

Evaluation of Eye Safety Hazard for VCSEL-MMF Channels

Rick Pimpinella and Jose Castro

IEEE P802.3cz Multi-Gigabit Optical Automotive Ethernet
Virtual Meeting, December 2020

Outline

- Laser Hazard Standards
- Safety Limits
- Spreadsheet Calculator
- Summary and Conclusions



Laser Safety Standards

- The series of standards IEC 60825 define the accessible emission limits for each laser class, laser requirements including labeling and guidelines for safe operation.
 - It also defines the safe limits for maximum permissible exposure (MPE)
 - MPE for eye and skin based on the International Commission for Non-Ionizing Radiation (ICNIRP)

Part 2 →

Reference	Title
IEC 60825-1	Equipment classification, requirements and user's guide
IEC 60825-2	Safety of optical fibre communication systems
IEC 60825-3	TR Guidance for laser displays and shows
IEC 60825-4	Laser guards
IEC 60825-5	TR Manufacturer's checklist for IEC 60825-1
IEC 60825-6	TS Safety of products with optical sources, exclusively used for visible information transmission to the human eye
IEC 60825-7	TS Safety of products emitting 'infrared' optical radiation, exclusively used for wireless 'free air' transmission and surveillance (NOHD < 2.5 m)
IEC 60825-8	TR Guidelines for the safe use of medical laser equipment
IEC 60825-9	TR Compilation of maximum permissible exposure to incoherent optical radiation
IEC 60825-10	Laser safety application guidelines and explanatory notes

Laser Safety Standards

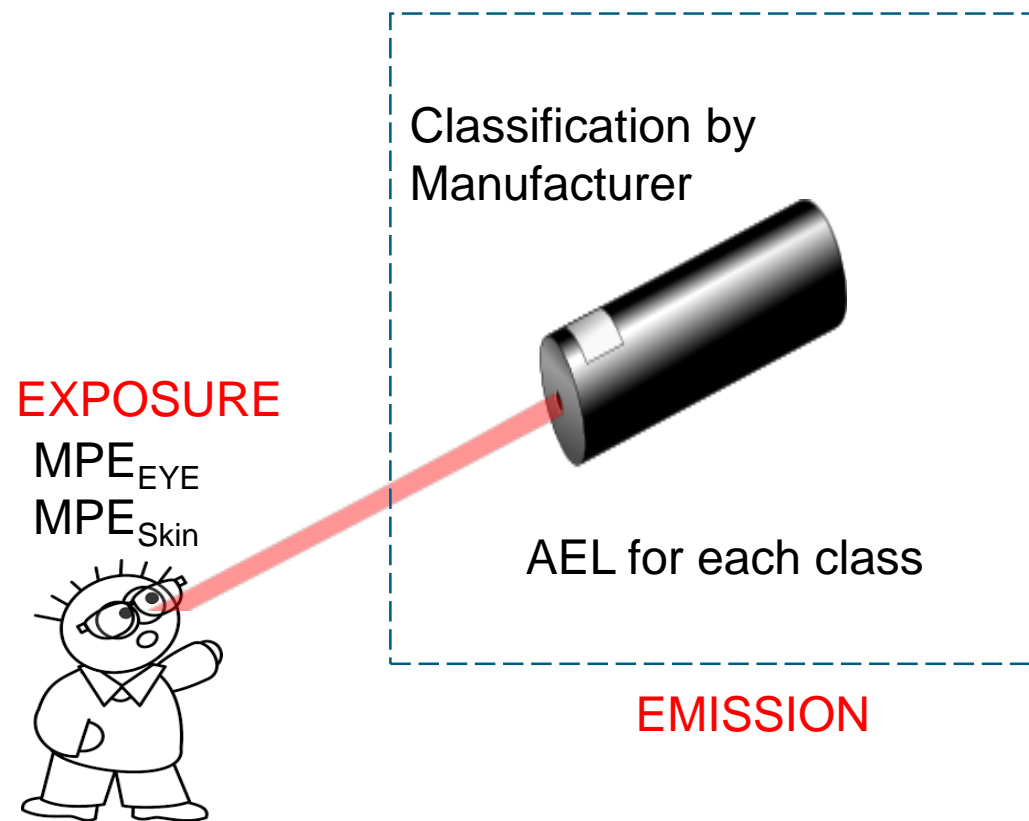
- Part 2 of IEC 60825 (Edition 3.2 2010) provides requirements and specific guidance for the safe operation and maintenance of optical fiber communication systems (OFCS).
- In these systems optical power may be accessible outside the confinements of transmitting equipment.
- The Standard applies to the complete installed end-to-end OFCS.



Safety Limits – AEL and MPE

- Accessible Emission Limit (AEL)
 - Maxim Accessible Emission permitted for a laser class.
- Maximum Permissible Exposure
 - Level of laser radiation to which under normal circumstances persons may be exposed without suffering adverse effects
 - For Class 1 and 1M this relationship was followed:

$$AEL_{\text{Class 1 and Class 1M}} = MPE_{\text{eye}} \times Area_{\text{limiting aperture}}$$



Laser Safety Classification

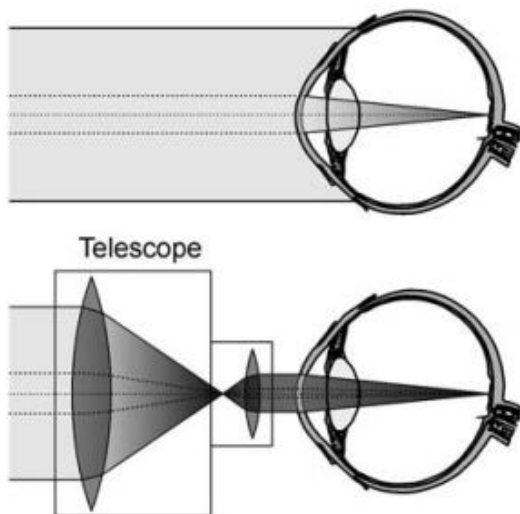
- Lasers for Optical communication systems applicable to the discussion belong to class 1 or class 1M

Class	Wavelength (nm)	Conditions	Applications	Notes
Class 1	---	1 (telescope), 3 (naked eye)	General	No risk for eye or skin
Class 1M	302.5-4000	3 (naked eye)	General	No risk for eye or skin
Class 1C	---		Skin contact (not ocular)	
Class 2	400-700	1 (telescope), 3 (naked eye)		No risk for eye or skin for short time exposure
Class 2M		3 (naked eye)		No risk for eye or skin for short time exposure
Class 3R				Medium/high risk to eye, low risk to skin
Class 3B				Medium/high risk to eye, low risk to skin
Class 4		L		High Risk to Eye and skin

Measurements Criteria/Conditions

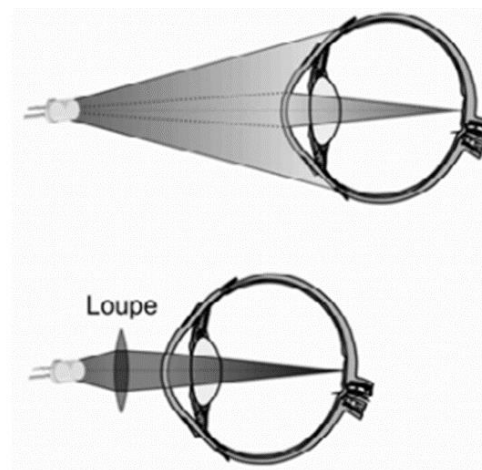
Condition 1

Used in IEC 60825-1 in Edition 2 (2007) and Edition 3 (2014)



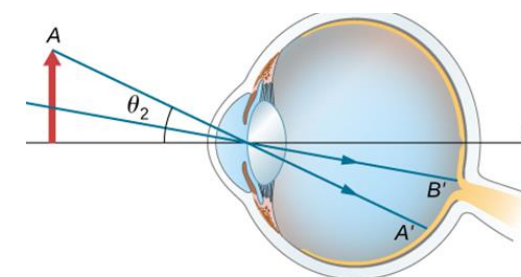
Condition 2

Used in IEC 60825-1 in Edition 2 (2007). Not used in Edition 3 (2014)



Condition 3

Naked eye use in IEC 60825-1 in both Ed. 2 (2007) and in Edition 3 (2014)



Notes:

- 60825-2 latest editions use IEC 60825-1 (Ed.2) as a reference!
- The distances relevant to those conditions are wavelength dependent.
- The distances relevant to those conditions have changed. Changes from 14mm to 28 for some conditions. From 100mm to 70 mm ...

Spreadsheet Calculator

- Panduit develop a spreadsheet calculator for AEL, Maximum Power for Hazard 1 or 1M, Hazard level
- Multi-wavelength and parallel fiber approach implemented based on 60825-2 Ed. 3.2 (latest edition).
- The input parameters (Blue font) are used to computed working parameters such as T2, d63, c4.
- Those working parameters are used to compute AEL, Max_Power for Hazard 1 or 1M and the Hazard level.

The working parameters are defined in IEC 60825-2:

- T2 depends on alpha. Is equal to 10 when used when $\alpha > 1.5$ mrad (extended source)
- C4 and C7 are wavelength and should be corrected according Table 9
- C6 is related with geometric optics and less wavelength dependent. For the range 400-1400 nm corrected using Table 9 (IEC 60825-1)

Eye Safety Spreadsheet Calculator – 4 Wavelength Transceiver

Class 1, 1M Emission Limits for range

700 nm to 1400 nm

Bi-directional = 0	1
Co-directional = 1	

Condition	1	= Telescope
	2	= Microscope
	3	= Naked eye

Class 1 Hazard	3.405	EXCEEDED
Class 1M Hazard	1.095	HAZARD

Parameter	Wavelength 1			Wavelength 2			Wavelength 3			Wavelength 4			Units
$\lambda =$	844			874			904			934			nm
Power =	4			4			4			4			dBm
NA =	0.18			0.18			0.18			0.18			-
N_{fiber_vert}				1.0									-
N_{fibers_horiz}				1.0									-
Spacing_y				0.25									mm
Spacing_x				0.25									mm
Source dia. (one)				0.05									mm
condition	1	2	3	1	2	3	1	2	3	1	2	3	
$d_0 =$	50.0	3.5	7.0	50.0	3.5	7.0	50.0	3.5	7.0	50.0	3.5	7.0	mm
$L =$	2000	14	100	2000	14.0	100	2000	14	100	2000	14	100	mm
$worst_comb_y$	1.00	1.00	1.00	1.0	1.0	1.0	1.00	1.00	1.00	1.00	1.00	1.00	
$worst_comb_x$	1.00	1.00	1.00	1.0	1.0	1.0	1.00	1.00	1.00	1.00	1.00	1.00	
$total_fibers$	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
$\alpha (worst)$	1.50	3.57	1.50	1.50	3.57	1.50	1.50	3.57	1.50	1.50	3.57	1.50	mrad
T_2	10.00	10.50	10.00	10.00	10.50	10.00	10.00	10.50	10.00	10.00	10.50	10.00	sec
$d_{\theta 3} =$	430.56	3.01	21.53	430.56	3.01	21.53	430.56	3.01	21.53	430.56	3.01	21.53	mm
$C_4 =$	1.941	1.941	1.941	2.228	2.228	2.228	2.559	2.559	2.559	2.938	2.938	2.938	
$C_6 =$	1.00	2.38	1.00	1.00	2.38	1.00	1.00	2.38	1.00	1.00	2.38	1.00	
$C_7 =$	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	-
$\eta =$	0.013	0.740	0.100	0.013	0.740	0.100	0.013	0.740	0.100	0.013	0.740	0.100	-

Input Parameters

Working Parameters

AEL per Class/condition

Class 1	AEL	0.757	1.797	0.757	0.869	2.063	0.869	0.998	2.369	0.998	1.146	2.720	1.146	mW
Class 1M	AEL	0.757	500.000	0.757	0.869	500.000	0.869	0.998	500.000	0.998	1.146	500.000	1.146	mW
Max permissible power for hazard 1:		56.51	2.43	7.54	64.88	2.79	8.66	74.49	3.20	9.95	85.53	3.67	11.42	mW
Max permissible power for hazard 1M:		56.51	500.00	7.54	64.88	500.00	8.66	74.49	500.00	9.95	85.53	500.00	11.42	mW
Total Power per wavelength per condition:		2.512	2.512	2.512	2.512	2.512	2.512	2.512	2.512	2.512	2.512	2.512	2.512	mW
Hazard per wavelength per conditions Class 1 =		0.0445	1.0348	0.3329	0.0387	0.9013	0.2900	0.0337	0.7850	0.2526	0.0294	0.6837	0.2200	-
Hazard per wavelength per conditions Class 1M =		0.0445	0.0050	0.3329	0.0387	0.0050	0.2900	0.0337	0.0050	0.2526	0.0294	0.0050	0.2200	-

Accessible Emission Level

Maximum power for Hazard 1

Maximum Level per wavelength

Class 1	1.035	0.901	0.785	0.684
Class 1M	0.333	0.290	0.253	0.220

Worst case for each wavelength Actual Hazard

G6

✕

✓

fx

0.22

	A	B	C	D	E	F	G	H	I	J	K
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											
16											
17											
18											
19											
20											
21											
22											
23											
24											
25											
26											
27											
28											
29											
30											
31											
32											
33											
34											
35											
36											
37											
38											
39											

Class 1, 1M Emission Limits for range

700 nm to 1400 nm

Condition	1	= Telescope
	2	= Microscope
	3	= Naked eye or Low power Magnifiers

Class 1 Hazard	1.098	EXCEEDED
Class 1M Hazard	0.125	PASS

Parameter	Wavelength 1			Units
$\lambda =$	844			nm
Power =	1.5			dBm
NA =	0.22			-
N_{fiber_vert}	1.0			-
N_{fibers_horiz}	1.0			-
Spacing_y	0.25			mm
Spacing_x	0.25			mm
Source dia. (one)	0.020			mm
condition	1	2	3	
$d_0 =$	50.0	3.5	7.0	mm
$L =$	2000	14	100	mm
worst_comb_y	1.00	1.00	1.00	
worst_comb_x	1.00	1.00	1.00	
Source count	1.00	1.00	1.00	
alpha (worst)	1.50	1.50	1.50	mrad
T_2	10.00	10.00	10.00	sec
$d_{63} =$	530.65	3.71	26.53	mm
$C_4 =$	1.941	1.941	1.941	
$C_6 =$	1.00	1.00	1.00	
$C_7 =$	1.0	1.0	1.0	-
$\eta =$	0.009	0.588	0.067	-

AEL per Class/condition

Class 1	AEL	0.757	0.757	0.757	mW
Max permissible power for hazard 1:		85.638	1.286	11.258	mW
Total Power per wavelength per condition:		1.413	1.413	1.413	mW
Hazard per wavelength per conditions Class 1 =		0.0165	1.0981	0.1255	-
Maximum Level per wavelength	Class 1	1.098			
	Class 1M	0.125			

Single Lambda

Notes

Single wavelength

Two wavelengths

Four wavelengths

+

Summary & Conclusion

- Implemented calculator for AEL, OFCS power limits and hazard levels based on current IEC 60825-2 standard.
 - Validated with available examples in standard
- Used in previous IEEE Task Forces to evaluate eye-safety.
 - Evaluated hazard levels for proposed 100G SWDM PMD in 802.3cm
- Spreadsheet calculator will be used in this Task Force to evaluate connector types
 - Presented in perezaranda_3cz_01_151220_eyesafety.pdf