Preliminary Evaluation of OFCS Hazards for VCSEL-MMF Channels

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IEEE P802.3cm 400 Gb/s over Multimode Fiber Task Force
Pittsburgh, PA, May 2018

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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.

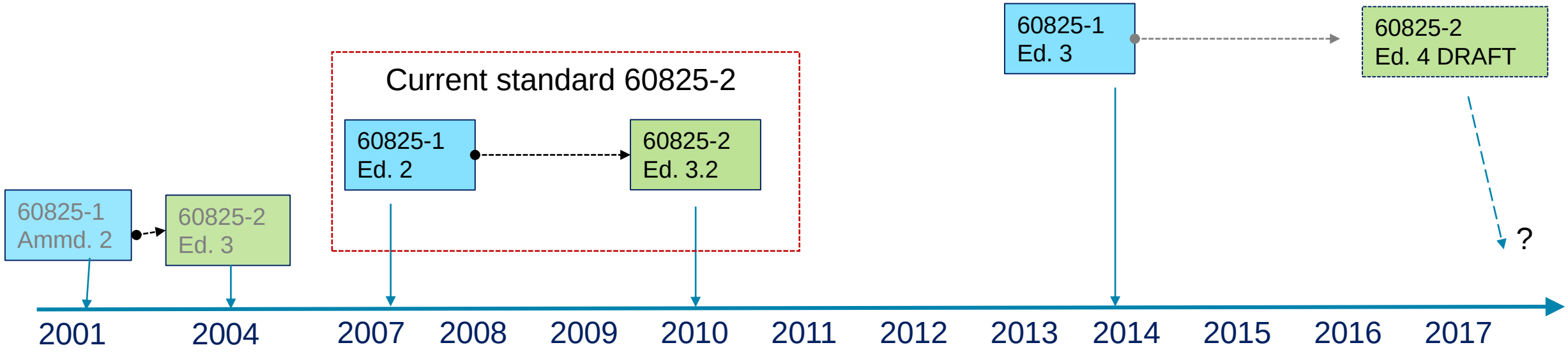
- It applies to the complete installed end-to-end OFCS. However, it is not clear if all components and subassemblies that generate or amplify optical radiation should be assessed by this standard. This ambiguity has caused different interpretations:
  - Based on CSA, individual components and subassemblies 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
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

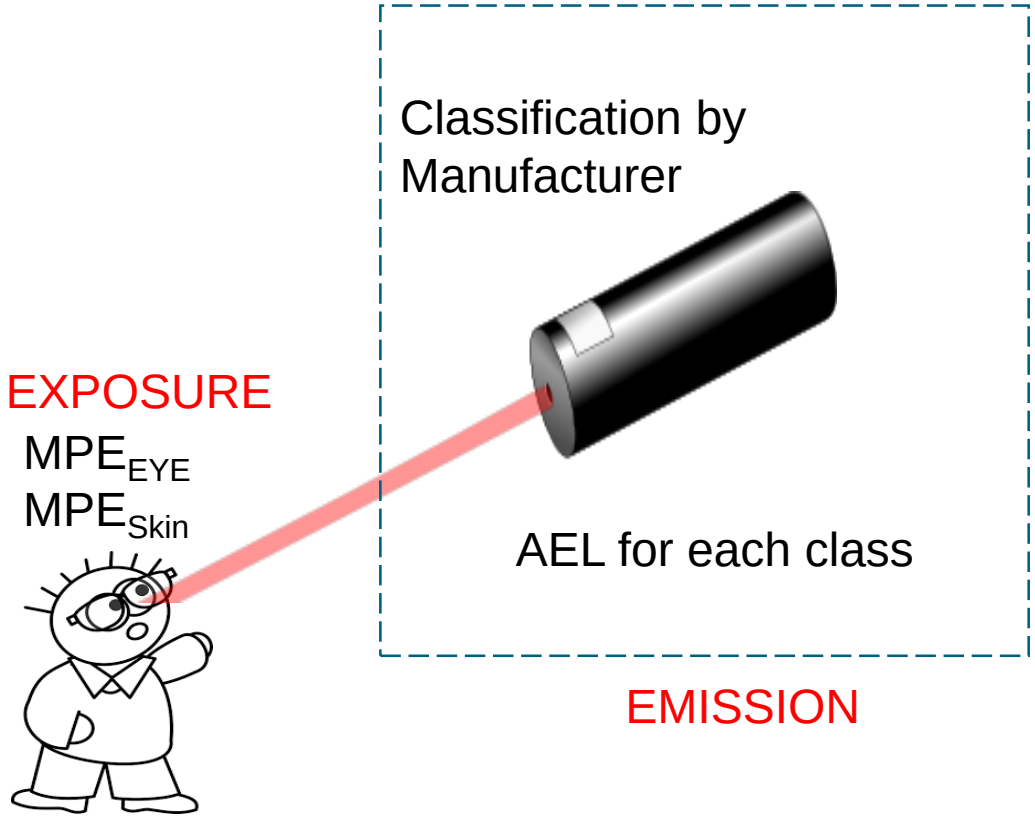
- 60825-2 Ed. 3.2 (valid standard) calculation methods and parameters are based on 60825-1 (Ed. 2)
  - AELs, MPE, correction constants and many other parameters
- However, revisions or updates of each standard are not necessarily in synch
  - Adoption of different editions of same standard occurs depending 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 2018.
  - 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:

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



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

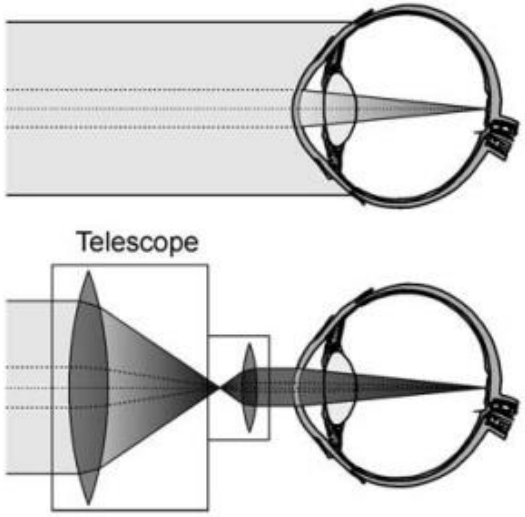
Laser Safety Classification

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

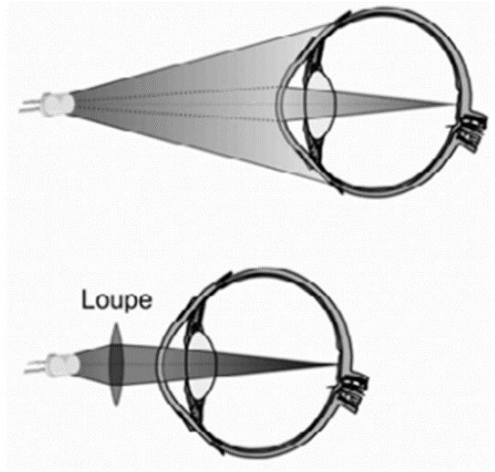
Class	Wavelength (nm)	Conditions	Applications	Notes
Class 1	---	1 (telescope), 3 (naked eye)	General	No risk for eye or skin
Class 1M	302.5-4000	3 (naked eye)	General	No risk for eye or skin
Class 1C	---		Skin contact (not ocular)	
Class 2	400-700	1 (telescope), 3 (naked eye)		No risk for eye or skin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

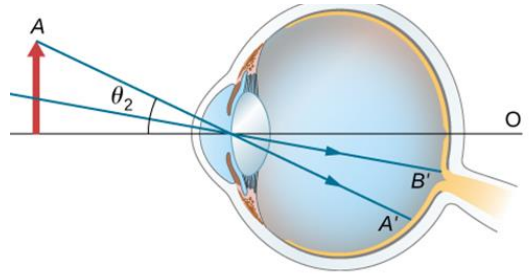
Condition 1
Used in IEC 60825-1 in Edition 2 (2007) and Edition 3 (2014)



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



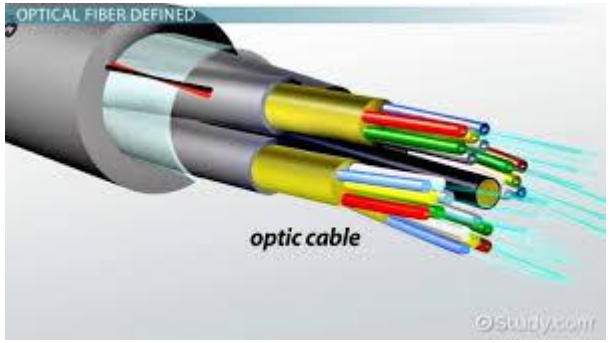
Condition 3
Naked eye use in IEC 60825-1 in both Ed. 2 (2007) and in Edition 3 (2014)



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	XCVR CLASS 1M LEVEL
	-1.29	0.11	dBm	COMPLIANT

Maximum power for Hazard 1

Max Power	7.179	9.910	mW
Hazard_1=	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 SR4.2

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 SR4.2

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 SR4.2

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

- Discussed challenges to implement a hazard estimator based on IEC 60825-1 and 60825-2.
  - Both documents are highly related. They share calculation methods, and model parameters.
  - However, standard updates are for part 1 and part 2 occur at different times. Also, users in different countries use different editions of same standard.
- Implemented calculator for AEL, OFCS power limits and hazard levels based on IEC 60825-2 (Ed. 3.2)
- Evaluated hazard levels for 400G BASE-SR4.2 based on current 60825-2 standard.
  - Results indicates that hazard 1, requires transmitted average power <=1.1 dBm per lane
  - Results indicates that hazard 1M, requires transmitted average power <=4.1 dBm per lane.
- The results presented should be considered as preliminary estimation.
  - The draft 60825-2 Ed. 4 is currently open for comments. It might solve some of the ambiguities discussed in this presentation.
  - Panduit engaged other companies/organizations (Finisar, FIT, OITDA) to review Ed.4 and to clarify measuring conditions for Hazard 1 M. The laser safety calculator described in this presentation will be uploaded in after clarification.
  - More updates to be provided during the next meeting.

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

Comparison with OFCS power limits from Table D1 in IEC 60825-2 Ed. 3.2

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)

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
$\lambda 1$ =	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
$\lambda 1$ =	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
λ1 =	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
λ1 =	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 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.