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General rules of laser diode modules for optical fiber amplifier

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Foreword

This translation has been made based on the original Japanese Industrial Standard established by the Minister of Economy, Trade and Industry through deliberations at the Japanese Industrial Standards Committee in accordance with the Industrial Standardization Law.

This revision has been made based on **IEC 62007-1 : 1999 *Semiconductor optoelectronic devices for fibre optic system applications—Part 1 : Essential ratings and characteristics*** for the purpose of making it easier to compare this Standard with International Standard; to prepare Japanese Industrial Standard conforming with International Standard; and to propose a draft of International Standard which is based on Japanese Industrial Standard.

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General rules of laser diode modules for optical fiber amplifier

Introduction This Japanese Industrial Standard has been prepared based on *section 9 Laser diode modules for pumping an optical fibre amplifier* of the first edition of **IEC 62007-1 Semiconductor optoelectronic devices for fibre optic system applications—Part 1 : Essential ratings and characteristics** published in 1999 with some modifications of the technical contents of the original International Standard.

The portions given dotted underlines are the matters in which the contents of the original International Standard have been modified. A list of modifications with the explanation is given in annex 5 (informative).

1 Scope This Standard specifies the general and common matters of laser diode modules for optical fiber amplifier (hereafter referred to as “laser diode modules”) used as a light source including terms, classification, maximum ratings, performance, etc.

Remarks 1 The laser diode modules mentioned above consist of the connecting parts of semiconductor laser diode and optical fiber and, when appropriate, temperature sensor, thermoelectronic cooling element and monitor photo diode which are built-in.

2 The International Standard corresponding to this Standard is as follows.

In addition, symbols which denote the degree of correspondence in the contents between the relevant International Standard and JIS are IDT (identical), MOD (modified), and NEQ (not equivalent) according to **ISO/IEC Guide 21**.

IEC 62007-1 : 1999 *Semiconductor optoelectronic devices for fibre optic system applications—Part 1 : Essential ratings and characteristics* (MOD)

2 Normative references The following standards contain provisions which, through reference in this text, constitute provisions of this Standard. The most recent editions of the standard (including amendments) indicated below shall be applied.

JIS C 0025 *Basic environmental testing procedures Part 2 : Tests Test N : Change of temperature*

JIS C 5947 *Measuring methods of laser diode modules for optical fiber amplifier*

JIS C 6802 *Safety of laser products*

JIS C 60068-2-1 *Environmental testing procedures Part 2 : Tests, Tests A : Cold*

NOTE : **IEC 60068-2-1** : 1990 *Environmental testing—Part 2 : Tests. Tests A : Cold* is identical with the said standard.

JIS C 60068-2-2 *Basic environmental testing procedures Part 2 : Tests, Test B : Dry heat*

NOTE : **IEC 60068-2-2** : 1974 *Environmental testing—Part 2 : Tests. Tests B : Dry heat* is identical with the said standard.

JIS C 60068-2-3 *Basic environmental testing procedures Part 2 : Tests, Test Ca : Damp heat, steady state*

NOTE : **IEC 60068-2-3** : 1969 *Environmental testing—Part 2 : Tests. Tests Ca : Damp Heat, steady state* is identical with the said standard.

JIS C 60068-2-6 *Environmental testing Part 2 : Tests—Test Fc : Vibration (sinusoidal)*

NOTE : **IEC 60068-2-6** : 1995 *Environmental testing—Part 2 : Tests—Test Fc : Vibration (sinusoidal)* is identical with the said standard.

JIS C 60068-2-7 *Basic environmental testing procedures Part 2 : Tests—Test Ga and guidance : Acceleration, steady state*

NOTE : **IEC 60068-2-7** : 1975 *Environmental testing. Part 2 : Tests. Test Ga : Acceleration, steady state* is identical with the said standard.

JIS C 60068-2-11 *Basic environmental testing procedures Part 2 : Tests—Test Ka : Salt mist*

NOTE : **IEC 60068-2-11** : 1981 *Environmental testing—Part 2 : Tests. Test Ka : Salt mist* is identical with the said standard.

JIS C 60068-2-17 *Basic environmental testing procedures—Part 2 : Tests—Test Q : Sealing*

NOTE : **IEC 60068-2-17** : 1994 *Basic environmental testing procedures—Part 2 : Tests—Test Q : Sealing* is identical with the said standard.

JIS C 60068-2-20 *Basic environmental testing procedures Part 2 : Tests. Test T : Soldering*

NOTE : **IEC 60068-2-20** : 1979 [including Amendment 1 (1986) and Amendment 2 (1987)] *Environmental testing. Part 2 : Tests. Test T : Soldering* is identical with the said standard.

JIS C 60068-2-21 *Environmental testing—Part 2-21 : Tests—Test U : Robustness of termination and integral mounting devices*

NOTE : **IEC 60068-2-21** : 1999 *Environmental testing—Part 2-21 : Tests—Test U : Robustness of terminations and integral mounting devices* is equivalent to the said standard.

JIS C 60068-2-27 *Basic environmental testing procedures Part 2 : Tests, Test Ea and guidance : Shock*

NOTE : **IEC 60068-2-27** : 1987 *Environmental testing. Part 2 : Tests. Test Ea and guidance : Shock* is identical with the said standard.

JIS C 60068-2-32 *Environmental testing Part 2 : Tests. Test Ed : Free fall*

NOTE : **IEC 60068-2-32** : 1975 [including Amendment 1 (1982) and Amendment 2 (1990)] *Environmental testing. Part 2 : Tests. Test Ed : Free fall* is identical with the said standard.

JIS C 60068-2-38 *Basic environmental testing procedures Part 2 : Tests Test Z/AD : Composite temperature/humidity cyclic test*

NOTE : **IEC 60068-2-38** : 1984 *Environmental testing—Part 2 : Tests. Test Z/AD : Composite temperature/humidity cyclic test* is identical with the said standard.

JIS Z 8202-1 *Quantities and units—Part 1 : Space and time*

JIS Z 8202-2 *Quantities and units—Part 2 : Periodic and related phenomena*

JIS Z 8202-3 *Quantities and units—Part 3 : Mechanics*

JIS Z 8202-4 *Quantities and units—Part 4 : Heat*

JIS Z 8202-5 *Quantities and units—Part 5 : Electricity and magnetism*

JIS Z 8202-6 *Quantities and units—Part 6 : Light and related electromagnetic radiations*

JIS Z 8203 *SI units and recommendations for the use of their multiples and of certain other units*

3 Definitions For the purpose of this Standard, the following definitions apply :

- a) **absolute maximum ratings** the limit value not allowed to be exceeded even instantaneously
Any one of the standard values is not allowed to be exceeded.
- b) **storage temperature (T_{stg})** permissible range of ambient temperature when not applying power source voltage and input signal
- c) **ambient temperature (T_{a})** the temperature of the environment in which the laser diode modules are placed
- d) **operating temperature (T_{op})** the ambient temperature at which the operation at a specified voltage or current is ensured
It is also called operating ambient temperature ($T_{\text{op (a)}}$), operating case temperature ($T_{\text{op (c)}}$) or operating submount temperature ($T_{\text{op (sub)}}$).
- e) **threshold current (I_{th})** the value of electric current which begins the oscillation of laser by stimulated emission
- f) **radiant power (P_{r})** optical output taken from the end of the optical fiber
- g) **operating current (I_{op})** forward current when obtaining a specified optical output
- h) **operating voltage (V_{op})** forward voltage when obtaining a specified optical output
- i) **differential efficiency (η_{d})** with respect to the optical fiber end output at operating current and the optical fiber end output at threshold current or current higher than the threshold current and sufficiently lower than the operating current, the value obtained by dividing the difference of the above two optical outputs by the difference of the currents

- j) **longitudinal mode** the respective emission spectrum when the spectrums of emission mode transmitting along the optical axis exists discretely
In particular, when emitting with one longitudinal mode, it is called single longitudinal mode emission.
- k) **mode spacing** difference of wavelength between the adjacent longitudinal modes
- l) **number of longitudinal modes** total number of longitudinal modes
Usually, a certain ratio is determined to the peak and only the modes of the strength exceeding it are enumerated.
- m) **peak emission wavelength (λ_p)** wavelength at which the laser emission becomes the strongest
- n) **central emission wavelength (λ_c)** wavelength at the centre of the emitted spectrum

It shall be obtained by any one of the following measuring methods :

- 1) Envelope method : When connecting the peaks of respective longitudinal modes with an envelope curve and when the envelope cuts at a specified value for the maximum peak of the longitudinal mode, the average wavelength of the wavelength on the longest wavelength side and the wavelength of the shortest wavelength side is taken.
- 2) N-dB method : the average wavelength of the longitudinal mode emission wavelength on the longest wavelength side and the longitudinal mode emission wavelength on the shortest wavelength out of the wavelengths of the specified value with respect to the peak in the wavelength band on the both sides of peak emission wavelength.
- 3) RMS method : The wavelength obtained from the longitudinal mode optical level of n th turn (A_n) and its emission wavelength (λ_n) using

$$\lambda_c = \sum (A_n \times \lambda_n) / \sum A_n$$

- o) **spectral radiation bandwidth ($\Delta\lambda_w$)** extension of emission spectrum

The extension width of the emission spectrum which makes 50 % of the maximum peak (full width) is called, in particular, spectrum width at half value ($\Delta\lambda$). The spectrum width at half value is called FWHM (full width at half maximum) as well. It is obtained by any one of the following methods :

- 1) Envelope method : When connecting the peaks of respective longitudinal modes with an envelope curve and when the envelope cuts at a specified value for the maximum peak of the longitudinal mode, the difference between the wavelength on the longest wavelength side and the one on the shortest wavelength side.
- 2) N-dB method : The width of the spectrum at the time of cutting at a specified value for the maximum peak of the longitudinal mode (in the case of single mode emission), the difference between the wavelength on the longest wavelength side and the one on the shortest wavelength side out of the longitudinal modes emitted at a value not less than specified for the maximum peak of the longitudinal mode (in the case of multi-mode emission) or the width of the expansion of the spectral line which becomes the specified value for the maximum peak of the emitting longitudinal mode (in the case of obtaining the spectral width at half value, the value of 50 % of the maximum peak) (case of single mode emission).

- 3) **RMS method** : the width at the wavelength obtained from the optical level of longitudinal mode at n th turn (A_n) and its emission wavelength (λ_n) using

$$\Delta\lambda_w = K \times (\sum (A_n \times (\lambda_n - \lambda_c)^2) / \sum A_n)^{1/2}$$

K is a constant and is required to be selected (1, 2, 2.35, 3) and clearly shown (if 2.35 is selected, it is equivalent to the spectral width at half value at the time of considering the shape of the spectrum as Gaussian distribution).

- p) **spectral shift with current ($\Delta\lambda_c$)** the coefficient that the emission wavelength changes when changing the operating current
- q) **spectral shift with radiant power ($\Delta\lambda_p$)** the coefficient that the emission wavelength changes when changing the radiant power
- r) **spectral shift with temperature ($\Delta\lambda_T$)** the coefficient that the emission wavelength changes when changing the ambient temperature or operating temperature
- s) **relative intensity noise (RIN)** ratio of the light intensity noise per unit frequency to the average optical output
Practically, as the fluctuation of light is measured and calculated using light intercepting element of photodiode or amplifier, the value obtained as a result that the shot noise of light intercepting element and the thermal noise of amplifier are removed from the noise detected at a specified frequency and then divided by the average output of semi-conductor laser (in general, detected by the photoelectric current of photo detector) and the measured frequency band width corresponds to it.
- t) **kink** In a forward current-radiant power characteristic curve at higher forward current than the threshold current, the part at which the deviation from the maximum value of its primary differential curve becomes a specified value
- u) **kink free fiber radiant power (P_k)** the maximum value of the radiant power in which kink is not generated
- v) **monitor current (I_m)** the value of output current of photodiode for monitoring
- w) **dark current of photodiode (I_d)** the value of the current flowing into the monitoring photodiode when the laser diode module is not made radiant
- x) **photodiode capacitance (C_t)** the capacitance between the terminals of the monitoring photodiode
- y) **tracking error (E_{r1} , E_{r2} or E_r)** fluctuation of optical output which is generated when changing the temperature within a specified range in an operating state of APC (automatic power control) using the monitoring photodiode built-in the laser diode module. The following two methods are used :
 - 1) When taking the value of optical output at a reference operating temperature (usually 25 °C) in an APC operating state as a reference value and changing the temperature within a specified range of operating temperature take the ratio of the reference value to the maximum fluctuation width in the direction of the decrease of optical output as (E_{r1}) and the ratio of reference value to the maximum fluctuation width in the direction of the increase of optical output as (E_{r2}).

2) Take the value of the optical output at a reference operating temperature in an APC operating state as the reference value and take the maximum value of its ratio to the optical output at a specific operating temperature in the operating temperature range as (E_r).

z) **resistance (R)** resistance of the built-in thermistor for detecting temperature

aa) **thermistor B constant** B in the following formula which indicates the resistance of thermistor-temperature characteristic
The constant determined according to materials.

$$R_1 = R_2 \times \exp (B ((1/T_1) - (1/T_2)))$$

where R_1 and R_2 mean the resistance of thermistor at the temperature of T_1 and T_2 respectively.

ab) **supply voltage (V_{sup})** supply voltage of the built-in thermistor for detecting temperature

ac) **peltier current (I_{PE})** the value of electric current of the built-in peltier cooler for controlling temperature

ad) **peltier voltage (V_{PE})** the value of voltage of the built-in peltier cooler for controlling temperature

ae) **minimum bend radius of pigtail (r_{min})** of the laser diode modules of pigtail shape, the minimum bend radius of the allowed pigtail optical fiber

af) **tensile force on fiber (F)** of the laser diode modules of pigtail shape, the maximum tensile strength of the allowed pigtail optical fiber

4 Individual specification The absolute maximum rating, performance, external form, etc. of respective laser diode modules shall be specified in individual specifications in accordance with the requirements of this Standard. The form of individual specification is recommended in Annex 1.

5 Unit symbols The unit symbols specified in **JIS Z 8202-1**, **JIS Z 8202-2**, **JIS Z 8202-3**, **JIS Z 8202-4**, **JIS Z 8202-5**, **JIS Z 8202-6** and **JIS Z 8203** apply to this Standard.

6 Classification The laser diode modules are classified as specified in table 1.

Table 1 Classification of laser diode modules

Classification item		Classification
Major item	Minor item	
Crystal material		Aluminium-gallium-arsenic/Gallium-arsenic (AlGaAs/GaAs) Indium-gallium-arsenic-phosphorus/Indium-phosphorus (InGaAsP/InP), etc.
Wavelength band		For 980 nm band, for 1 300 nm band, for 1 400 nm band, etc.
Element structure	Structure of junction	Double heterojunction (DH), separation-containment heterojunction, quantum well structure, etc.
	Stripe structure	Gain guided wave type, refraction index guided wave type, etc.
	Feedback structure	Fabry-Perot type, distribution feedback type (DFB), distribution Bragg reflection type (DBR), etc.
Optical fiber	Classification	Multi-mode optical fiber, single-mode optical fiber, polarization plane storage optical fiber, etc.
	Wavelength stabilization structure	Fiber grating, etc.
Package structure	Optical output structure	Pigtail type, optical connector type, etc.
	Terminal structure	Cylinder type, dual in-line package type, butterfly type, etc.
	Temperature control structure	Without temperature control, electronic cooling element built-in type, thermistor built-in type, etc.
	Optical isolating structure	Without isolator or isolator built-in type
Use		Use for optical fiber amplifier
Others		Thermal sensor, etc.

7 Maximum rating The maximum rating of laser diode modules shall be absolute maximum rating. Table 2 gives the specified items for the absolute maximum rating. For the specified values for storage temperature or operating temperature, the values in table 3 and table 4 are recommended respectively. Annex 1 table 1 is recommended as a specified form for absolute maximum rating in individual specification.

**Table 2 Specified items for absolute maximum rating
(unless otherwise specified, ambient temperature, case temperature or submount temperature is 25 °C)**

Item		Sym- bol	Condition	Value of absolute maximum rating	Unit
Temperature	Storage temperature	T_{stg}		— to + —	°C
	Operating temperature	T_{op}		— to + —	°C
	Soldering temperature	T_{sld}	Soldering time is specified	—	°C
Laser	Voltage	DC reverse voltage	V_{rl}	—	V
	Current	DC forward current	I_{fl}	—	mA
	Optical output	Radiant power	P_f	—	mW
Monitor photodiode	DC reverse voltage ⁽¹⁾	V_{rd}		—	V
	Forward current ⁽¹⁾	I_{fd}		—	mA
Peltier cooler	Peltier voltage ⁽²⁾	V_{PE}		—	V
	Peltier current ⁽²⁾	I_{PE}		—	A
Thermistor	Supply voltage ⁽³⁾	V_{sup}		—	V
Optical fiber	Minimum bend radius of pigtail	r_{min}		—	mm
	Tensile force on fiber	F		—	N

Notes ⁽¹⁾ Applicable to the case where monitor photodiode is built-in.

⁽²⁾ Peltier voltage and Peltier current are applicable to the case where Peltier cooler for temperature control is built-in.

⁽³⁾ Applicable to the case where thermistor is built-in.

Remarks : The part underlined in the column of absolute maximum rating is usually recorded.

Table 3 Storage temperature (T_{stg})

Unit : °C

Lower limit	0	-20	-40	-55	-65
Upper limit	60	70	85	100	125

Table 4 Operating temperature (T_{op} or T_a)

Unit : °C

Lower limit	0	-10	-20	-30	-40	
Upper limit	40	50	60	70	85	100