loupes - OFCS) [a]**		**For MPEs and determination of levels 1M and 2M**	
	Aperture (mm)	Distance (mm)	Aperture (mm)	Distance (mm)	Aperture (mm)	Distance (mm)
0.6 to 1.4	50	2000	7	70	7	100
1.4 to 2.8	7×A[b]	2000	7	28	A[b]	100
2.8 to 10^2	N/A	N/A	N/A	N/A	A[b]	0
10^2 to 10^3	N/A	N/A	N/A	N/A	11	0

NOTE 1—In cases where the source is not accessible by virtue of engineering design, e.g., recessed, the minimum measurement distance would be at the closest point of human access.

NOTE 2—The measurement distance is defined as the distance from the output aperture of the laser device.

[a] Generally, high divergence beams are at least 5 mrad, and low divergence beams are less than 5 mrad; however, where doubt exists, both conditions should be tested.

[b] A = 1 mm $t \le 0.3$ s

= $1.5\, t^{0.375}$ $0.3 \text{ s} < t < 10$ s

= 3.5 mm $t \ge 10$ s

Table 5a – Maximum Permissible Exposure (MPE) for Point-source Ocular Exposure to an OCS Laser Beam

Wavelength (µm)	Exposure Duration, *t* (s)	MPE (J·cm^{-2})	MPE (W·cm^{-2})
Visible			
0.600 to 0.700	10^{-3} to 10	$1.8\ t^{0.75} \times 10^{-3}$	
0.600 to 0.700	10 to 3×10^{4}		1×10^{-3}
Near Infrared			
0.700 to 1050	10^{-3} to 10	$1.8\ C_A\ t^{0.75} \times 10^{-3}$	
0.700 to 1050	10 to 3×10^{4}		$C_A \times 10^{-3}$
1.050 to 1.400	10^{-3} to 10	$9.0\ C_C\ t^{0.75} \times 10^{-3}$	
1.050 to 1.400	10 to 3×10^{4}		$5C_C \times 10^{-3}$
Far Infrared			
1.400 to 1.500	10^{-3} to 10	$0.56\ t^{0.25}$	
1.400 to 1.500	10 to 3×10^{4}		0.1
1.500 to 1.800	10^{-3} to 10	1.0	
1.500 to 1.800	10 to 3×10^{4}		0.1
1.800 to 10^{3}	10^{-3} to 10	$0.56\ t^{0.25}$	
1.800 to 10^{3}	10 to 3×10^{4}		0.1

NOTE 1—See table 7 for correction factors C_A and C_C

NOTE 2—For extended sources in the retinal hazard region (0.4 µm to 1.400 µm), see Table 5b

NOTE 3—For repeated (pulsed) exposures, see 8.2.3.

NOTE 4—The wavelength region λ_1 to λ_2 means $\lambda_1 \leq \lambda < \lambda_2$.

NOTE 5—The exposure duration t_1 to t_2 means $t_1 \leq t \leq t_2$.

Table 5b – Maximum Permissible Exposure (MPE) for Extended-source Ocular Exposure to an OCS Laser Beam

Wavelength (μm)	Exposure Duration, t (s)	MPE	
		($J \cdot cm^2$)	($W \cdot cm^2$)
Visible			
0.600 to 0.700	10^{-3} to T_2	$1.8\ C_E\ t^{0.75} \times 10^{-3}$	
0.600 to 0.700	T_2 to 3×10^4		$1.8\ C_E\ T_2^{-0.25} \times 10^{-3}$
Near Infrared			
0.700 to 1050	10^{-3} to T_2	$1.8\ C_A\ C_E\ t^{0.75} \times 10^{-3}$	
0.700 to 1050	T_2 to 3×10^4		$1.8\ C_A C_E\ T_2^{-0.25} \times 10^{-3}$
1.050 to 1.400	10^{-3} to T_2	$9.0\ C_C\ C_E\ t^{0.75} \times 10^{-3}$	
1.050 to 1.400	T_2 to 3×10^4		$9.0\ C_C\ C_E\ T_2^{-0.25} \times 10^{-3}$

NOTE 1—See Table 7 and Figures 1, 2 and 3 for correction factors C_A, C_C and C_E and time T_2.

NOTE 2—The wavelength region λ_1 to λ_2 means $\lambda_1 \leq \lambda < \lambda_2$.

NOTE 3—The exposure duration t_1 to t_2 means $t_1 \leq t \leq t_2$.

NOTE 4—See Tables 4a, 4b and 4c for limiting apertures.

NOTE 5—For sources subtending an angle greater than 11 mrad, the MPEs may also be expressed as an integrated radiance.

NOTE 6—Table 5a can be used as a default as the MPE values listed are worst-case. Table 5b provides relaxed MPE values associated with the effects of extended-source viewing.