Preliminary Evaluation of OFCS Hazards for VCSEL-MMF Channels

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IEEE P802.3cm 400 Gb/s over Multimode Fiber Task Force
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Agenda

- Introduction
- Laser Hazard Standards
- OFCS

Introduction

- Laser safety is a discipline that intend to control the risk of laser technology through the appropriated design and use of laser equipment.
  - Includes the assessment of potential hazards, their impact and adoption of safety precautions
- 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)

Introduction

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

This presentation focus on Part 2

Introduction

- 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.

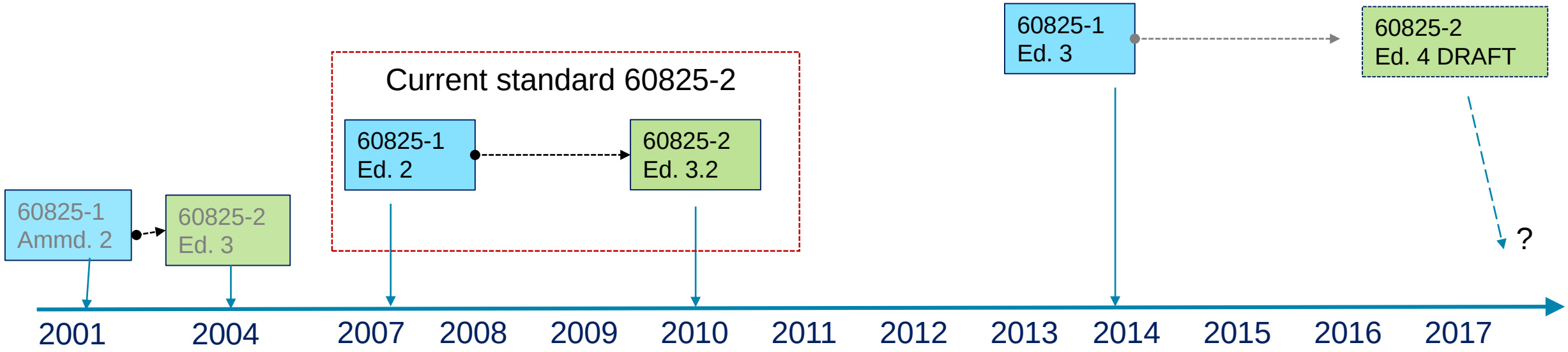
- It applies to the complete installed end-to-end OFCS. However, it is not clear if all components and subassemblies that generate or amplify optical radiation should be assessed by this standard. This ambiguity has caused different interpretations:
  - Based on CSA, individual components and subassemblies that are sold only to OEM vendors for incorporation into a complete installed end-to-end OFCS need not be assessed to this standard, since the final OFCS should itself be assessed according to this standard.
  - Based on TuV, a laser transceivers have no other obvious application but inside an optical fiber system, therefore it should be assessed and classified per IEC 60825-2.

- The draft edition 4 of IEC 60825-2 clarify this by stating that it is only applicable to individual components and subassemblies intended to be installed in OFCSs.


NORME INTERNATIONALE
INTERNATIONAL STANDARD
CEI IEC 60825-1
Deuxième édition Second edition 2007-03
PUBLICATION GROUPÉE DE SÉCURITÉ
GROUP SAFETY PUBLICATION
Sécurité des appareils à laser –
Partie 1:
Classification des matériels et exigences
Safety of laser products –
Part 1:
Equipment classification and requirements
IEC 60825-2
Edition 3.2 2010-12
INTERNATIONAL STANDARD
NORME INTERNATIONALE
colour inside
Safety of laser products –
Part 2: Safety of optical fibre communication systems (OFCS)
Sécurité des appareils à laser –
Partie 2: Sécurité des systèmes de télécommunication par fibres optiques (STFO)

Introduction

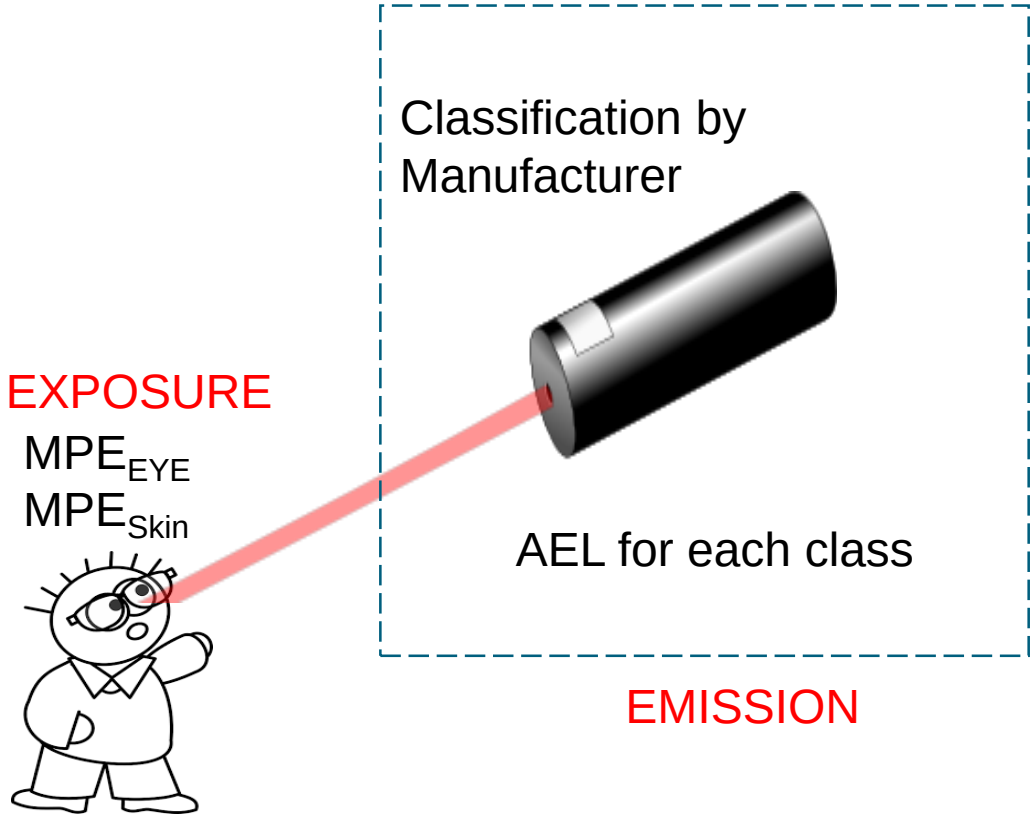
- 60825-2 Ed. 3.2 (valid standard) calculation methods and parameters are based on 60825-1 (Ed. 2)
  - AELs, MPE, correction constants and many other parameters
- However, revisions or updates of each standard are not necessarily in synch
  - Adoption of different editions of same standard occurs depending on geography and organization:
    - IEC 60825-1 Edition 3 : 2014 is now required in Europe. Edition 2 is obsolete for Europe.
    - IEC 60825-1 Edition 2 : 2007 is the latest officially recognized by the FDA in Laser Notice #50 of June 2007.
    - IEC 60825-1 Edition 3 is the topic of (draft – not for implementation) FDA Laser Notice #56, issued in January of this year
  - A reader of different versions of 60825-1 and 60825-2 might find them inconsistent or confusing.
  - This make the hazard evaluation more complicated than needed.



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:

$$\mathrm{AEL}_{\text{Class 1 and Class 1M}} = \mathrm{MPE}_{\text{eye}} \times \mathrm{Area}_{\text{limiting aperture}}.$$



Definitions and figure idea from Laser Safety book by Roy Henderson and Karl Schulmeister

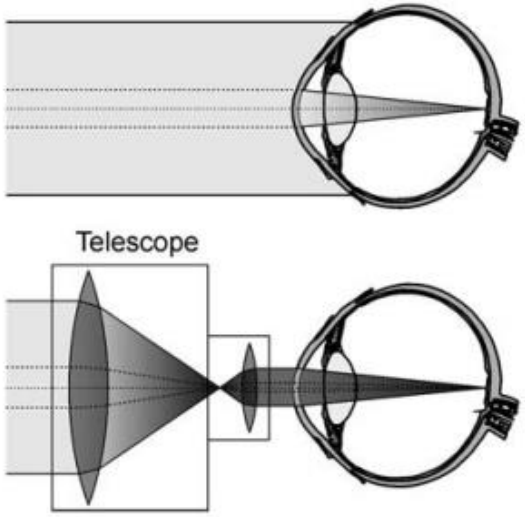
Laser Safety Classification

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

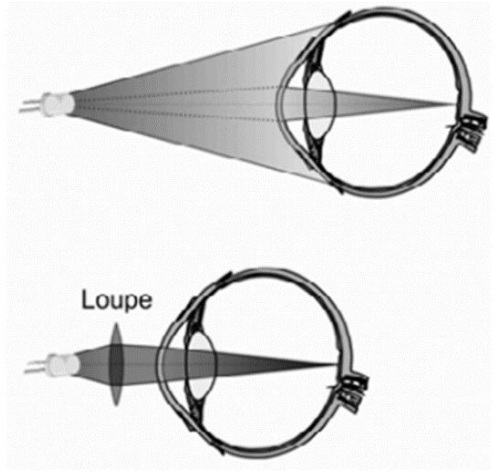
Class	Wavelength (nm)	Conditions	Applications	Notes
Class 1	---	1 (telescope), 3 (naked eye)	General	No risk for eye or skin
Class 1M	302.5-4000	3 (naked eye)	General	No risk for eye or skin
Class 1C	---		Skin contact (not ocular)	
Class 2	400-700	1 (telescope), 3 (naked eye)		No risk for eye or skin 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

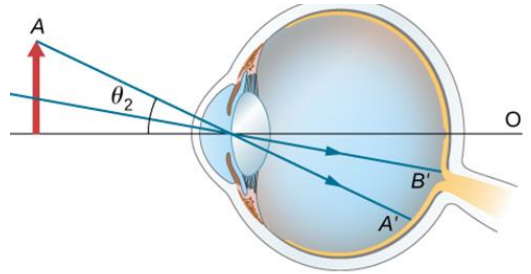
Condition 1
Used in IEC 60825-1 in Edition 2 (2007) and Edition 3 (2014)



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



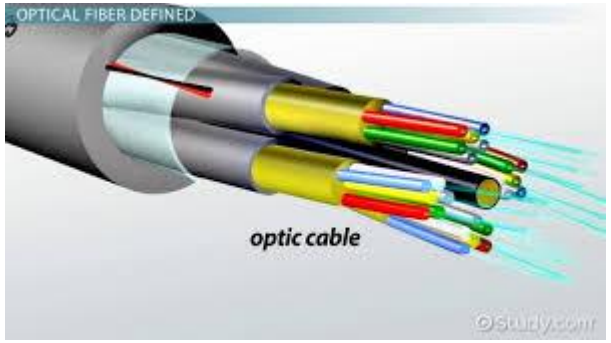
Condition 3
Naked eye use in IEC 60825-1 in both Ed. 2 (2007) and in Edition 3 (2014)



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 …

Hazard Level

- The potential hazard at <u>any</u> accessible location within an OFCS. It is based on the level of optical radiation which could become accessible in a reasonably foreseeable event, e.g. a fiber cable break. It is closely related to the laser classification procedure in IEC 60825-1.
  - For hazard 1, the level of radiation is measured with the conditions for Class 1 laser products (IEC 60825-1), but with condition 2 being as defined in clause 4.8.1 of IEC 60825-2
  - For hazard level 1M the level of radiation is measured with the conditions for Class 1M laser products (see IEC 60825-1), but with condition 2 being as defined in clause 4.8.1 of this (IEC 60825-2)
- Note that in 60825-1 we talk about class instead of hazard, and the classification is based to testing conditions described in the standard.



Spreadsheet Calculator

- Develop preliminary version for spreadsheet calculator for AEL, Maximum Power for Hazard 1 or 1M, Hazard level
- Multiwavelength and parallel fiber approach implemented based on 60825-2 Ed. 3.2 (latest edition).
- The input parameters (cyan cells) are used to computed working parameters such as T2, d63, c4 (yellow cells).
- Those working parameters are used to compute AEL, Max_Power for Hazard 1 or 1M and the Hazard level.

Parameter	Lane 1	Lane 2
λ =	840	910
Power =	6.1	6.1
NA =	0.18	0.18
d_0 =	7.0	
L =	100.0	
N_{fibers}	1.0	
D_{fibers}	0.25	
Source size (one)	0.05	
alpha (worst)	0.50	
$T2$	10.00	
d_{63} =	21.18	
A =	0.00	
C_4 =	1.905	2.630
C_6 =	1.000	
Worst Comb_$C_{6\ size}$	1.000	
C_7 =	1.0	1.0
η =	0.104	

Accessible Emission Level

Power_AEL	**0.743**	**1.026**
	-1.29	**0.11**
Max Power	**7.179**	**9.910**
Hazard_1=	**8.56**	**9.96**
Hazard Levels	**0.567**	**0.411**

Spreadsheet Calculator

Input Parameters

Working parameters

Parameter	Lane 1	Lane 2	Units	Notes
λ =	840	910	nm	Wavelenghts, each lane
Power =	6.1	6.1	dBm	Power each lane
NA =	0.18	0.18	-	Numerical Aperture - tolerance
d_0 =	7.0		*mm*	Stop aperture
L =	100.0		*mm*	*Source-aperture distance*
N_{fibers}	1.0			Number of fibers
D_{fibers}	0.25		*mm*	Fiber Separation
Source size (one)	0.05			MMF diameter or SMF MFD
alpha (worst)	0.50			Subtense source angle
T2	10.00		*sec*	Emission duraiton
d_{63} =	21.18		*mm*	Beam diam. 63%
A =	0.00		m^2	App. Area
C_4 =	1.905	2.630	-	Correction factor 4
C_6 =	1.000		-	Correction factor 6
Worst Comb_$C_{6\ size}$	1.000			
C_7 =	1.0	1.0	-	Correction factor 7
η =	0.104		-	Fraction Power accessible

Accessible Emission Level

Accessible Emission Level → **Power_AEL**

	0.743	1.026	mW
	-1.29	0.11	dBm

XCVR CLASS 1M LEVEL

COMPLIANT

Maximum power for Hazard 1 → **Max Power Hazard_1=**

	7.179	9.910	mW
	8.56	9.96	dBm

Actual Hazard per lane → **Hazard Levels**

0.567	0.411	

XCVR HAZARD LEVEL FOR H

0.978

The working parameters are defined in IEC 60825-2
Few Notes:

- 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)

Validation

- Results from the Eye Safety spreadsheet are compared with tables and examples shown in IEC 60825-2 (ed. 3.2 and draft 4)
- First we compare our results with the OFCS power limits shown in Table D1 of 60825-2 Ed. 3.2 (latest edition).
  - There were excellent agreement between Calculator results and table D1
- We also compare with examples shown in the same standard for multi-wavelength cases and extended sources such as a ribbon fibers.
- See Annex I for more information about the validation.

OFCS Power Limits (Table D1 in IEC 60825-2)

Wavelength and fibre type	1	1M
633 nm (MM)	1,23 mW (+0,9 dBm)	3,77 mW (+5,8 dBm)
780 nm (MM)	1,78 mW (+2,5 dBm)	5,45 mW (+7,4 dBm)
850 nm (MM)	2,46 mW (+3,9 dBm)	7,52 mW (+8,8 dBm)
980 nm (MM)	4,47 mW (+6,5 dBm)	13,7 mW (+11,4 dBm)
980 nm (SM)	1,80 mW (+2,5 dBm)	2,66 mW (+4,2 dBm)
1 270 nm (MM)	88,1 mW (+19,5 dBm)	270 mW (+24,3 dBm)
1 270 nm (SM)	28,0 mW (+14,5 dBm)	76,5 mW (+18,8 dBm)
1 400 nm 1 600 nm (MM)	13,3 mW (+11,2 dBm)	371 mW (+25,7 dBm)
1 420 nm (SM)	10,1 mW (+10,0 dBm)	115 mW (+20,6 dBm)
1 550 nm (SM)	10,2 mW (+10,1 dBm)	136 mW (+21,3 dBm)

Preliminary Evaluations for 400G BASE-SR4.1

- We used the calculator to evaluate the AEL maximum Power for Hazard level 1, and the hazard level for a given transmitted power for conditions to correspond to hazard 1 and hazard 1M
- Note that we might be using older assumptions for aperture diameter and distance from the source. Whereas 60825-1 (Ed. 3, 2014) eliminate condition 2, 60825-2 (latest valid version) seems to use condition 2 in order differentiate between Hazard 1 and Hazard 1M as shown in table D1 of 60825-2.
- The values for Hazard Level 1 and 1M used here are:
  - Hazard 1 : 3.5 mm aperture diameter at a distance of 14 mm from source
  - Hazard 1M: 7 mm aperture diameter at a distance of 100 mm from source
  - We also use 7 mm aperture diameter at a distance of 70 mm from source just as an exercise
- There are many changes occurring in latest draft 60825-2. Therefore the results cannot be taken as final values but only considered as a preliminary estimation.
- The next slides show the cases for:
  - Hazards 1 , using the 4 fibers (2 wavelength each fiber) ,
  - Hazard 1M using 4 fibers (2 wavelength each fiber)
  - Exercise for hazard 1M using only 1 fiber (100G)

Hazard 1 Evaluation for 400G SR4.1

Parameter	Lane 1	Lane 2	Units	Notes
λ =	840	910	nm	Wavelenghts, each lane
Power =	1.3	1.3	dBm	Power each lane
NA =	0.18	0.18	-	Numerical Aperture - tolerance
d'_0 =	3.5		*mm*	Stop aperture
L =	14.0		*mm*	*Source-aperture distance*
N_{fibers}	4.0			Number of fibers
D_{fibers}	0.25		*mm*	Fiber Separation
Source size (one)	0.05			MMF diameter or SMF MFD
alpha (worst)	3.57			Subtense source angle
T2	10.50		*sec*	Emission duraiton
d'_{63} =	2.96		*mm*	Beam diam. 63%
A =	0.00		m^2	App. Area
C_4 =	1.905	2.630	-	Correction factor 4
C_6 =	2.381		-	Correction factor 6
Worst Comb_$C_{6\ size}$	1.000			
C_7 =	1.0	1.0	-	Correction factor 7
η =	0.752		-	Fraction Power accessible

Accessible Emission Level

Power_AEL	**1.764**	**2.436**	**mW**	**XCVR CLASS 1M LEVEL**
	2.47	**3.87**	**dBm**	**COMPLIANT**
Max Power	**2.347**	**3.239**	**mW**	
Hazard_1=	**3.70**	**5.10**	**dBm**	
				XCVR HAZARD LEVEL FOR HAZARD 1
Hazard Levels	**0.575**	**0.416**		**0.991**
Eye Safety:	**SAFE**	**SAFE**		**SAFE**

Selected 840 nm and 910 nm as worst case. The 4 fibers are used. Results indicates that maximum 1.3 dBm can be transmitted per fiber in order to pass Hazard 1 requirements

Hazard 1M Evaluation for 400G SR4.1

Parameter	Lane 1	Lane 2	Units	Notes
λ =	840	910	nm	Wavelenghts, each lane
Power =	4.4	4.4	dBm	Power each lane
NA =	0.18	0.18	-	Numerical Aperture - tolerance
d_0 =	7.0		*mm*	Stop aperture
L =	100.0		*mm*	*Source-aperture distance*
N_{fibers}	4.0			Number of fibers
D_{fibers}	0.25		*mm*	Fiber Separation
Source size (one)	0.05			MMF diameter or SMF MFD
alpha (worst)	2.50			Subtense source angle
T2	10.24		*sec*	Emission duraiton
d_{63} =	21.18		*mm*	Beam diam. 63%
A =	0.00		m^2	App. Area
C_4 =	1.905	2.630	-	Correction factor 4
C_6 =	1.333		-	Correction factor 6
Worst Comb_$C_{6\ size}$	2.000			
C_7 =	1.0	1.0	-	Correction factor 7
η =	0.104		-	Fraction Power accessible

Accessible Emission Level

Power_AEL	**0.497**	**0.686**	**mW**	**XCVR CLASS 1M LEVEL**
	-3.04	**-1.64**	**dBm**	**COMPLIANT**
Max Power	**4.803**	**6.630**	**mW**	
Hazard_1=	**6.81**	**8.21**	**dBm**	
				XCVR HAZARD LEVEL FOR HAZARD 1M
Hazard Levels	**0.573**	**0.415**		**0.989**
Eye Safety:	**SAFE**	**SAFE**		**SAFE**

Selected 840 nm and 910 nm as worst case. The 4 fibers are used.
Results indicates that maximum 4.4 dBm can be transmitted per fiber in order to pass Hazard 1M requirements

Hazard 1 Evaluation for 400G SR4.1

Parameter	Lane 1	Lane 2	Units	Notes
λ =	840	910	nm	Wavelenghts, each lane
Power =	6.1	6.1	dBm	Power each lane
NA =	0.18	0.18	-	Numerical Aperture - tolerance
d_0 =	7.0		*mm*	Stop aperture
L =	100.0		*mm*	*Source-aperture distance*
N_{fibers}	1.0			Number of fibers
D_{fibers}	0.25		*mm*	Fiber Separation
Source size (one)	0.05			MMF diameter or SMF MFD
alpha (worst)	0.50			Subtense source angle
T2	10.00		*sec*	Emission duraiton
d_{63} =	21.18		*mm*	Beam diam. 63%
A =	0.00		m^2	App. Area
C_4 =	1.905	2.630	-	Correction factor 4
C_6 =	1.000		-	Correction factor 6
Worst Comb_$C_{6\ size}$	1.000			
C_7 =	1.0	1.0	-	Correction factor 7
η =	0.104		-	Fraction Power accessible

Accessible Emission Level

Power_AEL	**0.743**	**1.026**	**mW**	**XCVR CLASS 1M LEVEL**
	-1.29	**0.11**	**dBm**	**COMPLIANT**
Max Power	**7.179**	**9.910**	**mW**	
Hazard_1=	**8.56**	**9.96**	**dBm**	
				XCVR HAZARD LEVEL FOR HAZARD 1M
Hazard Levels	**0.567**	**0.411**		**0.978**
Eye Safety:	**SAFE**	**SAFE**		**SAFE**

Selected 840 nm and 910 nm as worst case. 1 fiber is used.
Results indicates that maximum 6.1 dBm can be transmitted per fiber in order to pass Hazard 1M requirements

Summary & Conclusions

- Implemented calculator for AEL, OFCS power limits and hazard levels based on current IEC 60825-2 standard.
  - Validated with available examples in standard
- Evaluated hazard levels for 400G BASE-SR4.2 based on current 60825-2 standard.
  - Results indicates that in order to pass hazard 1, it requires to transmit less than 1.1 dBm averaged power dBm per lane
  - Results indicates that to pass hazard 1M, it requires to transmit less than 4.1 dBm average power per lane.
- Discussed potential issues with relationships between IEC 60825-1 and 60825-2
  - Both documents are highly related. They share calculation methods and parameters such as AELs, MPE …
  - However, updates of each standard occurs at different time. This could cause inconsistencies confusion for a reader that do not participate actively in the standard definition.
  - Perhaps, due to this, the hazard evaluation more complicated than needed.
- Note that for us it is not clear if the assumptions for aperture diameter and distance from the source will be consistent with future version of the standard. Therefore the results cannot be taken as final values but only considered as a preliminary estimation.

Acknowledgement

- We want to thank Richard Johnson (Finisar) for his support helping us to understand better the rational behind many assumptions in the laser safety standards.

Annex I Validation

Validation

For validation we use the spread sheet to:

- Compare with OFCS power limits shown in Table D1 in IEC 60825.
- We include examples for several wavelengths and extended sources.

Wavelength and fibre type		
	1	1M
633 nm (MM)	1,23 mW (+0,9 dBm)	3,77 mW (+5,8 dBm)
780 nm (MM)	1,78 mW (+2,5 dBm)	5,45 mW (+7,4 dBm)
850 nm (MM)	2,46 mW (+3,9 dBm)	7,52 mW (+8,8 dBm)
980 nm (MM)	4,47 mW (+6,5 dBm)	13,7 mW (+11,4 dBm)
980 nm (SM)	1,80 mW (+2,5 dBm)	2,66 mW (+4,2 dBm)
1 270 nm (MM)	88,1 mW (+19,5 dBm)	270 mW (+24,3 dBm)
1 270 nm (SM)	28,0 mW (+14,5 dBm)	76,5 mW (+18,8 dBm)
1 400 nm 1 600 nm (MM)	13,3 mW (+11,2 dBm)	371 mW (+25,7 dBm)
1 420 nm (SM)	10,1 mW (+10,0 dBm)	115 mW (+20,6 dBm)
1 550 nm (SM)	10,2 mW (+10,1 dBm)	136 mW (+21,3 dBm)

Case 850 nm 1 MMF

From table D1 (60825-2) the OFS limits for Hazard 1 and Hazard 1M are 3.9 dBm and 8.8 dBm. The calculator shows similar values (blue arrow).

Hazard 1

Parameter	Value	Units
λ1 =	850	nm
Power =	2	dBm
NA =	0.18	-
d_0 =	3.5	mm
L =	14.0	mm
N_{fibers}	1	
D_{fibers}	0.20	mm
Source size (one)	0.05	mm
alpha (worst)	3.57	
T2	10.50	
d_{63} =	2.98	mm
A =	0.000	m^2
C_4 =	1.995	-
C_6 =	2.4	-
Worst Comb_$C_{6\ size}$	1.0	
C_7 =	1.0	-
η =	0.748	-

Accessible Emission Level

$Power\_AEL_{source1}$ = 1.848 mW / 2.67 dBm

$Max\_Power\_Hazard\_1_{source1}$= 2.470 mW / 3.93 dBm ←

Hazard 1M

Parameter	Value	Units
λ1 =	850	nm
Power =	2	dBm
NA =	0.18	-
d_0 =	7.0	mm
L =	100.0	mm
N_{fibers}	1	
D_{fibers}	0.20	mm
Source size (one)	0.05	mm
alpha (worst)	0.50	
T2	10.00	
d_{63} =	21.18	mm
A =	0.001	m^2
C_4 =	1.995	-
C_6 =	1.0	-
Worst Comb_$C_{6\ size}$	1.0	
C_7 =	1.0	-
η =	0.104	-

Accessible Emission Level

$Power\_AEL_{source1}$ = 0.778 mW / -1.09 dBm

$Max\_Power\_Hazard\_1_{source1}$= 7.518 mW / 8.76 dBm ←

Case 980 nm (MMF)

From table D1 (60825-2) the OFS limits for Hazard 1 and Hazard 1M are 6.5 dBm and 11.4 dBm. The calculator show similar values (blue arrow).

Hazard 1

Parameter	Value	Units
$\lambda 1$ =	980	nm
Power =	2	dBm
NA =	0.18	-
d_0 =	3.5	mm
L =	14.0	mm
N_{fibers}	1	
D_{fibers}	0.20	mm
Source size (one)	0.05	mm
alpha (worst)	3.57	
T2	10.50	
d_{63} =	2.96	mm
A =	0.000	m^2
C_4 =	3.631	-
C_6 =	2.4	-
Worst Comb_$C_{6\ size}$	1.0	
C_7 =	1.0	-
η =	0.752	-

Accessible Emission Level

Power_AEL$_{source1}$ = 3.362 mW / 5.27 dBm

Max_Power_Hazard_1$_{source1}$= 4.472 mW / 6.50 dBm

Hazard 1M

Parameter	Value	Units
$\lambda 1$ =	980	nm
Power =	2	dBm
NA =	0.18	-
d_0 =	7.0	mm
L =	100.0	mm
N_{fibers}	1	
D_{fibers}	0.20	mm
Source size (one)	0.05	mm
alpha (worst)	0.50	
T2	10.00	
d_{63} =	21.18	mm
A =	0.001	m^2
C_4 =	3.631	-
C_6 =	1.0	-
Worst Comb_$C_{6\ size}$	1.0	
C_7 =	1.0	-
η =	0.104	-

Accessible Emission Level

Power_AEL$_{source1}$ = 1.416 mW / 1.51 dBm

Max_Power_Hazard_1$_{source1}$= 13.680 mW / 11.36 dBm

Case 1270 nm (MMF)

From table D1 (60825-2) the OFS limits for Hazard 1 and Hazard 1M are 19.5 dBm and 24.3 dBm. The calculator show similar values (blue arrow).

Hazard 1

Parameter	Value	Units
$\lambda 1$ =	1270	nm
Power =	2	dBm
NA =	0.18	-
d_0 =	3.5	mm
L =	14.0	mm
N_{fibers}	1	
D_{fibers}	0.20	mm
Source size (one)	0.05	mm
alpha (worst)	3.57	
$T2$	10.50	
d_{63} =	2.96	mm
A =	0.000	m^2
C_4 =	5.000	-
C_6 =	2.4	-
Worst Comb_$C_{6\ size}$	1.0	
C_7 =	14.3	-
η =	0.752	-

Accessible Emission Level

Power_AEL$_{source1}$ = 66.250 mW / 18.21 dBm

Max_Power_Hazard_1$_{source1}$= 88.116 mW / 19.45 dBm ←

Hazard 1M

Parameter	Value	Units
$\lambda 1$ =	1270	nm
Power =	2	dBm
NA =	0.18	-
d_0 =	7.0	mm
L =	100.0	mm
N_{fibers}	1	
D_{fibers}	0.20	mm
Source size (one)	0.05	mm
alpha (worst)	0.50	
$T2$	10.00	
d_{63} =	21.18	mm
A =	0.001	m^2
C_4 =	5.000	-
C_6 =	1.0	-
Worst Comb_$C_{6\ size}$	1.0	
C_7 =	14.3	-
η =	0.104	-

Accessible Emission Level

Power_AEL$_{source1}$ = 27.904 mW / 14.46 dBm

Max_Power_Hazard_1$_{source1}$= 269.577 mW / 24.31 dBm ←

Case 1270 nm (SMF)

From table D1 (60825-2) the OFS limits for Hazard 1 and Hazard 1M are 14.5 dBm and 18.8 dBm. The calculator show similar values (blue arrow).

Hazard 1

Parameter	Value	Units
$\lambda 1$ =	1270	nm
Power =	2	dBm
NA =	0.18	-
d'_0 =	3.5	mm
L =	14.0	mm
N_{fibers}	1	
D_{fibers}	1.00	mm
Source size (one)	0.01	mm
alpha (worst)	0.79	
T2	10.00	
d'_{63} =	1.46	mm
A =	0.000	m^2
C_4 =	5.000	-
C_6 =	1.0	-
Worst Comb_$C_{6\ size}$	1.0	
C_7 =	14.3	-
η =	0.997	-

Accessible Emission Level

Power_AEL$_{source1}$ = 27.904 mW / 14.46 dBm

Max_Power_Hazard_1$_{source1}$= 27.990 mW / 14.47 dBm ←

Hazard 1M

Parameter	Value	Units
$\lambda 1$ =	1270	nm
Power =	2	dBm
NA =	0.18	-
d'_0 =	7.0	mm
L =	100.0	mm
N_{fibers}	1	
D_{fibers}	1.00	mm
Source size (one)	0.01	mm
alpha (worst)	0.11	
T2	10.00	
d'_{63} =	10.39	mm
A =	0.001	m^2
C_4 =	5.000	-
C_6 =	1.0	-
Worst Comb_$C_{6\ size}$	1.0	
C_7 =	14.3	-
η =	0.365	-

Accessible Emission Level

Power_AEL$_{source1}$ = 27.904 mW / 14.46 dBm

Max_Power_Hazard_1$_{source1}$= 76.531 mW / 18.84 dBm ←

Multiwavelength example D4.2 (60825-2 Ed4 draft)

An optical transmission system using single mode fibre of 11 μm mode field diameter carries six optical signals: at wavelengths of 1 270 nm, 1 280 nm, 1 290 nm, 1 300 nm, 1 310 nm and 1 320 nm. Each of these signals has a maximum time-averaged power of 10 dBm (10 mW). Determine the hazard level at the transmitter site.

Parameter	Lane 1	Lane 2	Lane 3	Lane 4	Units	Notes
λ =	1270	1280	1290	1300	nm	Wavelenghts, each lane
Power =	10	10	10	10	dBm	Power each lane
NA =	0.18				-	Numerical Aperture - tolerance
d'_0 =	3.50				*mm*	Stop aperture
L =	14.00				*mm*	*Source-aperture distance*
N_{fibers}	1.00					Number of fibers
D_{fibers}	0.25				*mm*	Fiber Separation
Source size (one)	0.01					MMF diameter or SMF MFD
alpha (worst)	0.79					Subtense source angle
T2	10.00				*sec*	Emission duraiton
d'_{63} =	1.46				*mm*	Beam diam. 63%
A =	0.00				m^2	App. Area
C_4 =	5.000	5.000	5.000	5.000	-	Correction factor 4
C_6 =	1.00				-	Correction factor 6
Worst Comb_$C_{6\,size}$	1.00					
C_7 =	14.3	23.8	47.8	108.0	-	Correction factor 7
η =	0.997				-	Fraction Power accessible

Accessible Emission Level

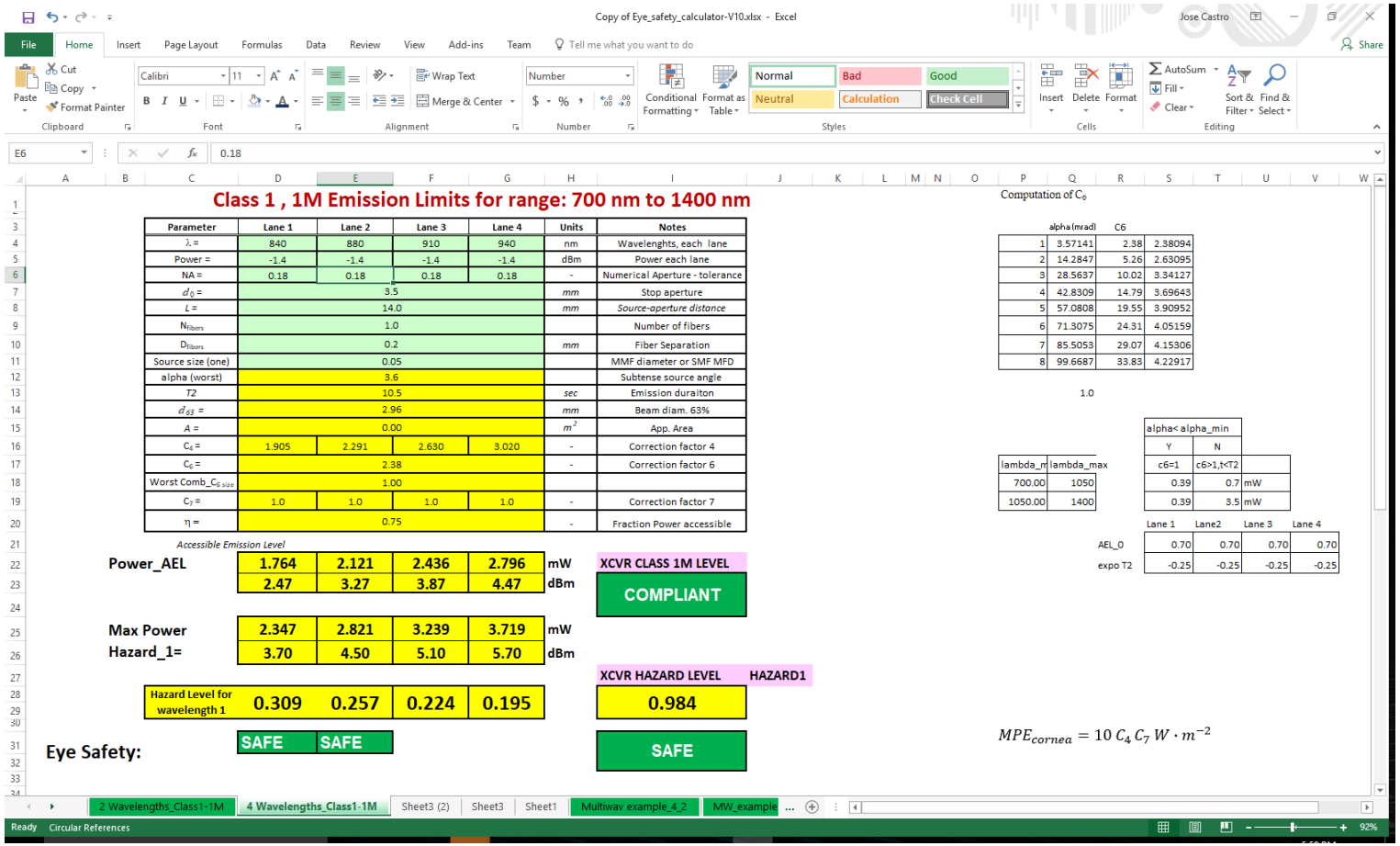
Power_AEL =	**27.904**	**46.505**	**93.231**	**96.200**	**mW**	**XCVR CLASS 1M LEVEL**
	14.46	**16.68**	**19.70**	**19.83**	**dBm**	**COMPLIANT**
Maximum Power for Hazard 1 =	**27.990**	**46.649**	**93.518**	**96.497**	**mW**	
	14.47	**16.69**	**19.71**	**19.85**	**dBm**	
						XCVR HAZARD LEVEL
Hazard Level for wavelength 1	**0.357**	**0.214**	**0.107**	**0.104**		**0.782**
Safety:	**SAFE**	**SAFE**	**SAFE**	**SAFE**		**SAFE**

Values from the calculator match the values in the draft standard for those conditions

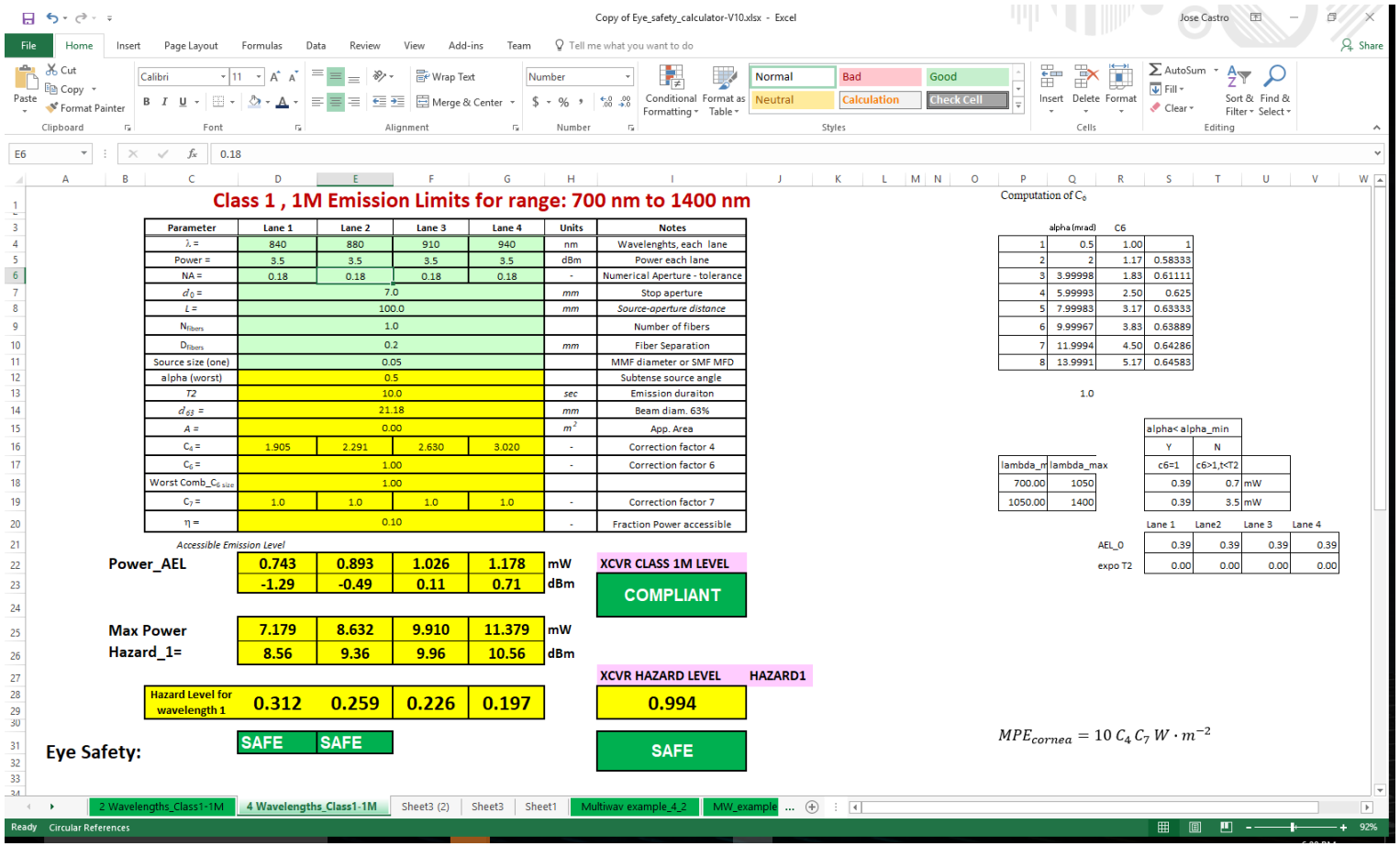
See more examples in the backup slides

Annex II 100 GSWDM-4

SWDM-4 class 1



Class 1M



Copy of Eye_safety_calculator-V10.xlsx - Excel

Class 1 , 1M Emission Limits for range: 700 nm to 1400 nm

Parameter	Lane 1	Lane 2	Lane 3	Lane 4	Units	Notes
λ =	840	880	910	940	nm	Wavelenghts, each lane
Power =	3.5	3.5	3.5	3.5	dBm	Power each lane
NA =	0.18	0.18	0.18	0.18	-	Numerical Aperture - tolerance
d'_0 =	7.0				*mm*	Stop aperture
L =	100.0				*mm*	*Source-aperture distance*
N_{Fibers}	1.0					Number of fibers
D_{Fibers}	0.2				*mm*	Fiber Separation
Source size (one)	0.05					MMF diameter or SMF MFD
alpha (worst)	0.5					Subtense source angle
T2	10.0				*sec*	Emission duraiton
d'_{63} =	21.18				*mm*	Beam diam. 63%
A =	0.00				m^2	App. Area
C_4 =	1.905	2.291	2.630	3.020	-	Correction factor 4
C_6 =	1.00				-	Correction factor 6
Worst Comb_$C_{6\ size}$	1.00					
C_7 =	1.0	1.0	1.0	1.0	-	Correction factor 7
η =	0.10				-	Fraction Power accessible

Accessible Emission Level

Power_AEL	**0.743**	**0.893**	**1.026**	**1.178**	mW	**XCVR CLASS 1M LEVEL**
	-1.29	**-0.49**	**0.11**	**0.71**	dBm	**COMPLIANT**
Max Power	**7.179**	**8.632**	**9.910**	**11.379**	mW	
Hazard_1=	**8.56**	**9.36**	**9.96**	**10.56**	dBm	
Hazard Level for wavelength 1	**0.312**	**0.259**	**0.226**	**0.197**		**XCVR HAZARD LEVEL** **HAZARD1**
						0.994
Eye Safety:	**SAFE**	**SAFE**				**SAFE**

Computation of C_6

	alpha (mrad)	C6	
1	0.5	1.00	1
2	2	1.17	0.58333
3	3.99998	1.83	0.61111
4	5.99993	2.50	0.625
5	7.99983	3.17	0.63333
6	9.99967	3.83	0.63889
7	11.9994	4.50	0.64286
8	13.9991	5.17	0.64583

1.0

lambda_m	lambda_max
700.00	1050
1050.00	1400

alpha< alpha_min		
Y	N	
c6=1	c6>1,t<T2	
0.39	0.7	mW
0.39	3.5	mW

	Lane 1	Lane2	Lane 3	Lane 4
AEL_0	0.39	0.39	0.39	0.39
expo T2	0.00	0.00	0.00	0.00

$$MPE_{cornea} = 10\, C_4\, C_7\, W \cdot m^{-2}$$

Sheets: 2 Wavelengths_Class1-1M | 4 Wavelengths_Class1-1M | Sheet3 (2) | Sheet3 | Sheet1 | Multiwav example_4_2 | MW_example

Ready | Circular References

Annex III Relevant tables in 60825-1

Table 3 – Accessible emission limits for Class 1 and Class 1M laser products and $C_6 = 1$ [a, b]

<table>
<tr><th rowspan="2">Wavelength
λ
nm</th><th colspan="10">Emission duration t
s</th></tr>
<tr><th>10^{-13} to 10^{-11}</th><th>10^{-11} to 10^{-9}</th><th>10^{-9} to 10^{-7}</th><th>10^{-7} to 5×10^{-6}</th><th>5×10^{-6} to $1{,}3 \times 10^{-5}$</th><th>$1{,}3 \times 10^{-5}$ to 1×10^{-3}</th><th>1×10^{-3} to 0,35</th><th>0,35 to 10</th><th>10 to 10^2</th><th>10^2 to 10^3</th><th>10^3 to 3×10^4</th></tr>
<tr><td>180 to 302,5</td><td colspan="2">3×10^{10} W·m^{-2}</td><td colspan="8">30 J·m^{-2}</td></tr>
<tr><td>302,5 to 315</td><td colspan="2" rowspan="2">$2{,}4 \times 10^4$ W</td><td colspan="6">Thermal hazard ($t \leq T_1$)
$7{,}9 \times 10^{-7}$ C_1 J</td><td colspan="4">Photochemical hazard
$7{,}9 \times 10^{-7}$ C_2 J
($t > T_1$)</td></tr>
<tr><td>315 to 400</td><td colspan="6">$7{,}9 \times 10^{-7}$ C_1 J</td><td colspan="2">$7{,}9 \times 10^{-3}$ J</td><td>$7{,}9 \times 10^{-6}$ W</td></tr>
<tr><td>400 to 450</td><td rowspan="3">$3{,}8 \times 10^{-8}$ J</td><td colspan="3" rowspan="3">$7{,}7 \times 10^{-8}$ J</td><td colspan="4" rowspan="3">7×10^{-4} $t^{0,75}$ J</td><td>$3{,}9 \times 10^{-3}$ J</td><td colspan="2" rowspan="2">$3{,}9 \times 10^{-5}$ C_3 W</td></tr>
<tr><td>450 to 500</td><td>$3{,}9 \times 10^{-3}$ C_3 J and [c] $3{,}9 \times 10^{-4}$ W</td></tr>
<tr><td>500 to 700</td><td colspan="3">$3{,}9 \times 10^{-4}$ W</td></tr>
<tr><td>700 to 1 050</td><td>$3{,}8 \times 10^{-8}$ J</td><td colspan="3">$7{,}7 \times 10^{-8}$ C_4 J</td><td colspan="4">7×10^{-4} $t^{0,75}$ C_4 J</td><td colspan="3" rowspan="2">$3{,}9 \times 10^{-4}$ C_4 C_7 W</td></tr>
<tr><td>1 050 to 1 400 [d]</td><td>$3{,}8 \times 10^{-8}$ C_7 J</td><td colspan="3">$7{,}7 \times 10^{-7}$ C_7 J</td><td colspan="4">$3{,}5 \times 10^{-3}$ $t^{0,75}$ C_7 J</td></tr>
<tr><td>1 400 to 1 500</td><td colspan="2">8×10^5 W</td><td colspan="3">8×10^{-4} J</td><td colspan="2">$4{,}4 \times 10^{-3}$ $t^{0,25}$ J</td><td>10^{-2} t J</td><td colspan="3" rowspan="4">$1{,}0 \times 10^{-2}$ W</td></tr>
<tr><td>1 500 to 1 800</td><td colspan="2">8×10^5 W</td><td colspan="5">8×10^{-3} J</td><td>$1{,}8 \times 10^{-2}$ $t^{0,75}$ J</td></tr>
<tr><td>1 800 to 2 600</td><td colspan="2">8×10^5 W</td><td colspan="3">8×10^{-4} J</td><td colspan="2">$4{,}4 \times 10^{-3}$ $t^{0,25}$ J</td><td rowspan="2">10^{-2} t J</td></tr>
<tr><td>2 600 to 4 000</td><td colspan="2">8×10^4 W</td><td>8×10^{-5} J</td><td colspan="4">$4{,}4 \times 10^{-3}$ $t^{0,25}$ J</td></tr>
<tr><td>4 000 to 10^6</td><td colspan="2">10^{11} W·m^{-2}</td><td>100 J·m^{-2}</td><td colspan="5">5 600 $t^{0,25}$ J·m^{-2}</td><td colspan="3">1 000 W·m^{-2}</td></tr>
</table>

NOTE Laser products that meet the requirements for classification as Class 1 by satisfying measurement Condition 1 may be hazardous when used with viewing optics having greater than ×7 magnification or objective diameters greater than those specified in Table 10.

[a] For correction factors and units, see Table 9.

[b] The AELs for emission durations less than 10^{-13} s are set to be equal to the equivalent power or irradiance values of the AEL at 10^{-13} s.

[c] In the wavelength range between 450 nm and 500 nm, dual limits apply and a product's emission shall not exceed either limit applicable to the class assigned.

[d] In the wavelength range between 1 250 nm and 1 400 nm, the upper value of the AEL is limited to the AEL value for Class 3B.

Table 4 – Accessible emission limits for Class 1 and Class 1M laser products in the wavelength range from 400 nm to 1 400 nm (retinal hazard region): extended sources [a, b, c, d, e, f]

Wavelength λ nm	Emission duration t s						
	10^{-13} to 10^{-11}	10^{-11} to 5×10^{-6}	5×10^{-6} to $1{,}3 \times 10^{-5}$	$1{,}3 \times 10^{-5}$ to $10^{\,e}$	10 to 10^2	10^2 to 10^4	10^4 to 3×10^4
400 to 700	$3{,}8 \times 10^{-8}\ C_6$ J	$7{,}7 \times 10^{-8}\ C_6$ J	$7 \times 10^{-4}\ t^{0,75}\ C_6$ J		400 nm to 600 nm – Retinal photochemical hazard [d, e] $3{,}9 \times 10^{-3}\ C_3$ J using γ_{ph} = 11 mrad	$3{,}9 \times 10^{-5}\ C_3$ W using $\gamma_{ph} = 1{,}1\ t^{0,5}$ mrad	$3{,}9 \times 10^{-5}\ C_3$ W using γ_{ph} = 110 mrad
					AND [c]		
					400 nm to 700 nm – Retinal thermal hazard $(t \le T_2)$ $7 \times 10^{-4}\ t^{0,75}\ C_6$ J / $7 \times 10^{-4}\ C_6\ T_2^{-0,25}$ W $(t > T_2)$		
700 to 1 050	$3{,}8 \times 10^{-8}\ C_6$ J	$7{,}7 \times 10^{-8}\ C_4\ C_6$ J	$7 \times 10^{-4}\ t^{0,75}\ C_4\ C_6$ J		$(t \le T_2)$ $7 \times 10^{-4}\ t^{0,75}\ C_4\ C_6$ J / $7 \times 10^{-4}\ C_4\ C_6\ T_2^{-0,25}$ W $(t > T_2)$		
1 050 to 1 400 [f]	$3{,}8 \times 10^{-8}\ C_6\ C_7$ J	$7{,}7 \times 10^{-7}\ C_6\ C_7$ J		$3{,}5 \times 10^{-3}\ t^{0,75}\ C_6\ C_7$ J	$(t \le T_2)$ $3{,}5 \times 10^{-3}\ t^{0,75}\ C_6\ C_7$ J / $3{,}5 \times 10^{-3}\ C_6\ C_7\ T_2^{-0,25}$ W $(t > T_2)$		

NOTE Laser products that meet the requirements for classification as Class 1 by satisfying measurement Condition 1 may be hazardous when used with viewing optics having greater than ×7 magnification or objective diameters greater than those specified in Table 10.

[a] For correction factors and units, see Table 9.

[b] The AELs for emission duration less than 10^{-13} s are set to be equal to the equivalent power or irradiance values of the AEL at 10^{-13} s.

[c] In the wavelength range between 400 nm and 600 nm, dual limits apply and a product's emission shall not exceed either limit applicable to the class assigned.

[d] The angle γ_{ph} is the limiting measurement angle of acceptance.

[e] If emission durations between 1 s and 10 s are used, for wavelengths between 400 nm and 484 nm and for apparent source sizes between 1,5 mrad and 82 mrad, the dual photochemical hazard limit of $3{,}9 \times 10^{-3}\ C_3$ J is extended to 1 s.

[f] In the wavelength range between 1 250 nm and 1 400 nm, the upper value of the AEL is limited to the AEL value for Class 3B.