The following glossary of terms is the means by which Lasertron defines, measures, and employs certain parameters and specifications outlined in this Product Guide.

Glossary

Absolute Maximum Ratings Absolute maximum ratings represent the minimum *damage thresholds*, and are therefore the "safe" *short-term* exposure limits. Absolute maximum ratings are intended to be used in designing "system limits" which may be reached during assembly, storage and operation. The "system limits" should take into consideration the extreme conditions arising from normal processes, as well as abnormal occurrences arising from failures of assembly equipment, air conditioning systems, power supplies, drive circuits, etc.

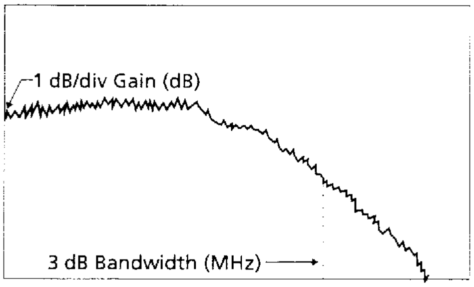
Instantaneous exposure to conditions that exceed the absolute maximum ratings, or prolonged exposure to conditions at or near the absolute maximum ratings, will have a negative effect on reliability, and voids the standard warranty.

Auto Power Control (APC) The feedback loop of a laser, utilizing a monitor photo detector, which controls a laser's optical output to a fixed level.

Bandwidth Measurement The maximum modulation frequency where the gain drops 3 dB from the gain at DC. Refer to Figure 1.

Figure 1

Bandwidth Measurement



Center Wavelength (nm) The wavelength which is midway between the wavelengths at which the source emission is 50% of its maximum value.

Chirping A rapid change with time of the emission wavelength of an optical source. Chirping is most often observed during pulsed operation of a source.

Cutoff Wavelength A single-mode fiber supports only one mode (the fundamental mode), if the wavelength is longer than the cutoff wavelength. Below this wavelength more modes may be guided.

dBm dBm is a unit of measurement for power (P_o), expressed as dB relative to 1 mW:

$$\text{dBm} = 10 \times \text{LOG}_{10}(P_o/1\ \text{mW})$$

From a power value in dBm, the power in mW is:

$$P_o = 10\text{^^}(\text{dB}/10)$$

dBm values can be positive (P_o>1 mW), negative (P_o< 1mW), or zero (P_o =1 mW).

For power values in dBm, the following approximations can be made:

- Adding 3 dBm doubles the power
- Subtracting 3 dBm halves the power

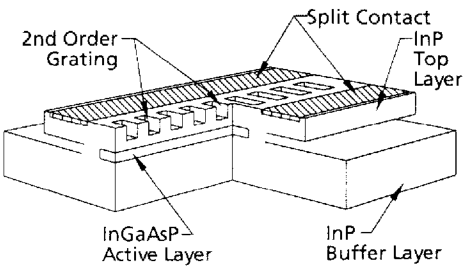
Equivalent values:

4 dBm ~ 2.5 mW	0 dBm = 1 mW	-10 dBm = 100 µW
3 dBm ~ 2 mW	-3 dBm ~ 500 µW	-20 dBm = 10 µW
2 dBm ~ 1.6 mW	-6 dBm ~ 250 µW	-30 dBm = 1 µW
1 dBm ~ 1.3 mW	-9 dBm ~ 125 µW	-40 dBm = 100 nW

Distributed Feedback Laser (DFB) The optical spectra of "DFB" lasers include a strongly dominant single emission line. These spectra represent single longitudinal mode operation. DFB laser diodes incorporate a grating close to the active layer which suppresses the optical gain at all but a single wavelength by 30 dB or more. Refer to Figure 2. The very narrow spectra are ideal for very high-speed or very long-distance applications which typically require low spectral dispersion.

Figure 2

DFB Laser



Drive Current For a laser, this is the total current at the rated output power, or simply the sum of the threshold current and the modulation current. For an LED, the drive current is generally specified as 150 mA.

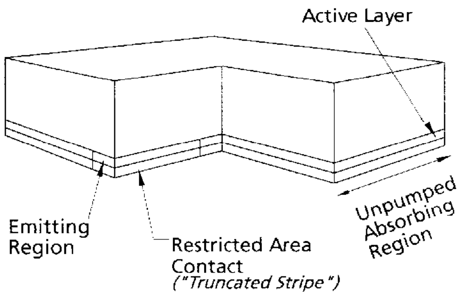
EDFA Erbium-doped fiber amplifier.

Electro-Static Discharge (ESD) High voltage electro-static charges may accumulate on ungrounded equipment and/or people. When discharged through a laser diode chip, an electro-static charge may cause a very large current and/or optical power spikes, which may cause instantaneous and/or hidden damage to the chip junction and facets. Damage from ESD reduces the lifetime of the laser chip.

Extinction Ratio A ratio of the optical output power in the "on" state (rated output power) to the optical output power in the "off" state (threshold power).

Fabry-Perot Laser The optical spectra of "F-P" lasers include distinct emission lines at several closely spaced wavelengths. These spectra represent multiple longitudinal mode operation. The number of emission lines is determined by the optical gain profile of the laser. The separation of the emission lines is determined by the length of the laser cavity.

Figure 3
Light Emitting Diode



Forward Voltage at Rated Power (V) The voltage produced by the flow of current through an optical source when biased for rated output.

Laser Chip Aging Effects The aging effects of all laser diode chips include gradual increase in threshold current and gradual decrease in efficiency. These effects can be offset by increasing the bias current to compensate for the change in threshold (ΔI_{th}), and increasing the modulation current (ΔI_m) to compensate for the change in efficiency.

Aging effects saturate exponentially. Burn-in allows delivery of lasers that are almost fully saturated.

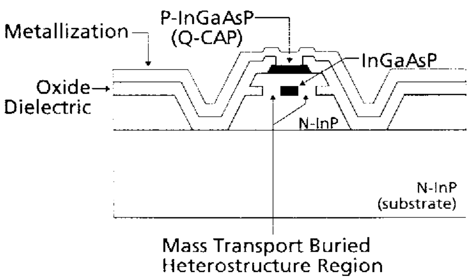
End-of-life (EOL) for a laser is usually defined as the time at which ΔI_{th} and /or ΔI_m have reached a set value, or a set percentage of their beginning-of-life (BOL) values. Lasertron defines EOL for lasers as the time at which ΔI_{th} reaches 30 mA.

Laser Threshold Laser diode threshold is characterized by a sharp bend in the light vs. current ("L-I" or "P-I") curve.

- Below threshold, the efficiency is low and the output is "incoherent" (i.e. like an LED)
- Above threshold, the efficiency is very high and the output is "coherent" (i.e — the device is "lasing").

Several methods may be used to precisely locate the threshold point. Lasertron extrapolates the linear portions of the L-I curve above and below the bend. The intersection of the two extrapolated lines is defined as the threshold point. Refer to Figure 10.

Figure 4
MTBH Laser

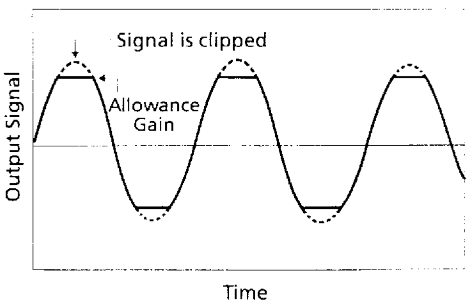


Light Emitting Diode (LED) A pn-junction semiconductor device that emits incoherent optical radiation when biased in the forward direction. Figure 3 outlines the basic chip structure used in the edge-emitting LED sold by Lasertron.

Longitudinal Mode Also known as *Axial Mode*. One of the oscillating frequencies of a laser determined by the requirement that the round-trip cavity length must coincide with an integer number of half wavelengths.

Mass Transport Buried Heterostructure Laser (MTBH) A strongly index-guided laser which employs a buried heterostructure. These lasers have an active region which is bound by low-index epitaxially grown layers both along and normal to the laser cavity. The lateral index difference is 0.2 for a strongly index-guided buried heterostructure laser. Refer to Figure 4.

Figure 5
Max Input Measurement Technique



Max Input Measurement Technique The Max Input of a pinFET is determined when the output signal voltage begins to clip. The formula for calculating the Pmax of the pinFET is described below. Refer to Figure 5.

$$\text{Max Optical Input} = 10 \text{ Log} \frac{I_{det}}{R}$$

I_{det} = Detector current (mA) when the output is at the clipping point
R = Responsivity (A/W)

Mean Wavelength (nm) The weighted average of all spectral modes that are at least 2% of the peak mode. Defined by:

$$\frac{\Sigma \lambda_n \cdot P_n}{\Sigma P_n}$$

λ_n = nth Wavelength
P_n = Power at nth Wavelength

Modulation Current: I_{mod} (mA) Also see **Slope Efficiency.** The amount of current required to achieve rated output power referenced to the threshold current (I_{th}). Modulation current can be calculated by dividing the rated output power by the slope efficiency. Refer to Figure 6.

$$I_{mod} = \frac{P_o}{\text{Slope Eff.}}$$

$$I_{mod} = I_{tot} - I_{th}$$

P_o = Rated power at 25°C (mW)
I_{tot} = Current at rated power (mA)
I_{th} = Threshold current (mA)

Monitor Detector Also known as the *Back Facet Detector*. The optical detector used to capture the light which exits the back facet of the laser source. It is typically used together with external control circuitry to maintain the laser at its proper operating output power.

Monitor Detector Responsivity (µA/µW) The photocurrent generated per unit optical power. The responsivity is a linear function of the optical power measured at a constant wavelength. Defined by:

$$R = \frac{I_p}{P_o}$$

R = Responsivity
I_p = Generated photocurrent
P_o = Fiber-coupled optical power

Monitor Detector Dark Current (nA) The output current of the detector when it is biased at -5 V and the source is completely off.

Multimode Fiber An optical fiber that will allow more than one spatial mode to propagate. The number of modes is dependent on the core diameter, the numerical aperture (acceptance angle), refractive index profile, and the wavelength.

Optical Rise/Fall Time (ns) The optical rise time is the time required for the laser to move from 10% of rated output power to 90% of rated output power. The optical fall time is the time required for the laser to move from 90% of rated output power to 10% of rated output power.

Peak Wavelength (nm) The wavelength at which the spectral emission of a source is a maximum.

Pigtail For the ease of connection to a fiber, some manufacturers supply sources and photodiodes with a short length of fiber, called pigtail.

Pigtailed Coupling Efficiency (%) The percentage of source submount power which is coupled into the fiber during the pigtailing assembly procedure. This measurement is taken under constant modulation current and constant photocurrent. Defined by:

$$\frac{P_s - P_p}{P_s} \times 100$$

P_s = Submount output power
P_p = Pigtailed output power

Power Linearity (%) This parameter is computed from the maximum deviation (%) of the P-I curve from a line drawn from the output power at 10% of the modulation current (I_{mod}) to the rated output power (P_o, $I_{th} + I_{mod}$). The power linearity is the maximum value of the following quantity. Refer to Figure 7.

$$\frac{P_{theoretical} - P_{actual}}{P_{theoretical}} \times 100$$

Figure 6

Modulation Current

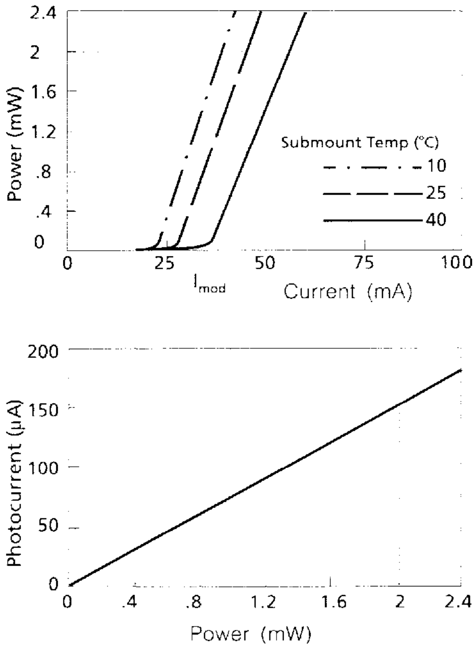
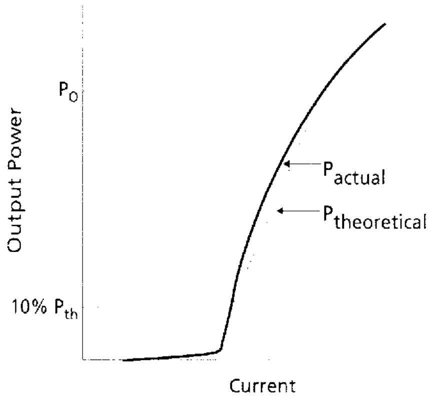


Figure 7

Power Linearity



$$\text{Power Linearity} = \frac{P_{theoretical} - P_{actual}}{P_{theoretical}}$$

Glossary

Rated Output Power The maximum recommended instantaneous power output level (i.e., maximum "peak power"). The rated power is determined by the efficiency of the laser or LED chip and the chip-to-fiber coupling efficiency. Laser modules are guaranteed to be linear and free of "kinks" up to the rated power.

Reliability A laser is considered at end of life when I_{th} has increased by 30 mA or 50% from the initial value, whichever is greater. Median Time to Failure (MTTF) is the time at which 50% of original samples have failed. Time to 10% Failure (TT10%F) is the time at which 10% of original devices can be expected to fail.

Responsivity Detector responsivity is the conversion factor between optical power and electrical current, typically presented in A/W. The responsivity is given by the quantity:

$$\text{Responsivity (A/W)} = \frac{I_s}{P_o}$$

I_s = Average signal current
P_o = Incident optical power

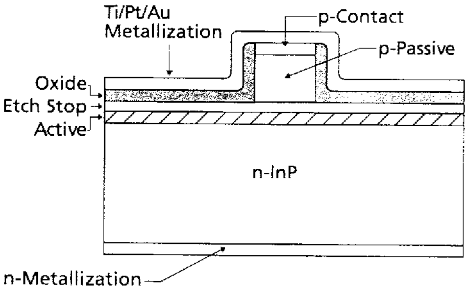
Return Loss The return loss of an optical component is the ratio of the incident optical power P_{in} to the reflected optical power P_{back}, in units of dB_{opt}. Therefore, return loss is usually a positive number.

$$\text{Return loss} = 10 \log (P_{in}/P_{back}) \quad [dB_{opt}]$$

Because of the pump laser's sensitivity to back-reflection, the return loss of optical components is gaining attention.

Figure 8

RWG Laser



Ridge Waveguide Laser (RWG) An index-guided laser in which the active region is continuous and the effective optical index discontinuity is provided by a cladding layer of varying thickness. The lateral index difference is 0.01 for a weakly index-guided laser. Refer to Figure 8.

Sensitivity Measurement Technique The sensitivity of a pinFET is typically measured by adjusting the optical input until the signal level is equal to six times the output noise voltage, the SNR needed to achieve a BER of 10^{-9}.

Series Resistance: dV/dI (Ohms) The first derivative of forward voltage with respect to current (dV/dI) measured at a current which produces the rated output power of the laser.

Slope Efficiency Change with Temperature (%/°C) Slope efficiency of lasers and LEDs decreases as temperature increases. The change is generally exponential and is defined as follows:

$$\frac{\log_e(S_1/S_2)}{(T_1 - T_2)} \times 100$$

T_1 = Temperature 1 (°C)
T_2 = Temperature 2 (°C)
S_1 = Slope efficiency at T_1
S_2 = Slope efficiency at T_2

Slope Efficiency, dP/dI or S (mW/mA) See **Modulation Current.** Also known as *Differential Efficiency*. The ratio between the optical output of a source and its input (drive) current. The slope efficiency is used only for that portion of the P-I curve between the threshold power (P_{th}) and the rated power (P_o). Refer to Figure 7 for illustrative reference. Defined by:

$$S = \frac{P_o - P_{th}}{I_{tot} - I_{th}}$$

P_o = Rated power at 25°C (μW)
P_{th} = Measured output power at I_{th} (μW)
I_{tot} = Total current at rated power (mA)
I_{th} = Threshold current (mA)

Spectral Shift with Temperature (nm/°C) The movement of the peak wavelength with temperature.

Spectral Width FWHM (nm) The width of an optical source's spectral characteristics when measured between the two wavelengths at which the optical intensity is 50% of its peak value. Refer to Figure 9.

Spectral Width RMS (nm) The root mean square value of an optical source's spectral width.

Submount A sub-assembly including the diode element (chip) mounted to a ceramic and metal carrier. The term is also used to differentiate the laser diode from the hermetic package which encases it.

Thermistor A negative temperature coefficient thermistor (NTC) whose resistance decreases with increasing temperature, typically at -4.4%/°C.

Thermoelectric Cooler A TEC is a semiconductor heat pump which utilizes the Peltier effect. The TEC is mounted between the laser or LED submount and the package body, and is used to maintain a stable submount temperature, typically 25°C, as follows:

- For ambient temperatures greater than 25°C, a forward bias voltage pumps heat from the submount to the package body.
- For ambient temperatures less than 25°C, a reverse bias voltage pumps heat from the package body to the submount.

When not operating, the TEC is a very good thermal insulator. If a TEC is included in a module, it should always be used to prevent high submount temperatures caused by self-heating.

Threshold Current Change with Temperature (%/°C) Threshold current of lasers increases with temperature. The change is generally exponential and is defined as follows:

$$\frac{\log_e(I_{th1}/I_{th2})}{(T_1 - T_2)} \times 100$$

T_1 = Temperature 1 (°C)
T_2 = Temperature 2 (°C)
I_{th1} = Threshold current at T_1
I_{th2} = Threshold current at T_2

Threshold Current (I_{th}) The current corresponding to the laser threshold. Refer to Figure 10.

Threshold Power (P_{th}) The optical power output corresponding to the laser threshold. Refer to Figure 10.

Tracking Error (dB) For a source component, the ratio of fiber-coupled power at two different case temperatures. This is a measure of the stability of the module coupling efficiency. For laser modules, power is measured at fixed monitor current (typically 200 µA), first at a case temperature of 25°C and then at the extremes of the expected operating temperature range (typically 0 and 65°C). Tracking Error is defined by:

$$\text{Tracking error} = 10 \text{ LOG} \left(\frac{\text{Power @ } T_{case} = 0, 65°C}{\text{Power @ } T_{case} = 25°C}\right)$$

WDM Wavelength division multiplexer.

Figure 9
Spectral Width FWHM

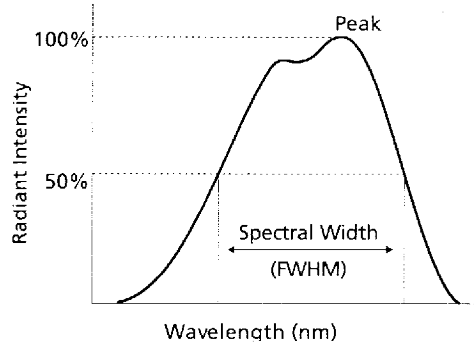
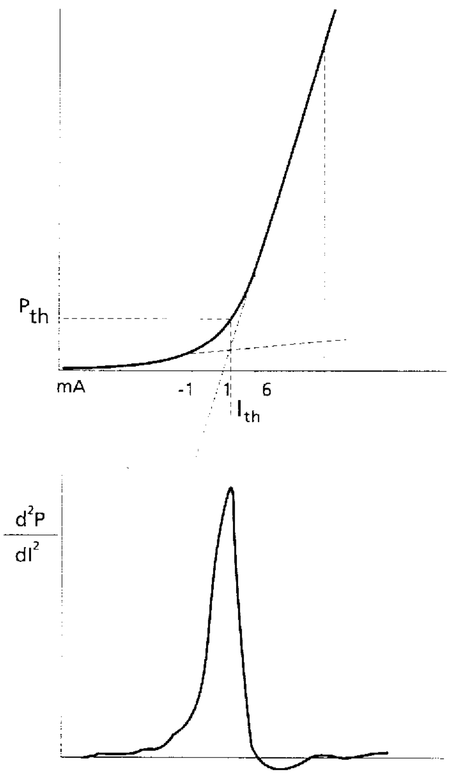


Figure 10
Threshold Current



Glossary