BS EN 62149-7:2012

BSI Standards Publication

Fibre optic active components and devices — Performance standards

Part 7: 1 310 nm discrete vertical cavity surface emitting laser devices

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National foreword

This British Standard is the UK implementation of EN 62149-7:2012. It is identical to IEC 62149-7:2012.

The UK participation in its preparation was entrusted by Technical Committee GEL/86, Fibre optics, to Subcommittee GEL/86/3, Fibre optic systems and active devices.

A list of organizations represented on this committee can be obtained on request to its secretary.

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EUROPEAN STANDARD

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English version

Fibre optic active components and devices - Performance standards - Part 7: 1 310 nm discrete vertical cavity surface emitting laser devices

(IEC 62149-7:2012)

Composants et dispositifs actifs à fibres optiques - Norme de performance - Partie 7: Dispositifs discrets à laser 1 310 nm émettant en surface (CEI 62149-7:2012)

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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Foreword

The text of document 86C/1021/CDV, future edition 1 of IEC 62149-7, prepared by IEC/TC 86 "Fibre optics" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 62149-7:2012.

The following dates are fixed:

• latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2013-02-03
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2015-05-03

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

Endorsement notice

The text of the International Standard IEC 62149-7:2012 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60191 series	NOTE	Harmonized as EN 60191 series (not modified).
IEC 60747-5-1	NOTE	Harmonized as EN 60747-5-1.
IEC 60793-2	NOTE	Harmonized as EN 60793-2.
IEC 60874 series	NOTE	Harmonized as EN 60874 series (not modified).
IEC 61280-1-3	NOTE	Harmonized as EN 61280-1-3.
IEC 62007-1	NOTE	Harmonized as EN 62007-1.
IEC 62007-2	NOTE	Harmonized as EN 62007-2.
IEC 62148-1	NOTE	Harmonized as EN 62148-1.
IEC 62149-1	NOTE	Harmonized as EN 62149-1.
IEC 62149-4	NOTE	Harmonized as EN 62149-4.

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
IEC 60749	Series	Semiconductor devices - Mechanical and climatic test methods	EN 60749	Series
IEC 60825-1	-	Safety of laser products - Part 1: Equipment classification and requirements	EN 60825-1	-
IEC 60950-1	-	Information technology equipment - Safety - Part 1: General requirements	EN 60950-1	-
IEC 61300-2-4	-	Fibre optic interconnecting devices and passive components - Basic test and measurement procedures - Part 2-4: Tests - Fibre/cable retention	EN 61300-2-4	-
IEC 61300-2-19	-	Fibre optic interconnecting devices and passive components - Basic test and measurement procedures - Part 2-19: Tests - Damp heat (steady state)	EN 61300-2-19	-
IEC 61300-2-48	-	Fibre optic interconnecting devices and passive components - Basic test and measurement procedures - Part 2-48: Tests - Temperature-humidity cycling	EN 61300-2-48	-
IEC 62148-15	-	Fibre optic active components and devices - Package and interface standards - Part 15: Discrete vertical cavity surface emitting laser packages	EN 62148-15	-
IEC Guide 107	1998	Electromagnetic compatibility - Guide to the drafting of electromagnetic compatibility publications	-	-

CONTENTS

INTRODUCTION

Fibre optic laser devices are used to convert electrical signals into optical signals. This part of IEC 62149 covers the performance specification for 1 310 nm discrete vertical cavity surface emitting laser devices in fibre optic telecommunication and optical data transmission applications.

FIBRE OPTIC ACTIVE COMPONENTS AND DEVICES – PERFORMANCE STANDARDS –

Part 7: 1 310-nm discrete vertical cavity surface emitting laser devices

1 Scope

This part of IEC 62149 covers the performance specification for 1 310-nm discrete vertical cavity surface emitting laser (VCSEL) devices of transverse single-mode and multimode types used for the fibre optic telecommunication and optical data transmission application in a form of the VCSEL chips mounted on a substrate with wire bonding to their chips' anode and cathode terminals without any fibre pigtails. The performance standard contains a definition of the product performance requirements together with a series of sets of tests and measurements with clearly defined conditions, severities, and pass/fail criteria. The tests are intended to be run on a "one-off" basis to prove any product's ability to satisfy the performance standard's requirements.

A product that has been shown to meet all the requirements of a performance standard can be declared as complying with the performance standard, but should then be controlled by a quality assurance/quality conformance program.

Depending on the signalling speed and application areas, subcategorized specifications of the 1 310-nm discrete VCSEL are defined as shown in Table 1.

Table 1 – Subcategorized specifications of the 1 310-nm discrete VCSEL

	1,0625 GBd	1,25 GBd	2,125 GBd	3,125 GBd	4,25 GBd	8,5 GBd	10 GBd[a]	16 GBd	25,78125 GBd
Fibre Channel	FC1GB		FC2GB		FC4GB	FC8GB		FC16GB[b]	
Ethernet		E1A1a E1A1b E1B		E3A1a E3A1b E10BLX4			E10BLR E10BLW E40BLR4		E25B[c]
NOTE Bd is baud rate; A1a is 50 μm core multimode fibre; A1b is 62, 5 μm core multimode fibre; B is single-mode fibre; LR is 10 G LAN; LW is 10 G WAN; LR4 is 40 G WDM. (Refer to IEC 60793-2, IEEE 802.3-2002, INCITS 450-2009, INCITS/Project 2118-D/Rev1.00-2008.09.25, IEEE 802.3-2005, and IEEE P802.3ba-2009.)									
[a] Nominal signal rate of 10 G Ethernet is 10,312 5 GBd for E10BLR and E40BLR4 and 9,953 28 GBd for E10BLW. [b, c] VCSEL specifications for signalling rates of 16 GBd, 25,781 25 GBd and above are left for future works.									

Each subcategorized specification is also defined by separate details depending on the device types, such as specifications for a VCSEL device without a monitor photodiode (Case a) and for a VCSEL device with a monitor photodiode (Case b).

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60749 (all parts), *Semiconductor devise – Mechanical and climate test methods*

IEC 60825-1: *Safety of laser products – Part 1: Equipment classification and requirements*

IEC 60950-1, *Information technology equipment – Safety – Part 1: General requirements*

IEC 61300-2-4, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 2-4: Tests – Fibre/cable retention*

IEC 61300-2-19, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 2-19: Tests – Damp heat (steady state)*

IEC 61300-2-48, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 2-48: Tests – Temperature-humidity cycling*

IEC 62148-15, *Fibre optic active components and devices – Package and interface standards – Part 15: Discrete vertical cavity surface emitting laser packages*

IEC Guide 107: 1998, *Electromagnetic compatibility – Guide to the drafting of electromagnetic compatibility publications*

3 Terms, definitions, symbols and abbreviated terms

NOTE Terminology concerning the physical concepts, the types of devices, the general terms, and that related to ratings and characteristics of semiconductor devices can be found in IEC 60747-5-1. In addition, the definition for the essential ratings and characteristics of the semiconductor optoelectronic devices for fibre optic system applications can be found in IEC 62007-1.

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

NOTE The following terms are defined for the specific characteristics of vertical cavity surface emitting laser devices.

3.1.1
modulation speed
digital modulation speed with an optimum modulation amplitude between the operating current and threshold current level

3.1.2
multimode
cross-section transverse mode of the laser beam profile with mode number greater than one

Note 1 to entry: This means that the intensity profile has more than one spot, compared to the single-mode which corresponds to the cross-section transverse mode of the laser beam profile with mode number of one having the intensity profile of one circular spot.

3.1.3
laser wavelength
peak central laser wavelength of the vertical cavity surface emitting laser device when it is operated at the normal operating conditions which is specified in the sectional specification of the VCSEL

3.1.4
submount
substrate upon which a laser is mounted for assembly into the further packaging

3.1.5
transverse mode
cross-sectional profile of the optical beam intensity at the laser output of the VCSEL

Note 1 to entry: Depending on the mode status between multimode and single-mode, the package type of the VCSEL devices is also defined.

3.1.6
VCSEL device with a monitor photodiode
VCSEL packaged device with a monitor photodiode

3.1.7
VCSEL device without a monitor photodiode
VCSEL packaged device without a monitor photodiode

3.2 Symbols and abbreviated terms

λ_p	peak laser wavelength
I_{th}	threshold current
V_{th}	threshold voltage
I_{op}	operating current
V_f	forward voltage at operating current
R_s	series resistance
η	slope efficiency
P_o	continuous laser output power (at connector output or pigtailed fibre output for packaged types)
$\Delta\lambda_T/\Delta T$	wavelength change over temperature
θ	beam divergence at $1/e^2$ intensity
t_r/t_f	rise and fall time from 20 % to 80 % of the peak intensity
C	capacitance of the VCSEL chip
$\Delta\lambda$	spectral width, RMS (at static condition) for multimode VCSELS, -20 dB for single-mode VCSELs
RIN	relative intensity noise
$\Delta R_S/\Delta T$	series resistance temperature coefficient

4 Product parameters

4.1 Absolute limiting ratings

Absolute limiting (maximum and/or minimum) ratings imply that no catastrophic damage will occur if the product is subject to these ratings for short periods, provided each limiting parameter is in isolation and all other parameters have values within the normal performance parameters. It should not be assumed that limiting value of more than one parameter can be applied at any one time. The absolute maximum ratings of the subcategorized types, E1, E3, E10, E40 BLR4, FC1GB, FC2GB, FC4GB and FC8GB for signalling speeds are listed in Annexes A through D, depending on the transverse mode of the VCSELs between multimode and single-mode and on the monitor photodiode packaged together or unpackaged.

4.2 Operating environment

The operating environment of all the subcategorized types of the 1 310 nm VCSEL is specified in Table 2.

Table 2 – Operating environment

Parameter	Symbol	Value		Unit
		Minimum	Maximum	
Operating temperature	T_{op}	-40	+85	°C

4.3 Functional specification

Functional specifications of all the subcategorized types, E1, E3, E10, E40BLR4, FC1GB, FC2GB, FC4GB, and FC8GB, for signalling speeds and application areas are listed in Annexes A through D depending on the transverse mode of the VCSELs between multimode and single-mode and on the monitor photodiode packaged together or unpackaged.

4.4 Diagrams

Diagrams of all the VCSEL device types are included in Annexes A through D.

5 Testing

5.1 General

Initial characterisation and qualification shall be undertaken when a build standard has been completed and frozen. Qualification maintenance is carried using periodic testing programs. Test conditions for all tests unless otherwise stated are 25 °C ± 2 °C.

5.2 Characterization testing

Characterisation shall be carried out on at least 20 products taken from at least three different manufacturing lots. The characteristics and conditions of laser diode are tested at the operating temperature and the operating current to satisfy the functional specifications defined in 4.3.

5.3 Performance testing

Performance testing is undertaken when characterization testing is complete. The performance test plan and recommended performance test failure criteria are specified in Annexes A through D, depending on the device types.

6 Environmental specifications

6.1 General safety

All products meeting this standard shall conform to IEC 60950-1.

6.2 Laser safety

Fibre optic transmitter and transceiver using the laser diode specified in this document shall be class 3R laser certified under any condition of operation. This includes single fault conditions whether coupled into a fibre or out of an open bore. Fibre optic transmitter and transceiver using the laser diode specified in this document shall be certified to be in conformance with IEC 60825-1.

Laser safety standards and regulations require that the manufacturer of a laser product provide information about the product's laser, safety features, labelling, use, maintenance and service. This documentation shall explicitly define requirements and usage restrictions on the host system necessary to meet these safety certifications.

6.3 Electromagnetic compatibility (EMC) requirements

Products defined in this specification shall comply with suitable requirements for electromagnetic compatibility (in terms of both, emission and immunity), depending on particular usage/environment in which they are intended to be installed or integrated. Guidance to the drafting of such EMC requirements is provided in IEC Guide 107. Guidance for electrostatic discharge (ESD) is still under study.

Annex A
(normative)

Specifications for multimode 1 310-nm VCSEL device without a monitor photodiode (Case a)

A.1 Absolute limiting ratings

Absolute limiting (maximum and/or minimum) ratings imply that no catastrophic damage will occur if the product is subject to these ratings for short periods, provided each limiting parameter is in isolation and all other parameters have values within the normal performance parameters. It should not be assumed that a limiting value of more than one parameter can be applied at any one time. Absolute limiting ratings are shown in Table A.1.

Table A.1 – Absolute limiting ratings

Parameter	Symbol	Value		Unit
		Minimum	Maximum	
Storage temperature	T_{stg}	–40	+85	°C
Soldering condition	T_{sol}		260 °C, 10 s	
Laser diode				
Reverse bias voltage	V_{RB}		5	V
Continuous forward current	I_{FLD}		15	mA

A.2 Operating environment

The requirements of 4.2 shall be met.

A.3 Functional specification

Tables A.2 and A.3 contain the operating conditions for functional specifications and the functional specifications of multimode 1 310-nm VCSEL devices of signalling speeds of 1,25 GBd and 3,125 GBd without a monitor photodiode at the operating conditions.

Table A.2 – Operating conditions for functional specification

Parameter	Symbol	Value		Unit	Note
		Minimum	Maximum		
Operating forward current	I_{op}		12	mA	
Operating forward bias voltage	V_f		2,5	V	

Table A.3 – Functional specification

Parameter	Symbol	Value		Unit	Note
		Minimum	Maximum		
Laser diode					
Laser wavelength (for single channel uses)	λ_p	1 270	1 355	nm	CW, E1A1a, E1A1b
Laser wavelength (for four WDM channel uses)	λ_{p_C0}	1 269,0	1 282,4	nm	CW, E3A1a, E3A1b
	λ_{p_C1}	1 293,5	1 306,9	nm	CW, E3A1a, E3A1b
	λ_{p_C2}	1 318,0	1 331,4	nm	CW, E3A1a, E3A1b
	λ_{p_C3}	1 342,5	1 355,9	nm	CW, E3A1a, E3A1b
Spectral width, RMS (for single channel uses)	$\Delta\lambda$		4	nm	CW
Spectral width, RMS (for four WDM channel uses)	$\Delta\lambda$		0,62	nm	CW. E3A1a, E3A1b
Threshold current	I_{th}	0,5	5,0	mA	T_0=20 °C
Threshold voltage	V_{th}	1,1	2,0	V	
Slope efficiency (at I_{op} in a TO package)	η	0,05	0,3	mW/mA	
Slope efficiency (at I_{op} in a TOSA or pigtailed package)	η	0,03	0,2	mW/mA	
Continuous laser output power (at I_{op} in a TO package)	P_O	-7	5	dBm	E1A1a E1A1b
		-7	5	dBm	E3A1a, E3A1b
Continuous laser output power (at I_{op} in a TOSA or pigtailed package)	P_O	-11,5	-3,5	dBm	E1A1a, E1A1b
			-0,5	dBm	E3A1a, E3A1b
Wavelength change over temperature	$\Delta\lambda/\Delta T$		0,2	nm/°C	
Rise and fall time (20 % – 80 %)	t_r/t_f		260/260	ps	E1A1a, E1A1b
			120/120	ps	E3A1a, E3A1b
Capacitance (VCSEL chip)	C		5	pF	E1A1a, E1A1b V_{rev} = 0 V, 1 MHz
			2	pF	E3A1a, E3A1b V_{rev} = 0 V, 1 MHz
Relative intensity noise	RIN		-120	dB/Hz	[a]
Series resistance temperature coefficient	$\Delta R_S/\Delta T$		-4 000	ppm/°C	[b]

[a] For 1 GHz bandwidth and optical power specified (typically a negative value)

[b] Series resistance of laser diodes decreases as temperature increases and thus its thermal dependent parameter is typically a negative value.

A.4 Diagrams

Refer to IEC 62148-15.

A.5 Testing

A.5.1 Characterization testing

The requirements of 5.1 shall be met.

A.5.2 Performance testing

Performance testing is undertaken when characterization testing is complete. A performance test plan is shown in Table A.4 and recommended performance test failure criteria in Table A.5.

Table A.4 – Performance test plan

No.	Test	Reference	Conditions	n[c]
1	Endurance test of:			
1.1	Package			
1.1.1	High temperature storage	IEC 60749-6	Temperature: T =Tstg max Duration: 1 000 h	11
1.1.2	Low temperature storage		Temperature: T =Tstg min Duration: > 2 000 h	11
1.1.3	Temperature cycling	IEC 60749-25	Temperature: T_A =Tstg min T_B =Tstg max Number of cycles = 100	11
1.1.4	Damp heat	IEC 61300-2-19	T= +40 °C ± 2 °C RH: 93 % ± 2 % 96 h duration	11
1.1.5	Temperature-humidity cycling	IEC 61300-2-48, method A	–40 °C ± 2 °C to +85 °C ± 2 °C 85 ± 5 % RH at the maximum temperature 1 hour minimum duration at extremes ≥ 1 °C/min rate of change 42 cycles	11
1.1.6	Fibre pull[a]	IEC 61300-2-4	5 N ± 0,5 N at 0,5 N/s 60 s duration for buffered fibres	11
1.2	Laser diode (submount)		Temperature: at least two test temperatures: φ_e specified, constant power	[b] [b]
1.2.1			Ts1=Ts max	
1.2.2			Ts2=< (Ts1-20 °C) Duration: > 5 000 h	
2	Mechanical shock	IEC 60749-10	1 500 G, 0,5 ms 5 times/axis	11
3	Vibration	IEC 60749-12	20 G, 20 Hz – 2 000 Hz, 4 min/cycle, 4cycle/axis	11

No.	Test	Reference	Conditions	n[c]
4	Rapid change of temperature	IEC 60749-11	ΔT=100 °C, Temperature change time < 10 s, dwell time > 2 min temperature reach time < 5 min 15 cycles	11
5	ESD	IEC 60749-26	Human body model, positive and negative voltage pulses with a pulse interval of 300 ms	3
6	Internal moisture	IEC 60749-7	$\leq 5\,000 \times 10^{-6}$ water vapour	11

[a] Applied to fibre pigtailed packages.

[b] These parameters can be determined from negotiation between manufacturer and user.

[c] Number of samples

Table A.5 – Recommended performance test failure criteria

Devices	Parameter	Failure criterion	Measurement condition
Laser diode	Operating current	50 % increase [a]	25 °C or life test temperature
	Slope efficiency	10 % change [a]	25 °C or life test temperature
	Forward voltage	10 % change [a]	25 °C or life test temperature
	Kinks in L/I curve	Kink-free within $1{,}2 \times P_{nom}$ (linearity change ≤10%) [a]	T_{op} min, 25 °C, T_{op} max
Laser package	Operating current	50 % increase [a]	25 °C or life test temperature
	Fibre or connector output power	10 % change [a]	Life test temperature I_{mon} set to initial value
	Kinks in L/I curve	Kink-free within $1{,}2 \times P_{nom}$ (linearity change ≤10 %) [a]	T_{op} min, 25 °C, T_{op} max
	Tracking ratio (I_{mon} / P_{fibre})	< LSL ≥ USL	T_{op} min ~ T_{op} max At rated power level

[a] Change of pre- and post-test values in the DS

Annex B
(normative)

Specifications for multimode 1 310-nm VCSEL device with a monitor photodiode (Case b)

B.1 Absolute limiting ratings

Absolute limiting (maximum and/or minimum) ratings imply that no catastrophic damage will occur if the product is subject to these ratings for short periods, provided each limiting parameter is in isolation and all other parameters have values within the normal performance parameters. It should not be assumed that limiting value of more than one parameter can be applied at any one time. Absolute limiting ratings are shown in Table B.1.

Table B.1 – Absolute limiting ratings

Parameter	Symbol	Value		Unit
		Minimum	Maximum	
Storage temperature	T_{stg}	−40	+85	°C
Soldering condition	T_{sol}		260 °C, 10 sec	
Laser diode				
Reverse bias voltage	V_{RB}		5	V
Continuous forward current	I_{FLD}		15	mA
Monitor photodiode				
Maximum reverse voltage	V_{mR}		5,0	V
Maximum forward current	I_{mF}		2	mA

B.2 Operating environment

The requirements of 4.2 shall be met.

B.3 Functional specification

Tables B.2 and B.3 contain the operating conditions for functional specifications and the functional specifications of multimode 1 310 nm VCSEL devices of signalling speeds of 1,25 GBd and 3,125 GBd with a monitor photodiode at the operating conditions.

Table B.2 – Operating conditions for functional specification

Parameter	Symbol	Value		Unit	Note
		Minimum	Maximum		
Operating forward current	I_{op}		12	mA	
Operating forward bias voltage	V_f		2,5	V	

Table B.3 – Functional specification

Parameter	Symbol	Value		Unit	Note
		Minimum	Maximum		
Laser diode					
Laser wavelength (for single channel uses)	λ_p	1 270	1 355	nm	CW, E1A1a, E1A1b
Laser wavelength (for four WDM channel uses)	λ_{p_C0}	1 269,0	1 282,4	nm	CW, E3A1a, E3A1b
	λ_{p_C1}	1 293,5	1 306,9	nm	CW, E3A1a, E3A1b
	λ_{p_C2}	1 318,0	1 331,4	nm	CW, E3A1a, E3A1b
	λ_{p_C3}	1 342,5	1 355,9	nm	CW, E3A1a, E3A1b
Spectral width, RMS (for single channel uses)	$\Delta\lambda$		4	nm	CW
Spectral width, RMS (for four WDM channel uses)	$\Delta\lambda$		0,62	nm	CW. E3A1a, E3A1b
Threshold current	I_{th}	0,5	5,0	mA	T_0=20 °C
Threshold voltage	V_{th}	1,1	2,0	V	
Slope efficiency (at I_{op} in a TO package)	η	0,05	0,3	mW/mA	
Slope efficiency (at I_{op} in a TOSA or pigtailed package)	η	0,03	0,2	mW/mA	
Continuous laser output power (at I_{op} in a TO package)	P_O	-8,5	5	dBm	E1A1a E1A1b
		-8,5	5	dBm	E3A1a, E3A1b
Continuous laser output power (at I_{op} in a TOSA or pigtailed package)	P_O	-11,5	-3,5	dBm	E1A1a, E1A1b
			-0,5	dBm	E3A1a, E3A1b
Wavelength change over temperature	$\Delta\lambda/\Delta T$		0,2	nm/°C	
Rise and fall time	t_r/t_f		260/260	ps	E1A1a, E1A1b
			120/120	ps	E3A1a, E3A1b
Capacitance (VCSEL chip)	C		5	pF	E1A1a, E1A1b V_{rev} = 0 V, 1 MHz
			2	pF	E3A1a, E3A1b V_{rev} = 0 V, 1 MHz
Relative intensity noise	RIN		-120	dB/Hz	[a]
Series resistance temperature coefficient	$\Delta R_S/\Delta T$		-4 000	ppm/°C	[b]
Monitor photodiode					[c]
Monitor current	I_m	0,1		mA	
Dark current	I_{mR0}		100	nA	P_{op} = 0 mW, V_{rev} = 3 V
Capacitance[d]	C_{tot}		100	pF	V_{rev} = 0 V, 1 MHz

[a] For 1 GHz bandwidth and optical power specified (typically a negative value).

[b] Series resistance of laser diodes decreases as temperature increases and thus its thermal dependent parameter is typically a negative value.

[c] This part applies only to the VCSELs with monitor photodiode at a room temperature condition of 25 °C.

[d] This indicates total capacitance between the anode and cathode terminals of the monitor photodiode subassembly.

B.4 Diagrams

Refer to IEC 62148-15.

B.5 Testing

B.5.1 Characterization testing

The requirements of 5.1 shall be met.

B.5.2 Performance testing

Performance testing is undertaken when characterization testing is complete. A performance test plan is shown in Table B.4 and recommended performance test failure criteria in Table B.5.

Table B.4 – Performance test plan

No.	Test	Reference	Conditions	n[c]
1	Endurance test of:			
1.1	Package			
1.1.1	High temperature storage	IEC 60749-6	Temperature: $T = T_{stg\ max}$ Duration: 1 000 h	11
1.1.2	Low temperature storage		Temperature: $T = T_{stg\ min}$ Duration: > 2 000 h	11
1.1.3	Temperature cycling	IEC 60749-25	Temperature: $T_A = T_{stg\ min}$ $T_B = T_{stg\ max}$ Number of cycles = 100	11
1.1.4	Damp heat	IEC 61300-2-19	T= +40 °C ± 2 °C RH: 93 % ± 2 % 96 h duration	11
1.1.5	Temperature-humidity cycling	IEC 61300-2-48, method A	–40 °C ± 2 °C to +85 °C ± 2 °C 85 ± 5 % RH at the maximum temperature 1 hour minimum duration at extremes ≥ 1 °C/min rate of change 42 cycles	11
1.1.6	Fibre pull[a]	IEC 61300-2-4	5 N ± 0,5 N at 0,5 N/s 60 s duration for buffered fibres	11
1.2	Laser diode (submount)		Temperature: at least two test temperatures: φ_e specified, constant power	[b] [b]
12.1			$T_{s1} = T_s$ max	
1.2.2			$T_{s2} =< (T_{s1}$-20 °C) Duration: >5 000 h	
1.3	Photodiode (in representative package)		Temperature: at least two test temperatures: V_r or I_r specified	[b] [b]
1.3.1			T_{s1}= 125 °C min.	11
1.3.2			$T_{s2} =< (T_{s1}$-30 °C) Duration: > 1 000 h	
2	Mechanical shock	IEC 60749-10	1 500 G, 0,5 ms 5 times/axis	11
3	Vibration	IEC 60749-12	20 G, 20 Hz – 2 000 Hz, 4 min./cycle, 4cycle/axis	11
4	Rapid change of temperature	IEC 60749-11	ΔT=100 °C, Temperature change time < 10 s, dwell time > 2 min. temperature reach time < 5min. 15 cycles	11
5	ESD	IEC 60749-26	Human body model, positive and negative voltage pulses with a pulse interval of 300 ms	3
6	Internal moisture	IEC 60749-7	≤ 5 000 $\times 10^{-6}$ water vapor	11

[a] Applied to fibre pigtailed packages.

[b] These parameters can be determined from negotiation between manufacturer and user.

[c] Number of samples.

Table B.5 – Recommended performance test failure criteria

Devices	Parameter	Failure criterion	Measurement condition
Laser diode	Operating current	50 % increase [a]	25 °C or life test temperature
	Slope efficiency	10 % change [a]	25 °C or life test temperature
	Forward voltage	10 % change [a]	25 °C or life test temperature
	Kinks in L/I curve	Kink-free within 1,2 × P_{nom} (linearity change ≤10%) [a]	T_{op} min, 25 °C, T_{op} max
Photodiode	Dark current	USL or 10 nA increase	25 °C
Laser package	Operating current	50 % increase [a]	25 °C or life test temperature
	Fibre or connector output power	10 % change [a]	Life test temperature *I*mon set to initial value
	Kinks in L/I curve	Kink-free within 1,2 × P_{nom} (linearity change ≤10 %) [a]	T_{op} min, 25 °C, T_{op} max
	Tracking ratio (I_{mon} / P_{fibre})	< LSL ≥ USL	T_{op} min ~ T_{op} max At rated power level
	Photodiode dark current	USL or 10 nA increase [a]	25 °C

[a] Change of pre- and post-test values in the DS.

Annex C
(normative)

Specifications for single-mode 1 310-nm VCSEL device without a monitor photodiode (Case c)

C.1 Absolute limiting ratings

Absolute limiting (maximum and/or minimum) ratings imply that no catastrophic damage will occur if the product is subject to these ratings for short periods, provided each limiting parameter is in isolation and all other parameters have values within the normal performance parameters. It should not be assumed that a limiting value of more than one parameter can be applied at any one time. Absolute limiting ratings are shown in Table C.1.

Table C.1 – Absolute limiting ratings

Parameter	Symbol	Value		Unit
		Minimum	Maximum	
Storage temperature	T_{stg}	–40	+85	°C
Soldering condition	T_{sol}		260 °C, 10 s	
Laser diode				
Reverse bias voltage	V_{RB}		5	V
Continuous forward current	I_{FLD}		12	mA

C.2 Operating environment

The requirements of 4.2 shall be met.

C.3 Functional specification

Tables C.2 and C.3 contain the operating conditions for functional specifications and the functional specifications of single-mode 1 310 nm VCSEL devices of signalling speeds of 1,0625 GBd, 1,25 GBd, 3,125 GBd, 4,25 GBd, 8,5 GBd and 10 GBd without a monitor photodiode at the operating conditions.

Table C.2 – Operating conditions for functional specification

Parameter	Symbol	Value		Unit	Note
		Minimum	Maximum		
Operating forward current	I_{op}		12	mA	
Operating forward bias voltage	V_f		2,5	V	

Table C.3 – Functional specification

Parameter	Symbol	Value		Unit	Note
		Minimum	Maximum		
Laser diode					
Laser wavelength (for single channel uses)	λ_p	1 270	1 355	nm	CW, E1B
		1 260	1 370	nm	CW, FC1, FC2, FC4
		1 260	1 360	nm	CW, FC8
		1 260	1 355	nm	CW, E10BLR, E10BLW
Laser wavelength (for four WDM channel uses with 3.125 GBd/each)	λ_{p_C0}	1 269,0	1 282,4	nm	CW, E10BLX4
	λ_{p_C1}	1 293,5	1 306,9	nm	CW, E10BLX4
	λ_{p_C2}	1 318,0	1 331,4	nm	CW, E10BLX4
	λ_{p_C3}	1 342,5	1 355,9	nm	CW. E10BLX4
Laser wavelength (for four WDM channel uses with 10.3125 GBd/each)	λ_{p_L0}	1 264,5	1 277,5	nm	CW, E40BLR4
	λ_{p_L1}	1284,5	1297,5	nm	CW, E40BLR4
	λ_{p_L2}	1 304,5	1 317,5	nm	CW, E40BLR4
	λ_{p_L3}	1 324,5	1 337,5	nm	CW, E40BLR4
Spectral width at -20 dB (for single channel uses)	$\Delta\lambda$		1	nm	CW
Spectral width at -20 dB (for four WDM channel uses)	$\Delta\lambda$		0,62	nm	CW, E10BLX4, E40BLR4
Threshold current	I_{th}	0,5	5,0	mA	T_0=20 °C
Threshold voltage	V_{th}	1,1	2,0	V	
Slope efficiency (at I_{op} in a TO package)	η	0,05	0,3	mW/mA	
Slope efficiency (at I_{op} in a TOSA or pigtailed package)	η	0,03	0,2	mW/mA	
Continuous laser output power (at I_{op} in a TO package)	P_O	-8,5	5	dBm	
Continuous laser output power (at I_{op} in a TOSA or pigtailed package)	P_O	-11,0	-3,0	dBm	FC2GB, E1B
		-9,5	-3,0	dBm	FC1GB
			-0,5	dBm	E10BLX4
		-8,4	-1	dBm	FC4GB
		-8,2	0,5	dBm	FC8GB, E10BLR, E10BLW
		-7	2,3	dBm	E40BLR4
Wavelength change over temperature	$\Delta\lambda/\Delta T$		0,1	nm/°C	

Parameter	Symbol	Value		Unit	Note
		Minimum	Maximum		
Rise and fall time (20% to 80%)	t_r/t_f		320/320	ps	FC1GB
			260/260	ps	E1B
			160/160	ps	FC2GB
			120/120	ps	E10BLX4
			90/90	ps	FC4GB
			50/50	ps	E10BLR, E10BLW, E40BLR4[a]
Capacitance (VCSEL chip)	C		5	pF	FC1GB V_{rev} = 0 V, 1 MHz
			5	pF	E1B V_{rev} = 0 V, 1 MHz
			2	pF	FC2GB V_{rev} = 0 V, 1 MHz
			2	pF	E10BLX4 V_{rev} = 0 V, 1 MHz
			1	pF	FC4GB V_{rev} = 0 V, 1 MHz
			0.5	pF	E10BLR, E10BLW, E40BLR4[a] V_{rev} = 0 V, 1 MHz
Relative intensity noise[b]	RIN		-117	dB/Hz	FC1GB, FC2GB
			-120	dB/Hz	FC4GB, E1B, E3B
			-128	dB/Hz	FC8GB E10BLR, E10BLW, E40BLR4
Side mode suppression ratio	SMSR	30		dB	at T_0 and $I_{op} > 2x\ I_{th}$
Series resistance temperature coefficient	$\Delta R_S/\Delta T$		-4 000	ppm/°C	[c]

[a] Informative only. Eye diagram masks and transmitter and dispersion penalty (TDP) should be considered more accurate guidelines.

[b] For 1 GHz bandwidth and optical power specified (typically a negative value)

[c] Series resistance of laser diodes decreases as temperature increases and thus its thermal dependent parameter is typically a negative value.

C.4 Diagrams

Refer to IEC 62148-15.

C.5 Testing

C.5.1 Characterization testing

The requirements of 5.1 shall be met.

C.5.2 Performance testing

Performance testing is undertaken when characterization testing is complete. A performance test plan is shown in Table C.4 and recommended performance test failure criteria in Table C.5.

Table C.4 – Performance test plan

No.	Test	Reference	Conditions	n[c]
1	Endurance test of:			
1.1	Package			
1.1.1	High temperature storage	IEC 60749-6	Temperature: T = Tstg max Duration: 1 000 h	11
1.1.2	Low temperature storage		Temperature: T = Tstg min Duration: > 2 000 h	11
1.1.3	Temperature cycling	IEC 60749-25	Temperature: T_A = Tstg min T_B = Tstg max Number of cycles = 100	11
1.1.4	Damp heat	IEC 61300-2-19	T= +40 °C ± 2 °C RH: 93 % ± 2 % 96 h duration	11
1.1.5	Temperature-humidity cycling	IEC 61300-2-48, method A	–40 °C ± 2 °C to +85 °C ± 2 °C 85 ± 5 % RH at the maximum temperature 1 hour minimum duration at extremes ≥ 1 °C/min rate of change 42 cycles	11
1.1.6	Fibre pull[a]	IEC 61300-2-4	5 N ± 0,5 N at 0,5 N/s 60 s duration for buffered fibres	11
1.2	Laser diode (submount)		Temperature: at least two test temperatures:	[b]
1.2.1			φ_e specified, constant power	[b]
1.2.2			Ts1=Ts m□x Ts2=< (Ts1-20 °C) Duration: > 5 000 h	
2	Mechanical shock	IEC 60749-10	1 500 G, 0,5 ms 5 times/axis	11
3	Vibration	IEC 60749-12	20G, 20 Hz – 2000 Hz, 4 min/cycle, 4cycle/axis	11
4	Rapid change of temperature	IEC 60749-11	ΔT=100 °C, Temperature change time < 10 s, dwell time> 2 min. temperature reach time < 5 min 15 cycles	11
5	ESD	IEC 60749-26	Human body model, positive and negative voltage pulses with a pulse interval of 300 ms	3
6	Internal moisture	IEC 60749-7	≤ 5 000 × 10^{-6} water vapor	11

[a] Applied to fibre pigtailed packages.

[b] These parameters can be determined from negotiation between manufacturer and user.

[c] Number of samples

Table C.5 – Recommended performance test failure criteria

Devices	Parameter	Failure criterion	Measurement condition
Laser diode	Operating current	50 % increase [a]	25 °C or life test temperature
	Slope efficiency	10 % change [a]	25 °C or life test temperature
	Forward voltage	10 % change [a]	25 °C or life test temperature
	Kinks in L/I curve	Kink-free within 1,2 × P_{nom} (linearity change ≤10 %) [a]	T_{op} min, 25 °C, T_{op} max
Laser package	Operating current	50 % increase [a]	25 °C or life test temperature
	Fibre or connector output power	10 % change [a]	Life test temperature I_{mon} set to initial value
	Kinks in L/I curve	Kink-free within 1,2 × P_{nom} (linearity change ≤10 %) [a]	T_{op} min, 25 °C, T_{op} max
	Tracking ratio (I_{mon} / P_{fibre})	< LSL ≥ USL	T_{op} min ~ T_{op} max At rated power level
[a] Change of pre- and post-test values in the DS			

Annex D
(normative)

Specifications for single-mode 1 310-nm VCSEL device with a monitor photodiode (Case d)

D.1 Absolute limiting ratings

Absolute limiting (maximum and/or minimum) ratings imply that no catastrophic damage will occur if the product is subject to these ratings for short periods, provided each limiting parameter is in isolation and all other parameters have values within the normal performance parameters. It should not be assumed that limiting value of more than one parameter can be applied at any one time. Absolute limiting ratings are shown in Table D.1.

Table D.1 – Absolute limiting ratings

Parameter	Symbol	Value		Unit
		Minimum	Maximum	
Storage temperature	T_{stg}	−40	+85	°C
Soldering condition	T_{sol}		260 °C, 10 sec	
Laser diode				
Reverse bias voltage	V_{RB}		5	V
Continuous forward current	I_{FLD}		12	mA
Monitor photodiode				
Maximum reverse voltage	V_{mR}		5,0	V
Maximum forward current	I_{mF}			mA

D.2 Operating environment

The requirements of 4.2 shall be met.

D.3 Functional specification

Tables D.2 and D.3 contain the operating conditions for functional specifications and the functional specifications of single-mode 1 310 nm VCSEL devices of signalling speeds of 1,0625 GBd, 1,25 GBd, 3,125 GBd, 4,25 GBd, 8,5 GBd and 10 GBd with a monitor photodiode at the operating conditions.

Table D.2 – Operating conditions for functional specification

Parameter	Symbol	Value		Unit	Note
		Minimum	Maximum		
Operating forward current	I_{op}		12	mA	
Operating forward bias voltage	V_f		2,5	V	

Table D.3 – Functional specification

Parameter	Symbol	Value		Unit	Note
		Minimum	Maximum		
Laser diode					
Laser wavelength (for single channel uses)	λ_p	1 270	1 355	nm	CW, E1B
		1 260	1 370	nm	CW, FC1, FC2, FC4
		1 260	1 360	nm	CW, FC8
		1 260	1 355	nm	CW, E10BLR, E10BLW
Laser wavelength (for four WDM channel uses with 3,125 GBd/each)	λ_{p_C0}	1 269,0	1 282,4	nm	CW, E10BLX4
	λ_{p_C1}	1 293,5	1 306,9	nm	CW, E10BLX4
	λ_{p_C2}	1 318,0	1 331,4	nm	CW, E10BLX4
	λ_{p_C3}	1 342,5	1 355,9	nm	CW. E10BLX4
Laser wavelength (for four WDM channel uses with 10,3125 GBd/each)	λ_{p_L0}	1 264,5	1 277,5	nm	CW, E40BLR4
	λ_{p_L1}	1 284,5	1 297,5	nm	CW, E40BLR4
	λ_{p_L2}	1 304,5	1 317,5	nm	CW, E40BLR4
	λ_{p_L3}	1 324,5	1 337,5	nm	CW, E40BLR4
Spectral width at -20 dB (for single channel uses)	$\Delta\lambda$		1	nm	CW
Spectral width at -20 dB (for four WDM channel uses)	$\Delta\lambda$		0,62	nm	CW, E10BLX4, E40BLR4
Threshold current	I_{th}	0,5	5,0	mA	T_0=20 °C
Threshold voltage	V_{th}	1,1	2,0	V	
Slope efficiency (at I_{op} in a TO package)	η	0,05	0,3	mW/mA	
Slope efficiency (at I_{op} in a TOSA or pigtailed package)	η	0,03	0,2	mW/mA	
Continuous laser output power (at I_{op} in a TO package)	P_O	-8,5	5	dBm	
Continuous laser output power (at I_{op} in a TOSA or pigtailed package)	P_O	-11,0	-3,0	dBm	FC2GB, E1B
		-9,5	-3,0	dBm	FC1GB
			-0,5	dBm	E10BLX4
		-8,4	-1	dBm	FC4GB
		-8,2	0,5	dBm	FC8GB, E10BLR, E10BLW
		-7	2,3	dBm	E40BLR4
Wavelength change over temperature	$\Delta\lambda/\Delta T$		0,1	nm/°C	

Parameter	Symbol	Value		Unit	Note
		Minimum	Maximum		
Rise and fall time (20 % – 80 %)	t_r/t_f		320/320	ps	FC1GB
			260/260	ps	E1B
			160/160	ps	FC2GB
			120/120	ps	E10BLX4
			90/90	ps	FC4GB
			50/50	ps	E10BLR, E10BLW, E40BLR4[a]
Capacitance (VCSEL chip)	C		5	pF	FC1GB V_{rev} = 0 V, 1 MHz
			5	pF	E1B V_{rev} = 0 V, 1 MHz
			2	pF	FC2GB V_{rev} = 0 V, 1 MHz
			2	pF	E10BLX4 V_{rev} = 0 V, 1 MHz
			1	pF	FC4GB V_{rev} = 0 V, 1 MHz
			0,5	pF	E10BLR, E10BLW, E40BLR4[a] V_{rev} = 0 V, 1 MHz
Relative intensity noise[b]	RIN		-117	dB/Hz	FC1GB, FC2GB
			-120	dB/Hz	FC4GB, E1B, E3B
			-128	dB/Hz	FC8GB E10BLR, E10BLW, E40BLR4
Side mode suppression ratio	SMSR	30		dB	at T_0 and I_{op} > 2x I_{th}
Series resistance temperature coefficient	$\Delta R_S/\Delta T$		-4 000	ppm/°C	[c]
Monitor photodiode					[d]
Monitor current	I_m	0,1		mA	
Dark current	I_{mR0}		100	nA	P_{op} = 0 mW, V_{rev} = 3 V
Capacitance[e]	C_{tot}		100	pF	V_{rev} = 0 V, 1 MHz

a	Informative only. Eye diagram masks and transmitter and dispersion penalty (TDP) should be considered more accurate guidelines.
b	For 1 GHz bandwidth and optical power specified (typically a negative value)
c	Series resistance of laser diodes decreases as temperature increases and thus its thermal dependent parameter is typically a negative value.
d	This part applies only to the VCSELs with monitor photodiode at a room temperature condition of 25 °C.
e	This indicates total capacitance between the anode and cathode terminals of the monitor photodiode subassembly.

D.4 Diagrams

Refer to IEC 62148-15.

D.5 Testing

D.5.1 Characterization testing

The requirements of 5.1 shall be met.

D.5.2 Performance testing

Performance testing is undertaken when characterization testing is complete. A performance test plan is shown in Table D.4 and recommended performance test failure criteria in Table D.5.

Table D.4 – Performance test plan

No.	Test	Reference	Conditions	n[c]
1	Endurance test of:			
1.1	Package			
1.1.1	High temperature storage	IEC 60749-6	Temperature: T =$T_{stg\ max}$ Duration: 1 000 h	11
1.1.2	Low temperature storage		Temperature: T =$T_{stg\ min}$ Duration: > 2 000 h	11
1.1.3	Temperature cycling	IEC 60749-25	Temperature: T_A =$T_{stg\ min}$ T_B =$T_{stg\ max}$ Number of cycles = 100	11
1.1.4	Damp heat	IEC 61300-2-19	T= +40 °C ± 2 °C RH: 93 % ± 2 % 96 h duration	11
1.1.5	Temperature-humidity cycling	IEC 61300-2-48, method A	–40 °C ± 2 °C to +85 °C ± 2 °C 85 ± 5 % RH at the maximum temperature 1 hour minimum duration at extremes ≥1 °C/min rate of change 42 cycles	11
1.1.6	Fibre pull[a]	IEC 61300-2-4	5 N ± 0,5 N at 0,5 N/s 60 s duration for buffered fibres	11
1.2	Laser diode (submount)		Temperature: at least two test temperatures: φ_e specified, constant power	[b] [b]
12.1			T_{s1}=T_s max	
1.2.2			T_{s2}=< (T_{s1}-20 °C) Duration: >5 000 h	
1.3	Photodiode (in representative package)		Temperature: at least two test temperatures: V_r or I_r specified	[b] [b]
1.3.1			T_{s1}= 125 °C min.	11
1.3.2			T_{s2}=< (T_{s1}-30°C) Duration: >1 000h	
2	Mechanical shock	IEC 60749-10	1 500G, 0,5 ms 5 times/axis	11
3	Vibration	IEC 60749-12	20 G, 20 Hz – 2 000 Hz, 4 min./cycle, 4cycle/axis	11
4	Rapid change of temperature	IEC 60749-11	ΔT=100 °C, Temperature change time < 10 s, dwell time > 2 min. temperature reach time < 5 min 15 cyles	11
5	ESD	IEC 60749-26	Human body model, positive and negative voltage pulses with a pulse interval of 300 ms	3
6	Internal moisture	IEC 60749-7	≤ 5 000 ×10^{-6} water vapor	11

[a] Applied to fibre pigtailed packages.

[b] These parameters can be determined from negotiation between manufacturer and user.

[c] Number of samples.

Table D.5 – Recommended performance test failure criteria

Devices	Parameter	Failure criterion	Measurement condition
Laser diode	Operating current	50 % increase [a]	25 °C or life test temperature
	Slope efficiency	10 % change [a]	25 °C or life test temperature
	Forward voltage	10 % change [a]	25 °C or life test temperature
	Kinks in L/I curve	Kink-free within 1,2 × P_{nom} (linearity change ≤10 %) [a]	T_{op} min, 25 °C, T_{op} max
Photodiode	Dark current	USL or 10 nA increase	25 °C
Laser package	Operating current	50 % increase [a] *	25 °C or life test temperature
	Fibre or connector output power	10 % change [a]	Life test temperature Imon set to initial value
	Kinks in L/I curve	Kink-free within 1,2 × P_{nom} (linearity change ≤10 %) [a]	T_{op} min, 25 °C, T_{op} max
	Tracking ratio (I_{mon} / P_{fibre})	< LSL ≥ USL	T_{op} min ~ T_{op} max At rated power level
	Photodiode dark current	USL or 10 nA increase [a]	25 °C

[a] Change of pre- and post-test values in the DS.

Bibliography

IEC 60191 (all parts), *Mechanical standardization of semiconductor devices*

IEC 60747-5-1, *Discrete semiconductor devices and integrated circuits – Part 5-1: Optoelectronic devices – General*

IEC 60793-2, *Optical fibre – Part 2: Product specifications*

IEC 60874 (all parts), *Connectors for optical fibres and cables*

IEC 61280-1-3, *Fibre optic communication subsystem test procedures – Part 1-3: General communication subsystems – Central wavelength and spectral width measurement*

IEC 62007-1, *Semiconductor optoelectronic devices for fibre optic system applications – Part 1: Specification template for essential ratings and characteristics*

IEC 62007-2, *Semiconductor optoelectronic devices for fibre optic system applications – Part 2: Measuring methods*

IEC 62148-1, *Fibre optic active components and devices – Package and interface standards – Part 1: General and guidance*

IEC 62149-1, *Fibre optic active components and devices – Performance Standards Part 1: General and guidance*

IEC 62149-4, *Fibre optic active components and devices – Performance standards – Part 4: 1 300 nm fibre optic transceivers for Gigabit Ethernet application*

IEEE 802.3-2002, *Local and metropolitan area networks – Carrier Sense Multiple Access with Collision Detection (CSMA/CD) access method and Physical layer specifications:* Clause 38. Physical Medium Dependent (PMD) sublayer and baseband medium, type 1000BASE-LX (Long Wavelength Laser) and 1000BASE-SX (Short Wavelength Laser), July 1988

IEEE 802.3-2005, *Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) access method and physical layer specifications, SECTION FOUR: This section includes Clause 44 through Clause 54 and Annex 44A through Annex 50A*

IEEE P802.3ba-2009, *Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements, Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications, Amendment: Media Access Control Parameters, Physical Layers and Management Parameters for 40 Gb/s and 100 Gb/s Operation*

INCITS 450-2009 *FIBRE CHANNEL-Physical Interface-4 (FC-PI-4)*

INCITS/Project 2118-D/Rev1.00 – 2008.09.25, *FIBRE CHANNEL Physical Interface-5 (FC-PI-5)*

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