TOSHIBA

Visible Laser Diodes

PRODUCT GUIDE

1. Outline of Laser Diode

1–1 The Principles of Operations

1) Absorption and Emission of Radiation

Electrons tend to exist in non-continuous discrete energy states (or probability states) and can move into higher energy states with the addition of energy or move into lower energy states by giving off energy.

An electron can "fall" to a lower energy state either by being stimulated to do so or spontaneously, the resultant energy being termed stimulated and spontaneous emission respectively.

Similarly electrons can be enticed into moving into a higher energy level by the addition of an appropriate amount of energy -stimulated absorption.

This absorption and emission of radiation is schematically shown.

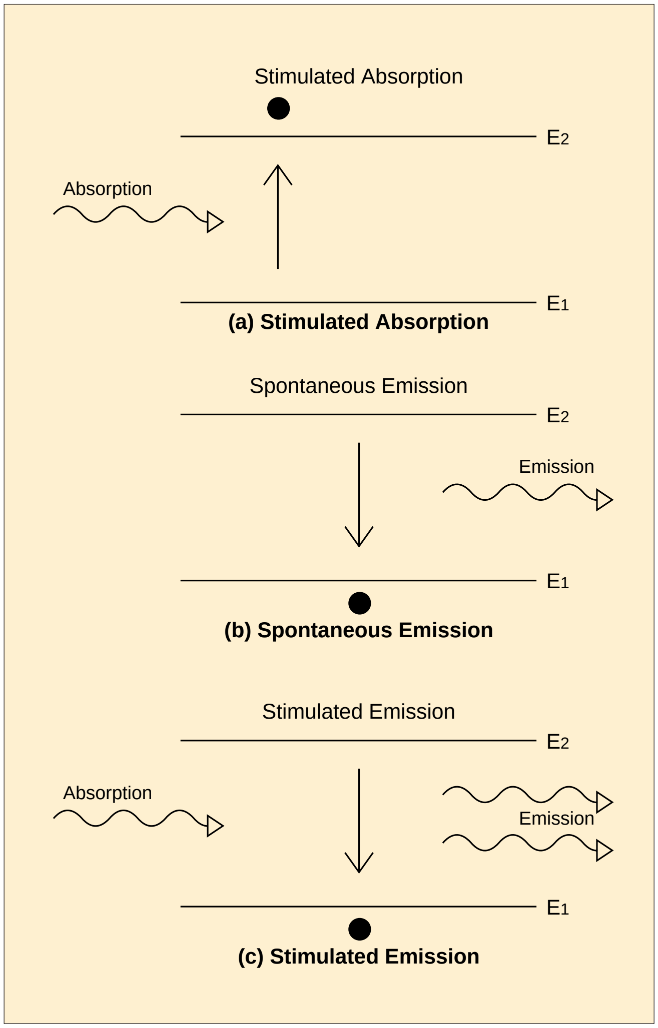


Fig. 1 Absorption and Emission of Radiation

2) LASER—Light Amplification by Stimulated Emission of Radiation

Unlike the LED a LASER produces light radiation that is coherent (ie. Light that is highly directional, of single wavelength and in-phase). The LASER's operation is based on the setting up of an optical oscillator which can be used to amplify light by some inherent gain mechanism. The fundamental structure of any laser, be it a gas based laser or a semiconductor laser, is an active medium with end reflectors to contain the light. This allows for the setting up of a "Fabry-Perot resonator" — the reflectors feed back the optical signal into the active medium many times and the signal is amplified during each pass. By making the end mirrors partially transmitting, laser radiation can escape from the oscillator cavity. To allow emission to occur electrons are initially held at higher energy levels than they would normally occupy (a condition known as population inversion) and are then stimulated to fall giving off energy in the form of light radiation. Since these electrons will fall the same "energy distance" they give off light that is coherent. By utilizing the principle of stimulated emission from semiconductor materials with energy gaps that allow for emission of optical frequency, a semiconductor material can be used as the active medium and so allow for the construction of a semiconductor laser.

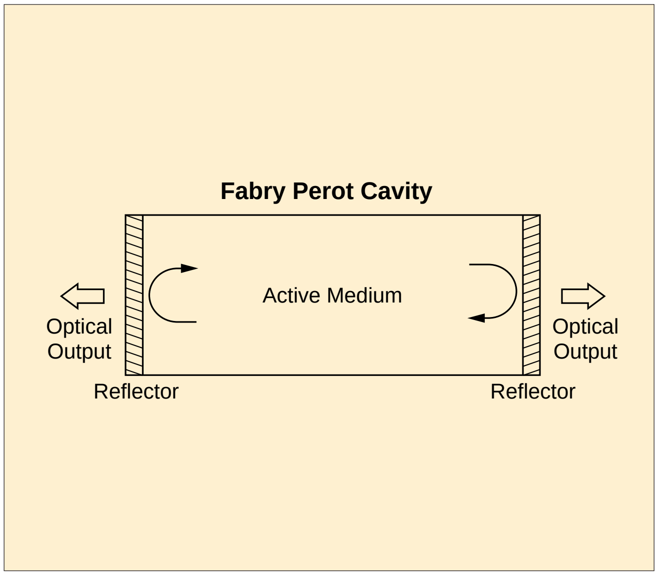


Fig. 2 Fabry Perot Cavity

3) Laser vs. LED

The fundamental difference between LED light output and LASER light output is that the led output is incoherent whereas the laser output is coherent ie. the laser light is highly directional and of the same frequency and phase. It is this characteristic of lasers which has allowed for the development of many of today's optical applications.

4) Semiconductor Laser (Laser diode)

Semiconductor Laser Structures

In its simplest form the semiconductor laser is a p–n junction of a single crystal semiconductor material with the wavelength of the output light determined by the material used. Semiconductor laser is consisted of p-n junction and it is called laser diode, LD. A Fabry-Perot cavity, required to provide the necessary optical feedback so that laser oscillation can occur, is established by polishing the end facets of the junction diode (so that they act as mirrors) and also by roughening the side edges to prevent leakage of light from the sides of the device. This structure is known as a homojunction laser.

By using the interface between two single crystal semiconductors with different bandgap energies (ie a heterojunction) the properties of the homojunction laser can be improved. As a result of the difference in the refractive index and the difference in band-gap energies of the materials used, the heterojunction structure can considerably increase device efficiency. By using a heterojunction of either side of the active layer (Double Heterojunction structure) both optical and carrier confinement are improved.

The Double Heterostructure provides for optical confinement perpendicular to the junction, but confinement within the active layer is also desirable. The use of a stripe in the laser structure allows for optical confinement parallel to the active layer. The stripe essentially acts as a guiding mechanism by limiting current spread over the active layer. This is achieved by creating an area of high resistance over the region of the active layer in which lasing is to be suppressed - a current blocking layer. The efficiency of the blocking layer will depend on its geometry and the current spread.

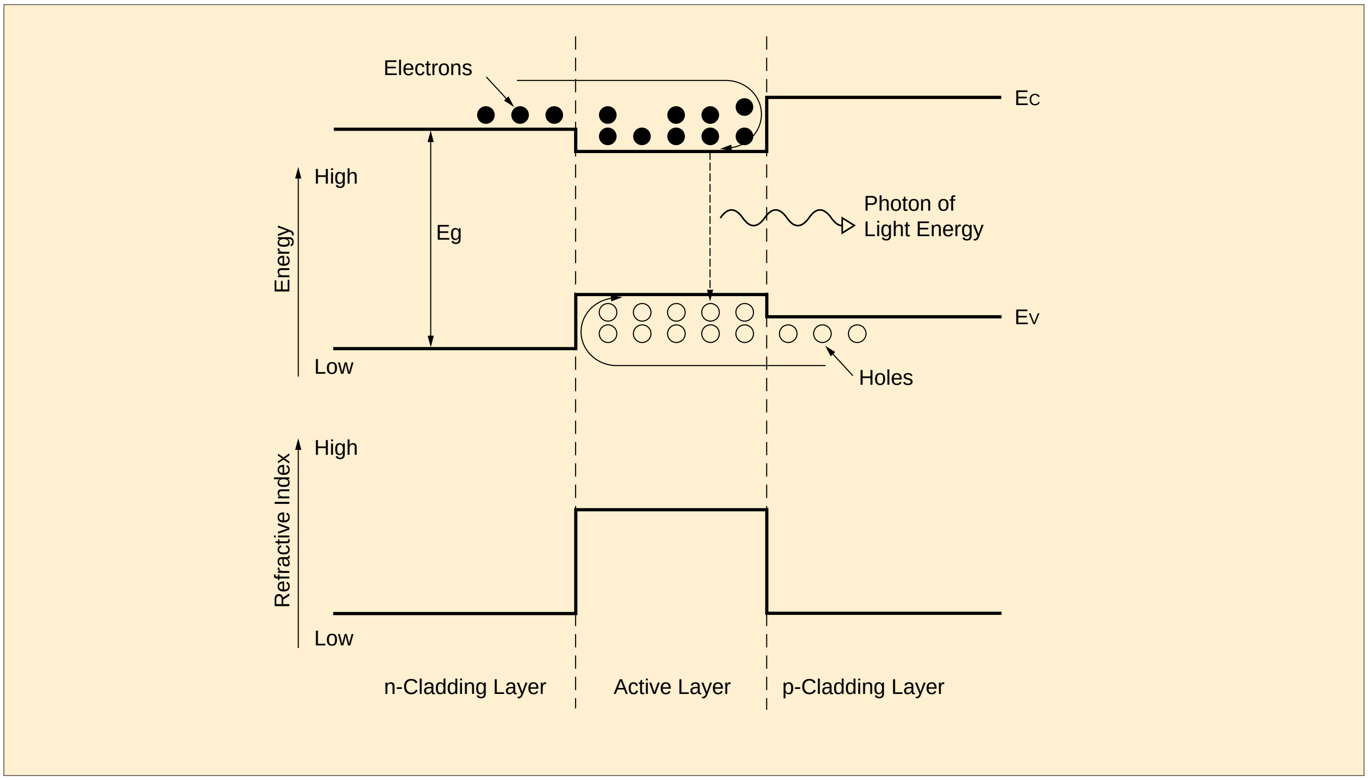


Fig. 3 Double Heterostructure Energy Levels and Refractive Indexes

1. Outline of Laser Diode

1–1 The Principles of Operations

5) Chip Structures

Multi-Quantum Well

By growing a series of wells and barriers in the active layer and/or cladding layer device efficiency can be increased, the resulting structures being known as Multi-Quantum Well (MQW) respectively.
Due to the quantum confinement effect the use of an MQW structure in the active layer results in higher gain than the normal double heterostructure and so leads to increased device efficiency, this in turn leads to increased design flexibility.

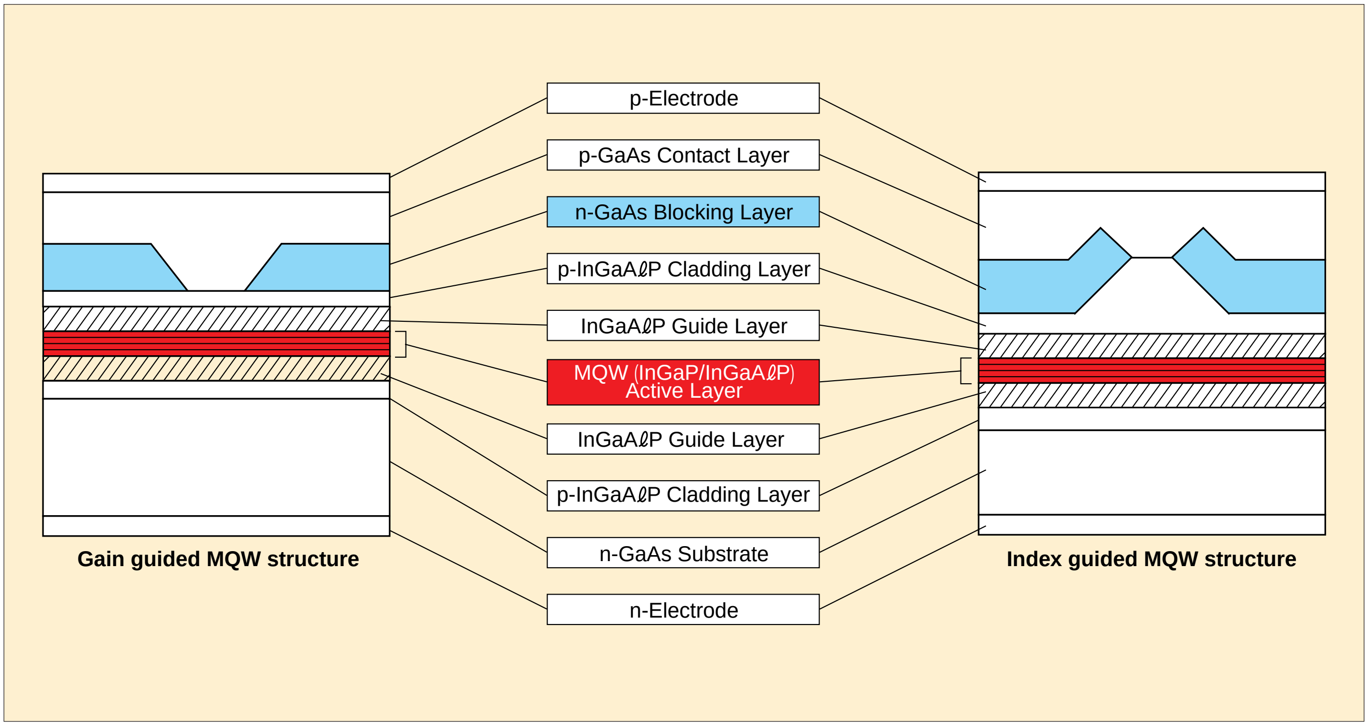


Fig. 4

6) Longitudinal Modes and Transverse Modes

a) Longitudinal Modes

Since the distance between the end reflectors of the resonant cavity is much longer than the lasing wavelength many modes can exist within the cavity, these modes are called longitudinal modes.
However, standing waves only exist at frequencies where the distance between the end reflectors is an integral number of half wavelengths, giving the following relationship:—

$$\frac{m\lambda}{2n} = L$$

L : Cavity length
λ : Wavelength
n : Refractive index of amplifying medium at λ

m = 1, 2, 3......

Although many modes are possible, the laser emission will only include those modes within the spectral gain curve of the device. If a population inversion has been established, lasing will occur when the gain is sufficient to overcome the optical losses.

b) Transverse Modes

Oscillation may also occur transverse to the axis of the cavity ie. transverse to the direction of propagation. These transverse modes will influence the radiation pattern of the output.

7) Gain Profile

Although many longitudinal modes may exist in the laser cavity, the modes that exist in the laser output will be dictated by the gain profile of the active medium.

The gain profile is a result of the carrier distribution in the active layer and will influence the output as shown below:

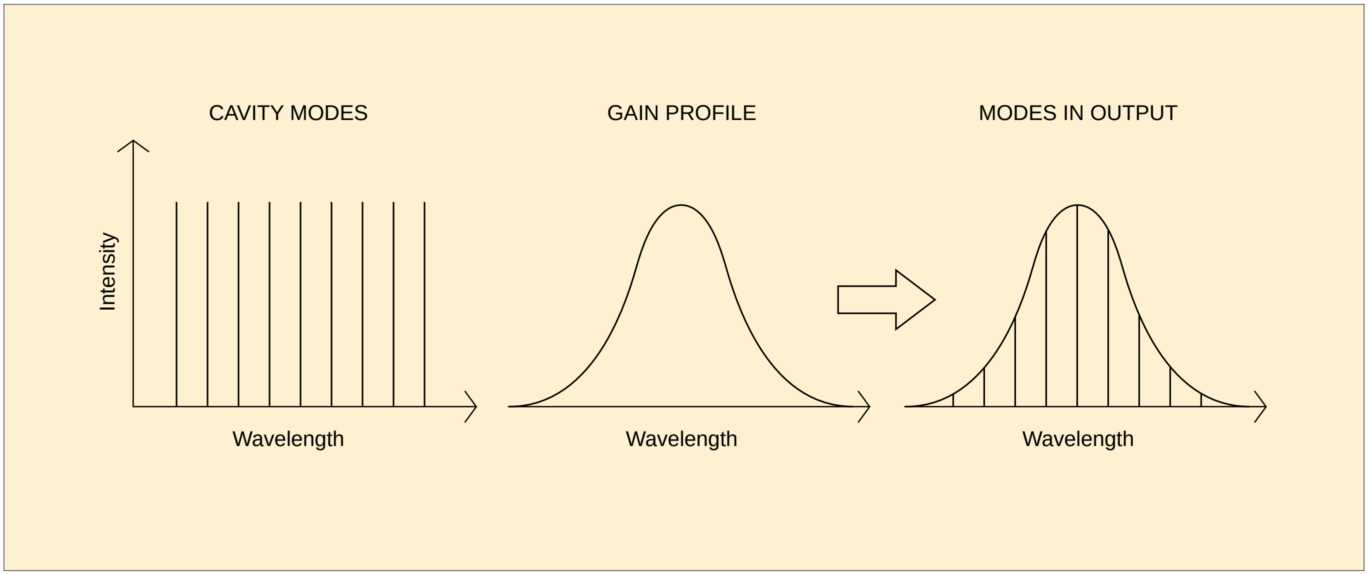


Fig. 5 Gain Profile and Lasing Wavelength

8) Mode Hopping

As the case temperature (and hence junction temperature) of the semiconductor laser increases the wavelength will be found to become longer.
However, rather than a continuous increase in wavelength, the wavelength is found to make discrete jumps to longer wavelength modes as temperature increases.
Stabilisation of the wavelength can be achieved by severe control of the lasers operation conditions.
A more practical solution is the use of internal grating structures such as a DFB type structure, however these types of structure are not yet available at visible wavelengths.

9) Higher Power

For applications such as read/write optical memory systems and some medical applications high power output is a requirement.
The main factor limiting available output power is facet susceptibility to Catastrophic Optical Damage (COD).
Catastrophic optical damage is the irreversible damage to the laser's end facets caused by the intense optical densities within the device.

This melting of the facets reduces the efficiency of the Fabry-Perot cavity and therefore reduces the structures ability to lase. Susceptibility to this type of damage can be reduced by increasing the size of the optical spot at the end facets. This can be achieved by reducing the thickness of the active layer.
Another method often used to obtain higher output power, is to reduce the amount of light exiting from the rear facet of the laser chip while increasing the amount of light exiting from the front facet of the laser chip.

This is acomplished by increasing the reflectivity of the rear facet of the laser diode and reducing that of the front facet. Although this technique allows for increased usable output power from the front of the laser, it has the drawbacks of reduced monitor current (a result of the reduced amount of light on the monitor photodiode). Another method of increasing the optical output power is the use of a broad-stripe structure however this results in inferior beam characteristics.

1. Outline of Laser Diode

1–1 The Principles of Operations

10) Shorter Wavelength

Visible wavelength laser diodes not only allow for increased performance of many conventional laser applications but also open the way, for many new applications that exploit the unique characteristics of VLD's. Their short wavelength is visible to the human eye and also allows for increased density of information storage both on optical storage media and on printed paper. The lasing wavelength is essentially determined by the material used for the active region. However, when growing the heterojunctions it is important to achieve good lattice matching of the materials used and this limits the flexibility in the choice of material for the active layer.

Toshiba VLD's use InGaP / InGaAlP which has a similar lattice constant to that of GaAs - the material used as the substrate. The bandgap of the active layer will determine the emission wavelength. The addition of Al to the InGaP active layer will cause the bandgap to increase and the lasing wavelength to shorten. However this results in a reduction in the energy step between the active and cladding layer and so allows for an increase in the overflow leakage current) ie. reduced device efficiency and a deterioration of thermal characteristics).

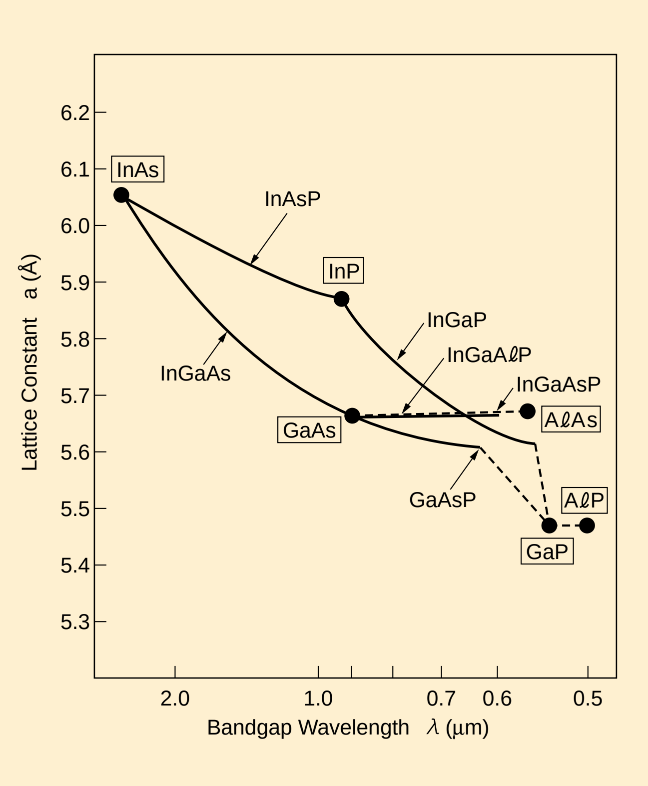


Fig. 6 Relationship between Lattice Constant and Bandgap Wavelength for Ⅲ–Ⅴ group semiconductor

11) Metal-Organic Chemical Vapour Deposition

Toshiba VLD's are grown using a Metal-Organic Chemical Vapour Deposition (MOCVD) process. This process is well adapted to heterostructure and sub-micron layer growth and offers improved uniformity and compositional homogenity over a large surface area.

The growth substrate is placed in a quartz reaction tube, into which controlled amounts of Group III alkyls and Group V hydrides are introduced. The RF-heated susceptor surface has a catalytic effect on the decomposition of the gaseous products.

At the sesceptor surface the metal alkyls and hydrides decompose into their Group III and Group V elemental species which move to find available lattice sites causing growth to occur.

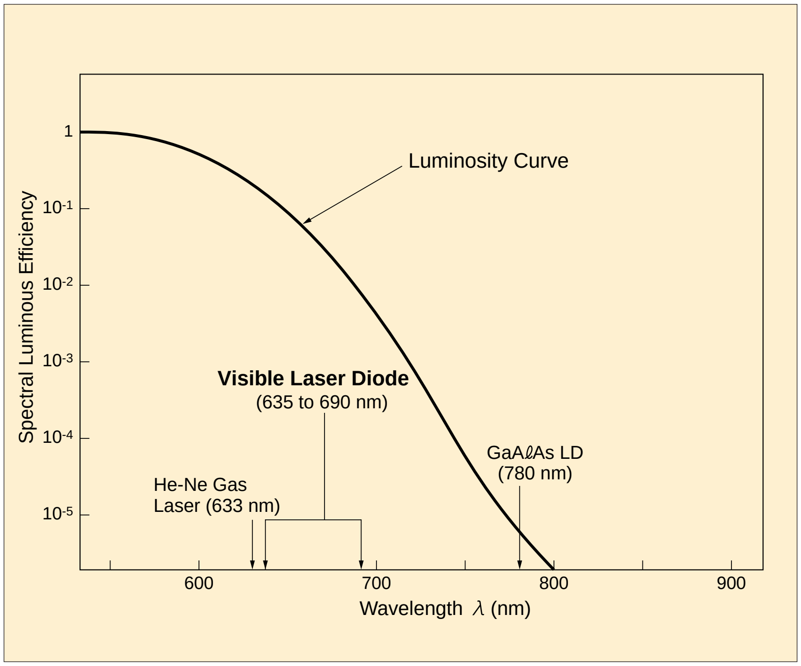


Fig. 7 Spectral Luminous Efficiency Vs. Wavelength

1–2 Glossary of Terms

Symbol	Term	Description
APC	Auto Power Control	Drive circuit with feedback loop to ensure the optical output power is kept constant
AR	Aspect Ratio	The ratio of $\theta_{\perp}$ to $\theta_{//}$ (Fig. 8)
As	Astigmatism	The difference between the focal point for the output parallel and perpendicular to the junction, when the laser output is focused
$C_{T(PD)}$	PD Total Capacitance	Total capacitance of photodiode
FFP	Far Field Pattern	Intensity profile of the light output measured at a distance from the laser chip (Fig. 8)
$I_{D(PD)}$	PD Dark Current	Leakage current of photodiode under reverse bias conditions (in the absence of incident light)
I_F	Forward Current	Forward current through the laser diode (Fig. 9)
I_m	Monitor Current	Current through reverse biased built-in photodiode used to monitor the optical output power from the laser diode (Fig. 9)
I_{op}	Operation Current	Forward current to obtain standard operation power (Fig. 10)
I_{th}	Threshold Current	Current marking the onset of laser oscillation obtained by linearly extrapolating the I-L curve back to the crossing point on the forward current axis (Fig. 10)
NFP	Near Field Pattern	Intensity profile of the light output measured at the laser chip facet
P_o	Optical Power	Optical output power from the laser diode
R_{th}	Thermal Resistance	The temperature difference per unit of input electrical power
SE	Slope Efficiency	Optical output power increase with unit increase in forward current
T_a	Ambient Temperature	The temperature of the environment in which the laser is operating
T_c	Case Temperature	The actual temperature of the VLD package
TE / TM	Polarisation Ratio	The ratio of the output polarised parallel to the junction and perpendicular to the junction
T_{stg}	Storage Temperature	Permitted storage temperature range while VLD not in use
t_f	Fall Time	The time taken for the optical output to fall from 90% to 10% of its maximum value
t_r	Rise Time	The time taken for the optical output to rise from 10% to 90% of its maximum value
V_f	Forward Voltage	The forward voltage drop across the laser diode
V_{op}	Operation Voltage	The voltage drop across the laser diode while the laser is operating at standard operation power (Fig. 9)
$V_{R(LD)}$	LD Reverse Voltage	Laser diode reverse voltage
$V_{R(PD)}$	PD Reverse Voltage	Photodiode reverse voltage
V_{th}	Threshold Voltage	The voltage drop across the laser diode at the onset of laser oscillation
$\Delta P_{(\%)}$	Droop	Fall-off in optical output power due to thermal heating of laser
$\theta_{//}$	Beam divergence	Full width at half maximum of beam divergence parallel to the junction
$\theta_{\perp}$	Beam divergence	Full width at half maximum of beam divergence perpendicular to the junction
λ_p	Lasing wavelength	Lasing wavelength of peak longitudinal mode in output spectrum

1. Outline of Laser Diode

1–2 Glossary of Terns

Optical Characteristics (Fig. 8)

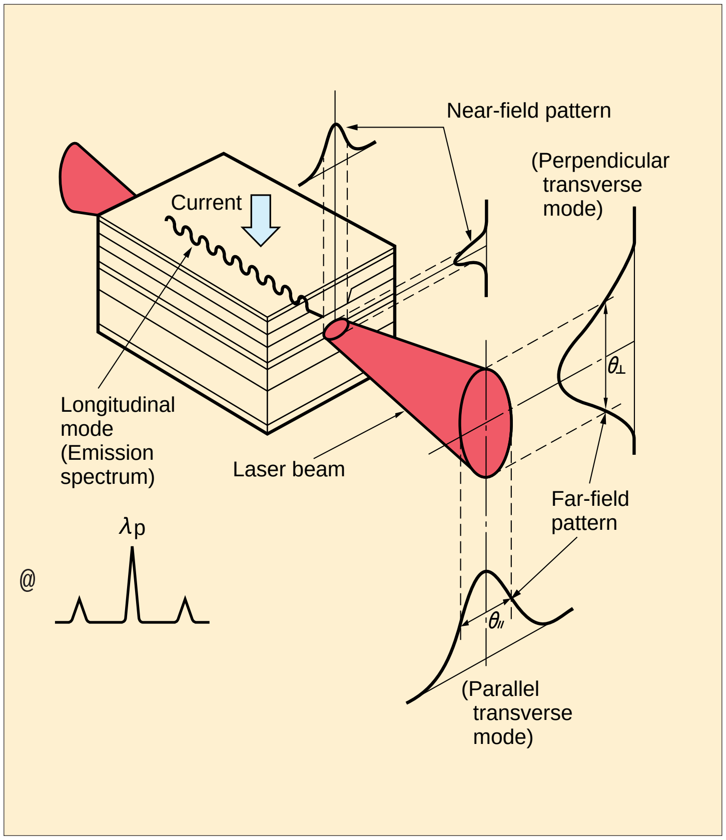


Fig. 8

Light exiting from the laser chip diverges both parallel and perpendicular to the laser's active layer. The profile of this light at the laser's end facet is known as the Near Field Pattern (NFP) while that measured a distance away is known as the Far Field Pattern (FFP). The FFP is measured at the Full Width at Half Maximum (FWHM) and is labelled $\theta_{//}$ and $\theta_{\perp}$ (ie. beam divergence parallel and perpendicular to the active layer).

The peak wavelength of the emission spectrum is the typical wavelength of the laser's optical output. This wavelength will increase with temperature and this change in wavelength with case temperature is shown in the enclosed technical data.

Electrical Characteristics (Fig. 9)

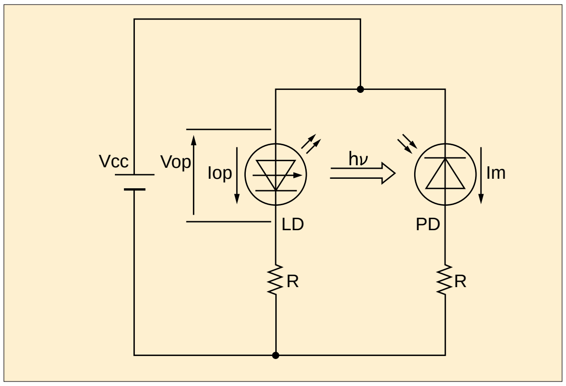


Fig. 9

VF is the forward voltage drop across the laser diode, while IF is the forward current through the laser diode. Im is the monitor current resulting from the light exiting from the rear of the laser chip incident on the internal monitor photodiode.

Opto-Electrical Characteristics (Fig. 10)

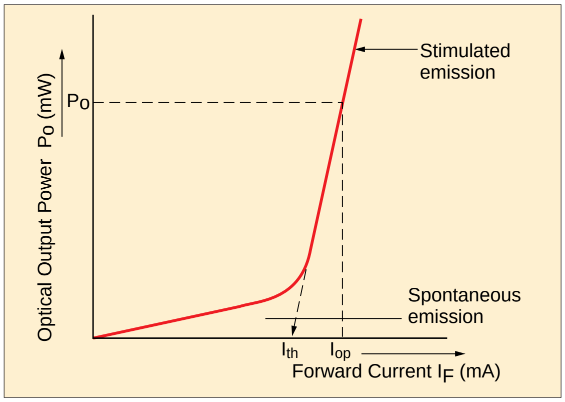


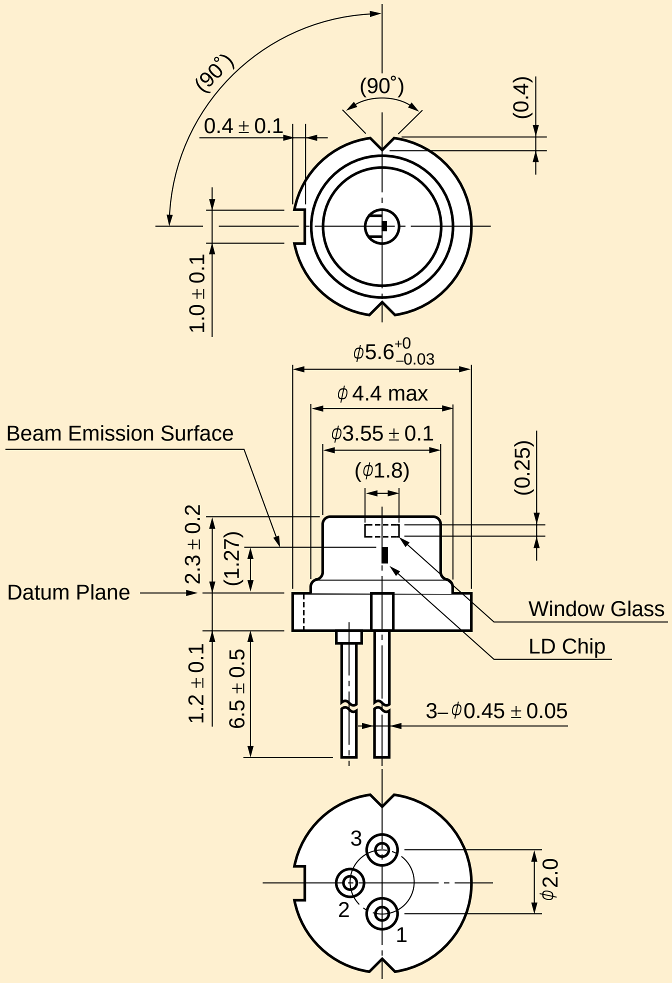
Fig. 10

One of the most important characteristic graphs of a laser diode is what is commonly known as the I-L Curve. This graph shows the optical output power from the laser as the forward current through the laser is increased. At a certain current known as the threshold current, a "knee" occurs in the graph marking the onset of lasing. Below the threshold current the optical output is spontaneous (led type) emission, above the threshold current the output is predominantly stimulated (laser type) emission and this is the useful operation region of the laser. The threshold current will change with temperature.

2. Product List

2-1 Package Dimension (M/MB/MC/MD)

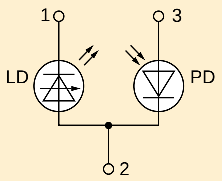
Units in mm



( ) denotes typical value

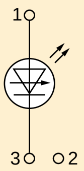
2-2 Pin Connection

M Type



1. Laser diode cathode
2. Laser diode anode
   Photodiode cathode
3. Photodiode anode

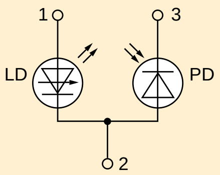
MB Type



1. Laser diode anode
2. Case
3. Laser diode cathode

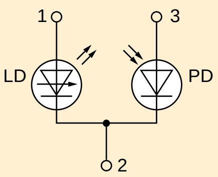
Note: Photodiode is not built-in for MB type

MC Type



1. Laser diode anode
2. Laser diode cathode
   Photodiode anode
3. Photodiode cathode

MD Type



1. Laser diode anode
2. Laser diode cathode
   Photodiode cathode
3. Photodiode anode

2. Product List

2-3 Main Characteristics of VLD

Type	Structure	Max Ratings		Typical Data							
		P_o (nW)	T_c (˚C)	λ_p (nm)	I_{th} (mA)	I_{op} (mA)	$\theta_{\parallel}$ (˚C)	$\theta_{\perp}$ (˚C)	V_{op} (V)	I_m (mA)	A_s (µm)
TOLD9231M	Gain Guided MQW	5	–10 to 60	670	50	60	10	32	2.3	0.9	40
TOLD9221M	Index Guided MQW	5	–10 to 60	670	35	45	8	30	2.2	1.0	10
TOLD9225M		10	–10 to 60	670	40	60	8	18	2.3	0.2	6
TOLD9441MC /MD		7	–10 to 70	650	40	50	8	28	2.2	0.25	8
TOLD9442M /MC		5	–10 to 60	650	30	35	8	28	2.2	0.25	8
TOLD9443MC /MD		10	–10 to 70	650	45	60	8	28	2.2	0.2	8
TOLD9451MB /MC		30 (50 Note(1))	–10 to 60	658	45	85	9	22	2.4	0.1 Note(2)	

Note (1) Pulse Condition : Pulse Width 100 ns, Duty Cycle 50%
(2) For MC type only

Table 1

2-4 VLD Structure

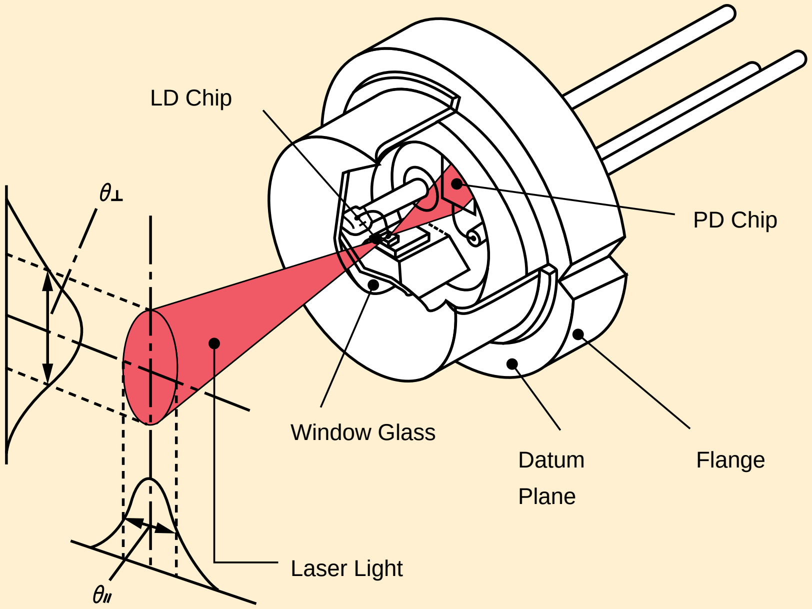
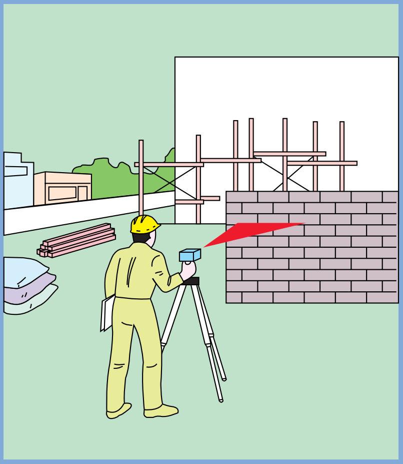


Fig. 11 Interior Diagram of Package

2-5 VLD Applications

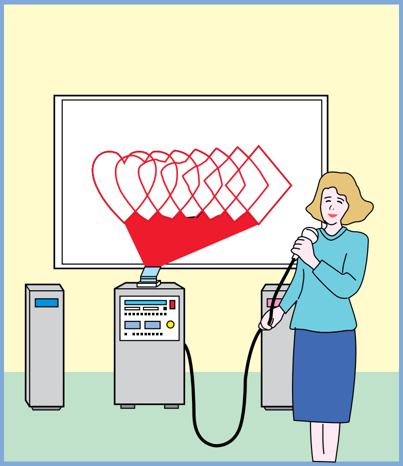
Laser Alignment



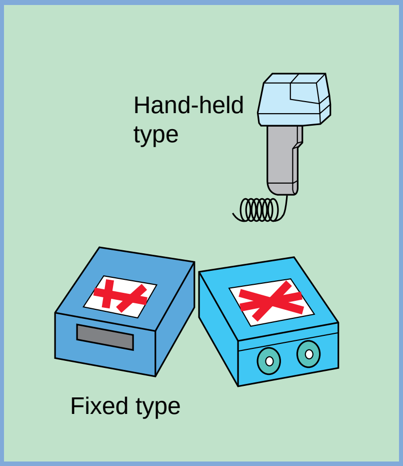
Optical Memory

Laser Pointer

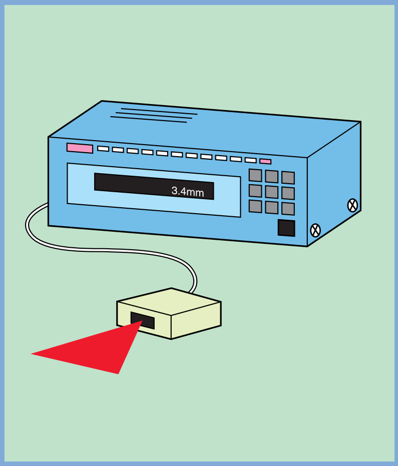
Laser Art



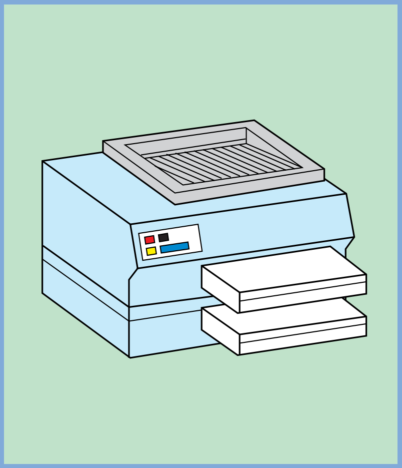
Bar Code Reader



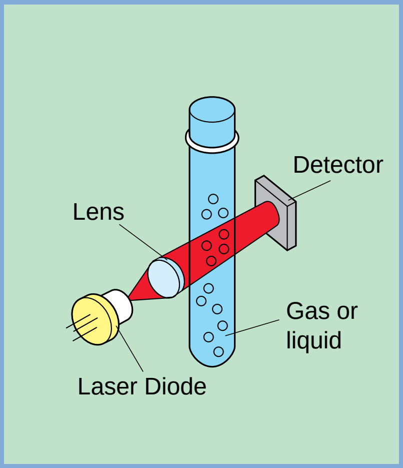
Laser Measurement



Laser Beam Printer



Laser Analysis



Digital Video Disk

3. Measurement of Main Characteristics

3–1 I-L Characteristic

Equipment :

Optical Power Meter
(with analogue output),
Current Sweeper, XY-Recorder,
Thermal Controller

The I-L curve is a plot of the forward current against optical output power. It indicates the threshold and operation currents of the VLD. The I-L curve is obtained by sweeping the forward current through the laser and measuring the resulting optical output power. By means of a thermal controller the temperature dependence of the I-L Characteristic may be observed, and this data can be used to obtain the Case Temperature Dependence of Threshold Current.

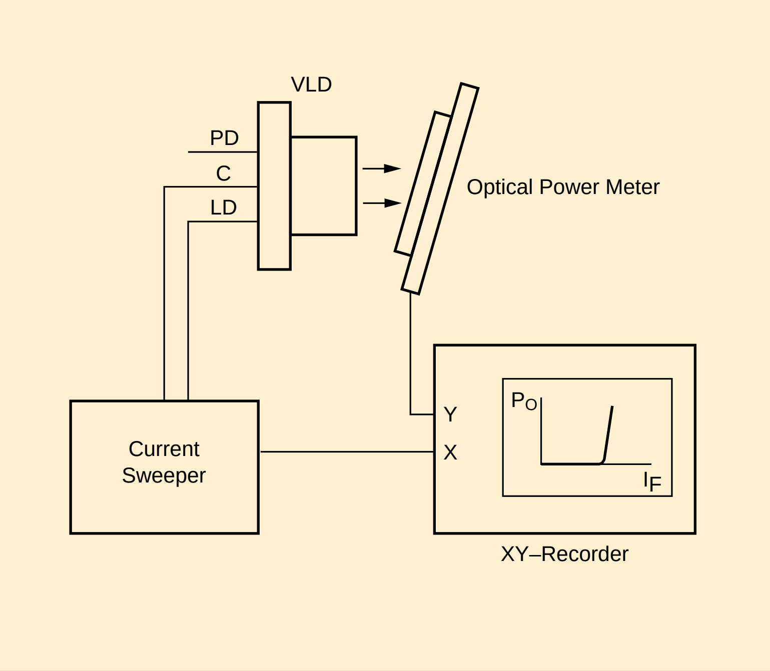


Fig. 12

3–2 Monitor Current Vs. Optical Output Power

Equipment :

Optical Power Meter (with analogue output), Current Sweeper, Bias Voltage Source, 1KΩ Resistor, Ammeter (with analogue output), XY-Recorder

The monitor current results from light from the rear facet of the VLD falling on the internal monitor photodiode.
With the internal photodiode reverse-biased by an external bias source, the monitor current is measured using an ammeter and a plot of monitor current against optical output power is made.

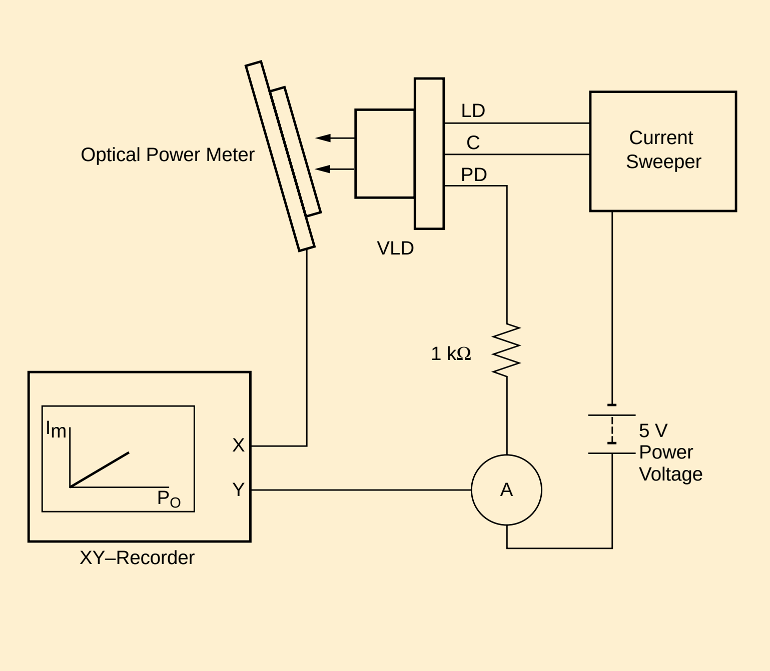


Fig. 13

Note: For these measurements the VLD should be heat-sinked, the thermal controller should be connected to the heat-sink.

3–3 Forward Current Vs. Forward Voltage

Equipment :

Current Sweeper,
Optical Power Meter,
XY-Recorder,
Thermal Controller

The voltage drop across the laser diode is measured across the Common and LD pins while the current is swept to bring the laser to rated power.
By using a thermal controller the VLD temperature can be changed and the resulting change in voltage drop measured

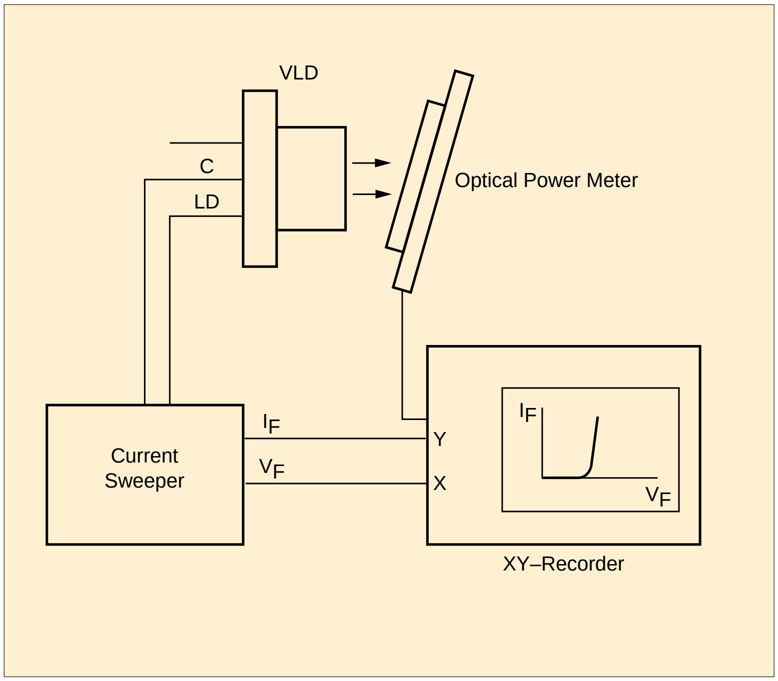


Fig. 14

3–4 Lasing Spectrum

Equipment :

APC Driver,
Focussing Lens,
Optical fiber,
Spectrum Analyser

With the VLD operating in APC mode the laser output is focussed into an optical fiber. The spectrum of this light can then be observed by means of a spectrum analyser.

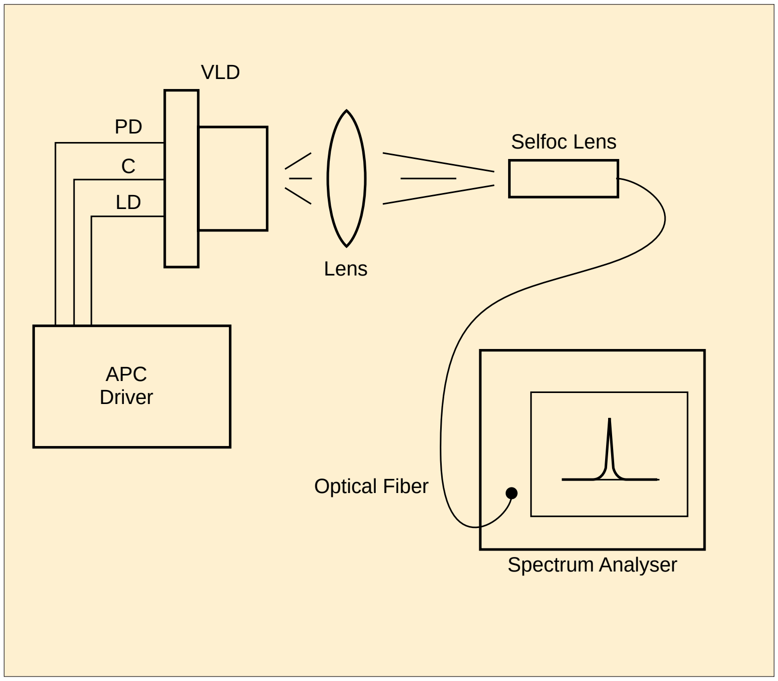


Fig. 15

Note: For these measurements the VLD should be heat-sinked, the thermal controller should be connected to the heat-sink.

3. Measurement of Main Characteristics

3–5 Case Temperature Dependence of Lasing Wavelength

Equipment :

APC Driver, Focussing Lens,
Optical Fiber, Spectrum Analyser,
Temperature Controller

The VLD should be driven using an APC driver. The laser output is focussed into an optical fiber and the spectrum of the output observed using a spectrum analyser.
While measuring the spectrum the temperature of the VLD case should be swept by means of a temperature controller.
As the temperature of the laser is increased the wavelength will be found to increase in a "staircase" like fashion, known as Mode-Hopping.

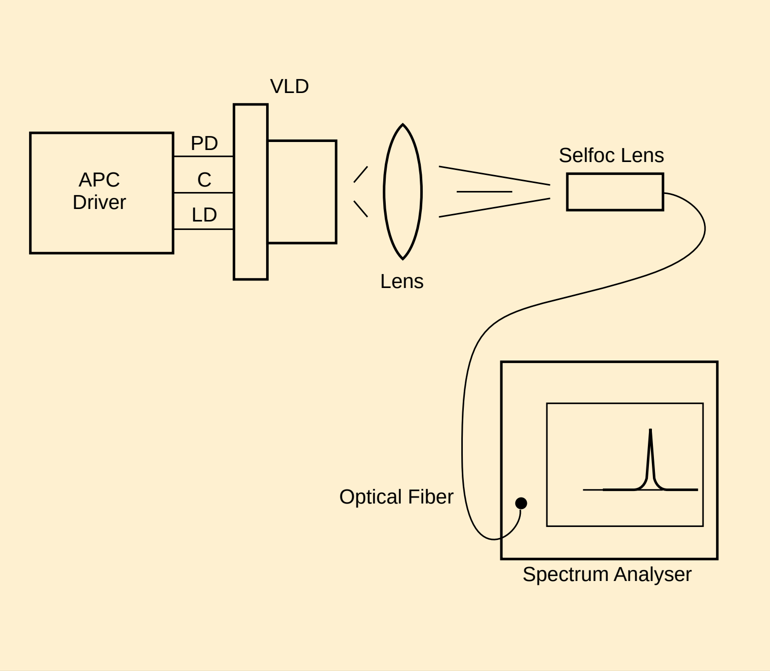


Fig. 16

3–6 Far-Field Patterns

Equipment :

APC Driver,
Photodiode (on rotatable axes)

While operating the VLD in APC mode the photodiode is swept in an arc both parallel and perpendicular to the laser junction. The intensity of the light output at each angle is recorded.

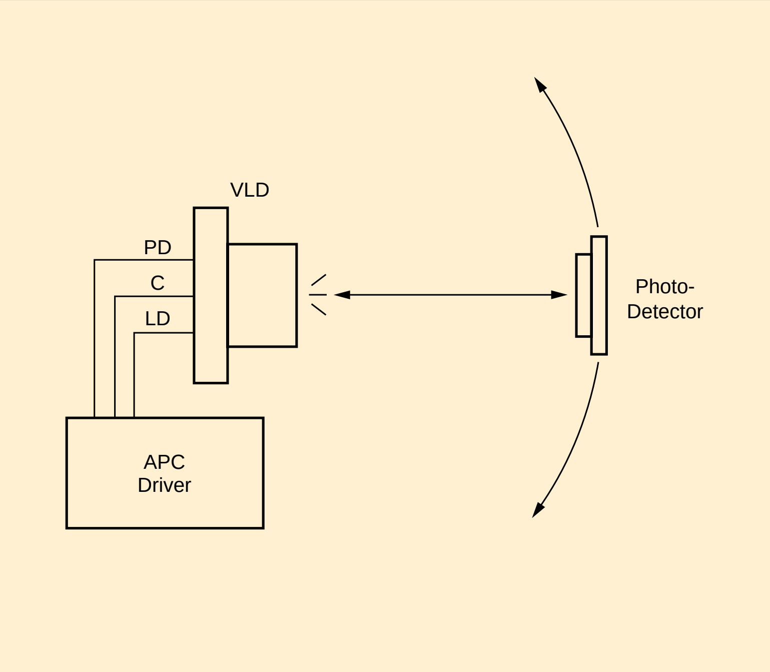


Fig. 17

Note: For these measurements the VLD should be heat-sinked, the thermal controller should be connected to the heat-sink.

3–7 Polarization Ratio Vs. Optical Output Power

Equipment :

APC Driver, Focussing Lens,
Gram-Thompson Prism,
Optical Power Meter.

The polarization ratio is defined as the ratio of power in the TE and TM modes. Since the TE and TM modes are perpendicular they can be separated by means of a Gram-Thompson prism, their respective intensities measured and their ratio calculated. The value for the polarization ratio is dependent on the numerical aperture of the lens.

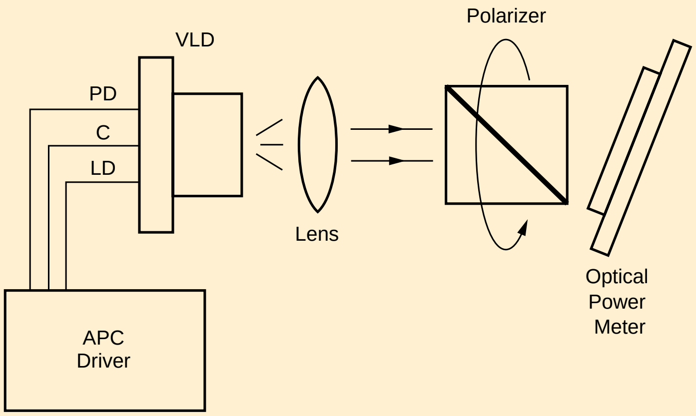


Fig. 18

Note: For these measurements the VLD should be heat-sinked, the thermal controller should be connected to the heat-sink.

4. Measurement Method for Other Characteristics and Typical Data

4–1 Rise/Fall Times

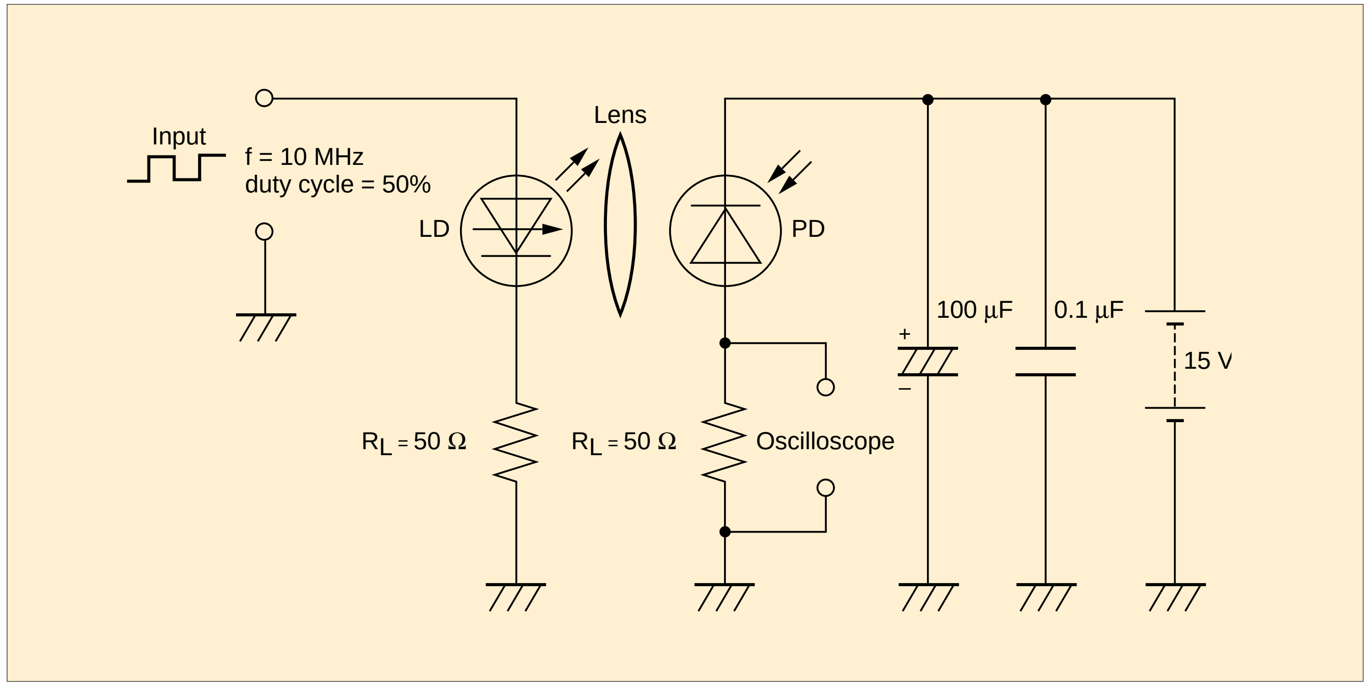


Fig. 19

Measurement:

To measure the rise and fall times the VLD is driven in pulsed mode by a pulse generator operating at a frequency of 10MHz and a duty of 50% (ie. a pulse width of 50nsecs).

The Optical output from the VLD is focused onto a photodetector of high response.

The output of the photodetector is observed by means of an oscilloscope.

Using the oscilloscope the time taken for the laser output to rise from 10% to 90% and fall from 90% to 10% of maximum optical output power can be measured.

If the VLD pre-bias (DC-bias) is less than the threshold current or if no pre-bias is used, a time delay between the drive pulse and the optical output occurs.

This delay time can be observed by means of a current probe used to observe the diode forward current.

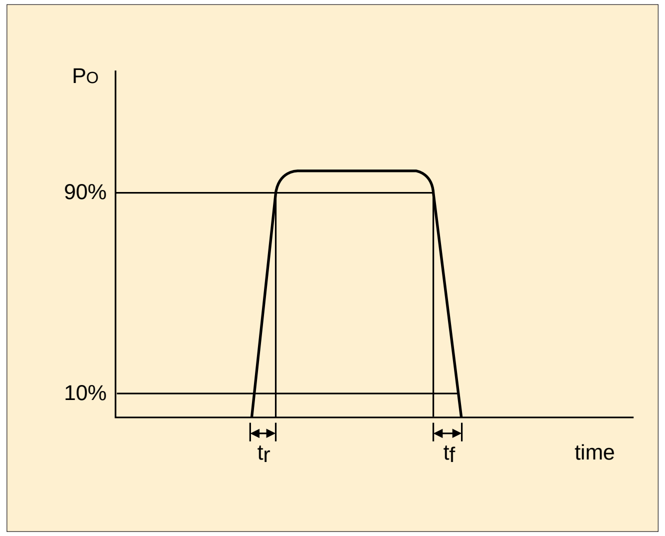
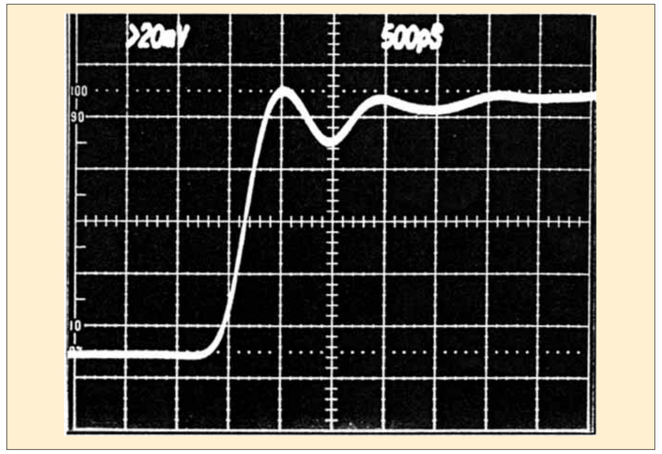


Fig. 20

NOTE:
It is important that both the oscilloscope and the photodetector have fast response, also the test system should be designed to minimize mismatching and so prevent overshooting of the VLD (eg. the use of microstrip lines recommended).

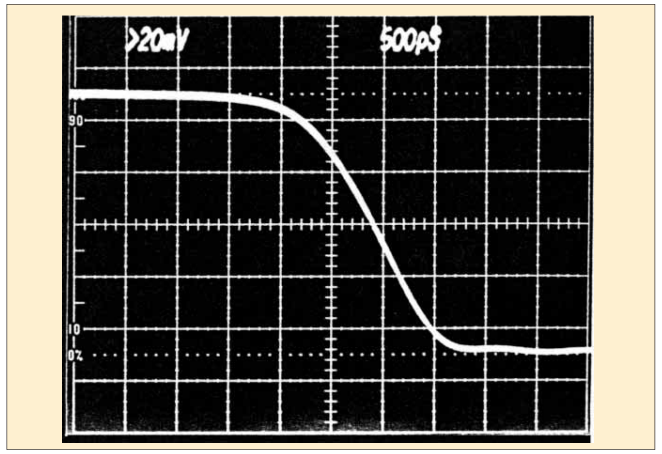
Sample Data: TOLD9451MB/MC

P_O = 5 mW, with no pre-bias



t_r = 0.3 ns

Fig. 21

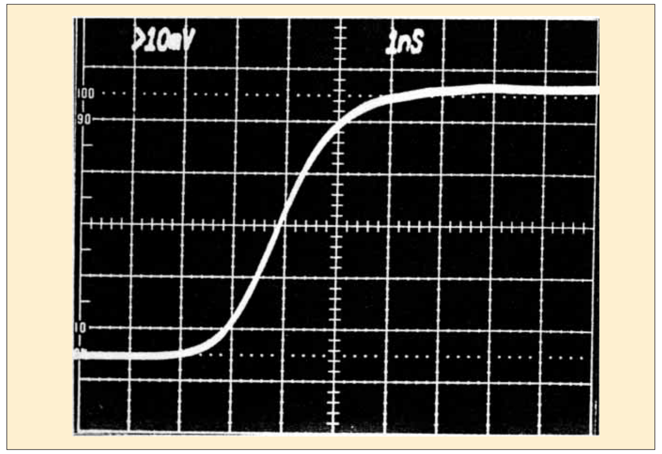


t_f = 1.2 ns

Fig. 22

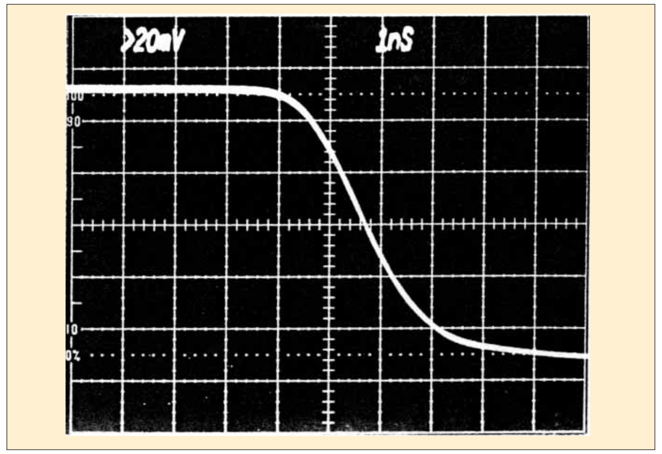
Sample Data: TOLD9451MB/MC

P_O = 5 mW, with pre-bias 0.5 mW



t_r = 2 ns

Fig. 23



t_f = 2.4 ns

Typical value:

Type	Test Power Po (mW)	Test Conditions	Rise Time tr (ns)	Fall Time tf (ns)
TOLD9231M	5	f = 10 MHz duty cycle = 50% tr = 2 ns tf = 2 ns	0.5	1.5
TOLD9221M	5		0.5	1.5
TOLD9225M	10		0.5	1.5
TOLD9441MC/MD	5		0.5	1.5
TOLD9442M/MC	5		0.5	1.5
TOLD9443MC/MD	10		0.5	1.5
TOLD9445M/MC	10		0.5	1.5
TOLD9451MB/MC	30		0.5	1.5

* Data measured with no pre-bias

Table 2

4. Measurement Method for Other Characteristics and Typical Data

4–2 Thermal Resistance (R_{th})

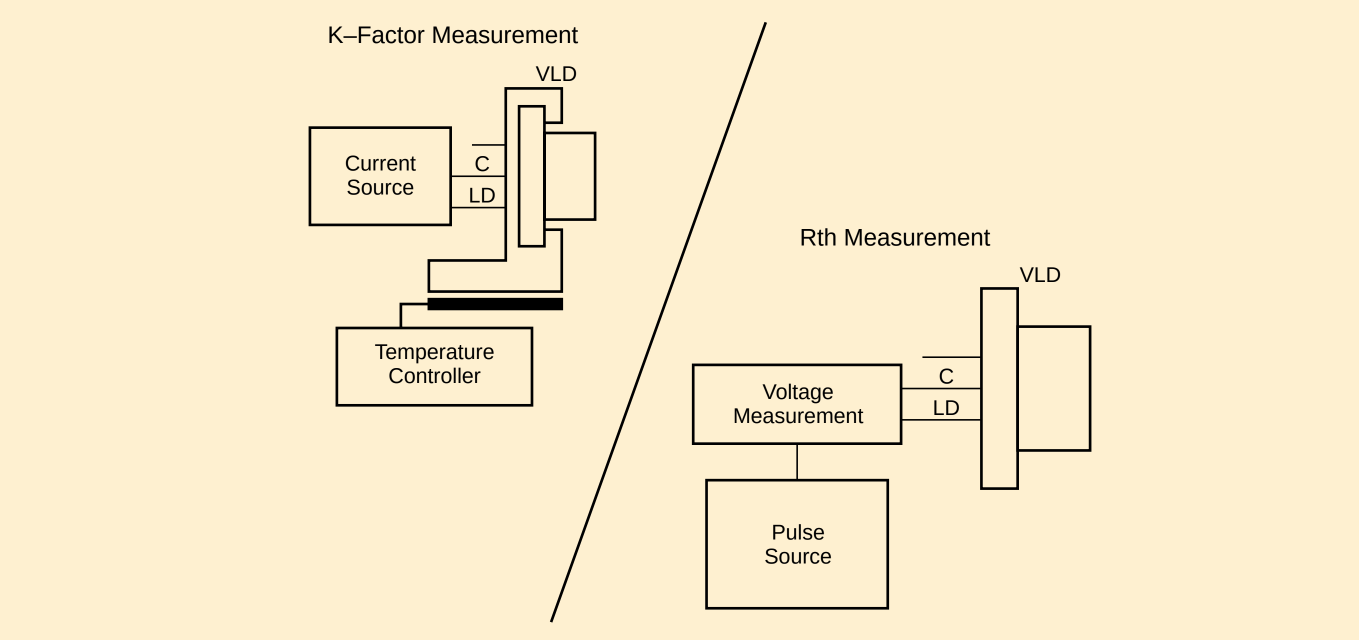


Fig. 25

Definition:

$$R_{th} = \frac{\Delta mV \cdot \frac{1}{K}}{V_F \cdot I_F}$$

R_{th} = Thermal Resistance (˚C/W)
ΔmV = change between V_{f1} and V_{f2}
K = Constant (slope of V_F–T_C)
I_F = forward current during main pulse
V_F = forward voltage (avg.) during main pulse

Measurement:

The K-factor, relating change in V_F to changes in T_C, is first evaluated. While using a 1mA constant current the voltage drop across the laser diode is measured. By means of a thermal controller and heat sink the rate of change in V_F with T_C is measured (slope K). Next the VLD is disconnected from the thermal controller and tested without using a heat-sink. A short Sense Pulse forward current of 1mA is sent through the laser diode, the associated forward voltage (V_{f1}) is measured. Next a Main Pulse of 30mA and a set duration is used. During this Main Pulse the value of the forward voltage is averaged and recorded (V_F). This is followed by another Sense Pulse of 1mA (1 µsec after Main Pulse) and the associated forward voltage (V_{f2}) is measured. The increase in the laser temperature resulting from the main pulse can be calculated by the difference in the voltages measured during the sense pulses ΔmV (ie. V_{f1}–V_{f2}) divided by the K-factor. The Thermal Resistance is then defined as the temperature change divided by the input power ($V_F \cdot I_F$). This proceedure is repeated with Main Pulses of different durations (eg 10 µs, 20 µs, 50 µs,...).

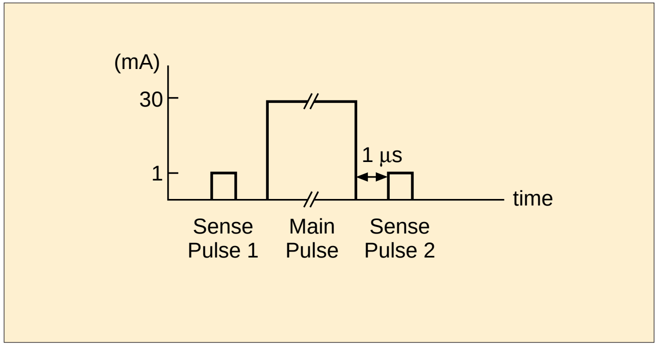


Fig. 26

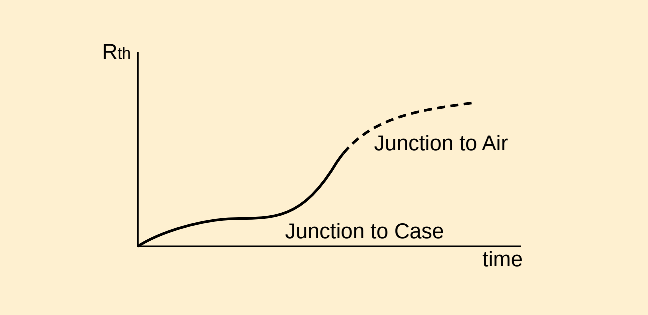
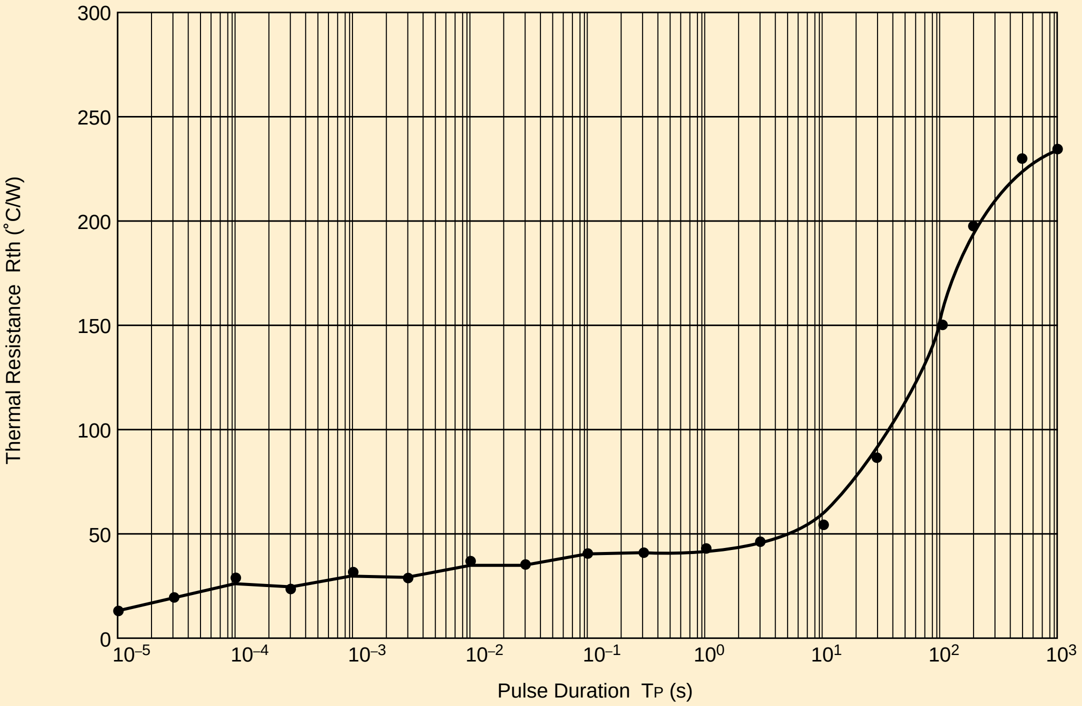


Fig. 27

Sample Data:

TOLD9221M



TOLD9231M

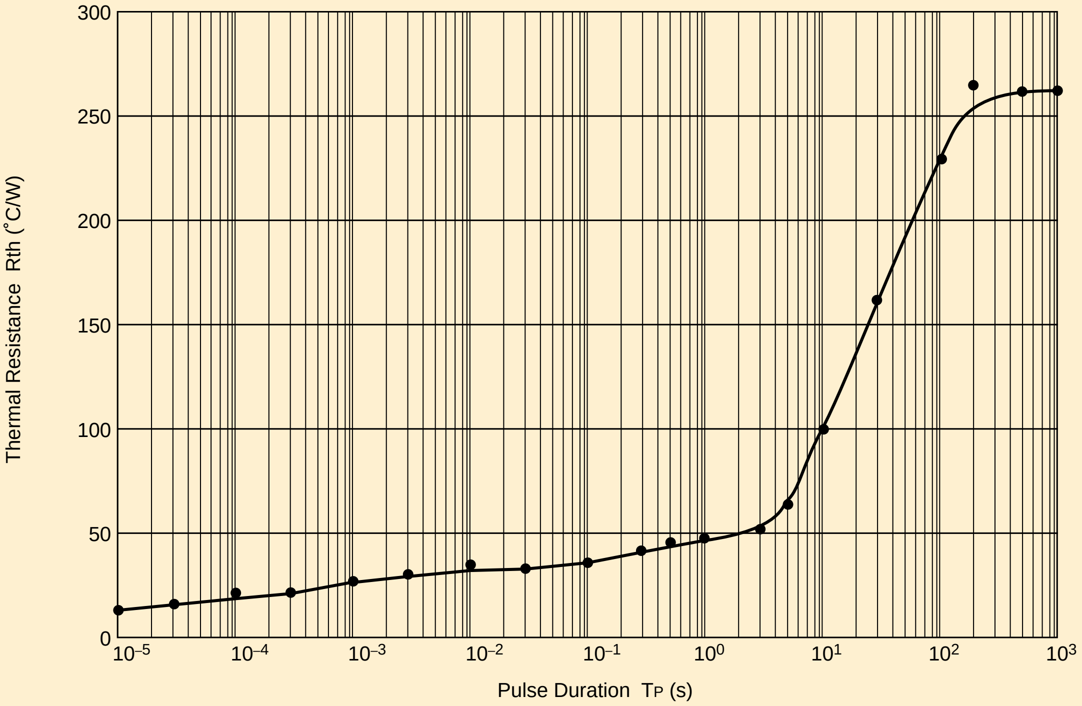


Fig. 28

4. Measurement Method for Other Characteristics and Typical Data

4–3 Relative Intensity Noise (RIN)

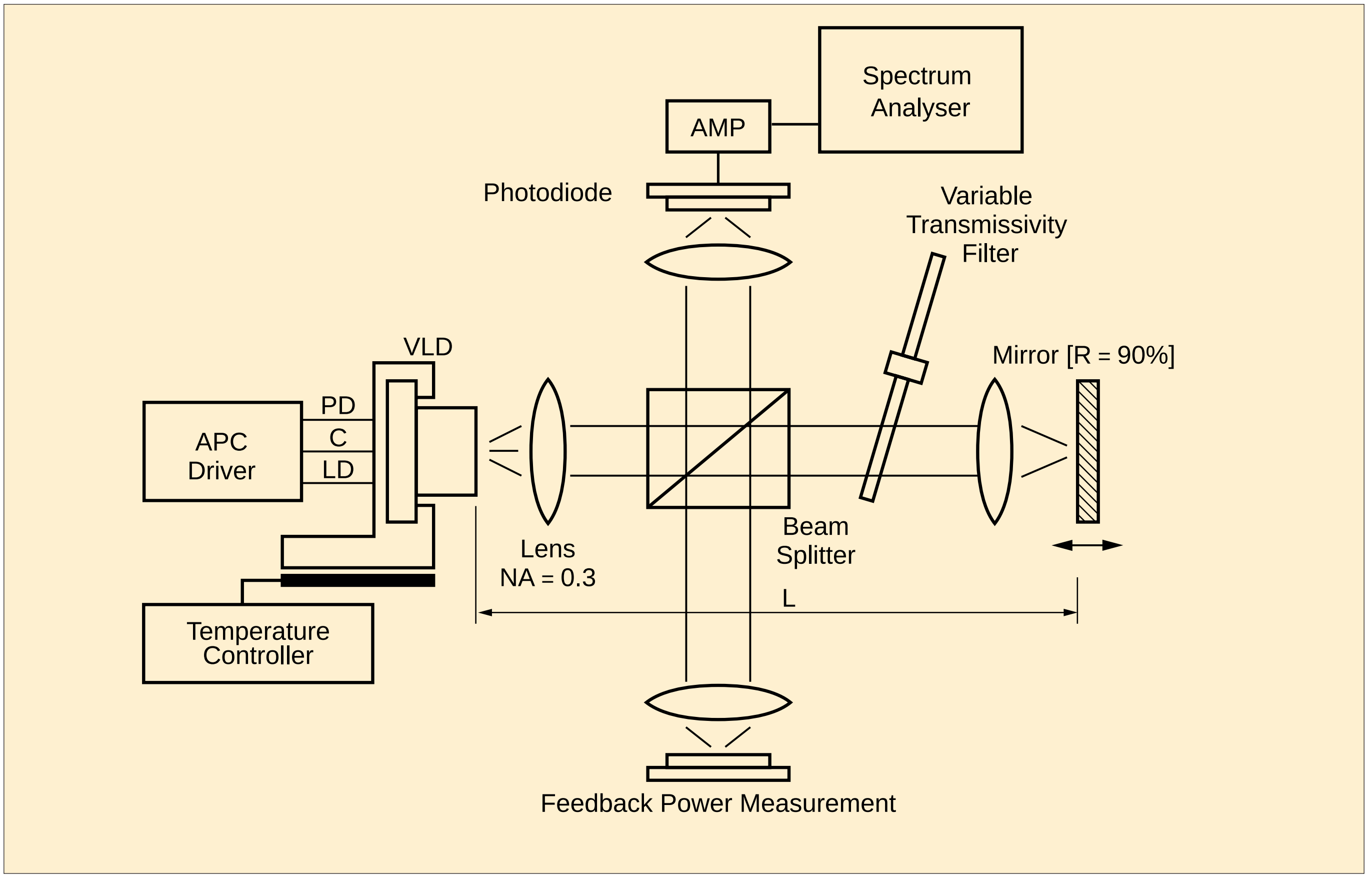


Fig. 29

Definition:

$$RIN = \frac{(P_{AC})^2}{(P_{DC})^2} \cdot \frac{1}{BW}$$

RIN = Relative Intensity Noise [Hz^{-1}]
P_{AC} = AC component of measured power
P_{DC} = DC component of measured power
BW = Measuring Bandwidth

Measurement:

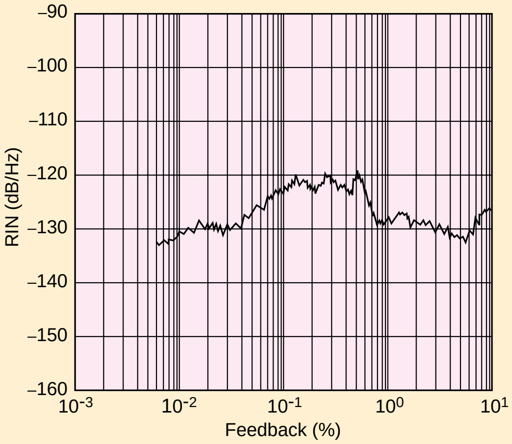
While operating the VLD in APC mode the laser output is split by means of a beam splitter. One part of the laser output is directed towards a vibrating mirror of 90% coating and reflected back towards the laser.
On return the light is again split by the beam splitter to enable measurement of the amount of light feedback.
The amount of feedback can be adjusted by means of a variable transmissivity filter.
While varying the amount of feedback the signal noise is measured by the spectrum analyser and the maximum and minimum noise levels are recorded. Alternatively by sweeping the VLD operation temperature mode-hopping noise can be measured.

Test Conditions

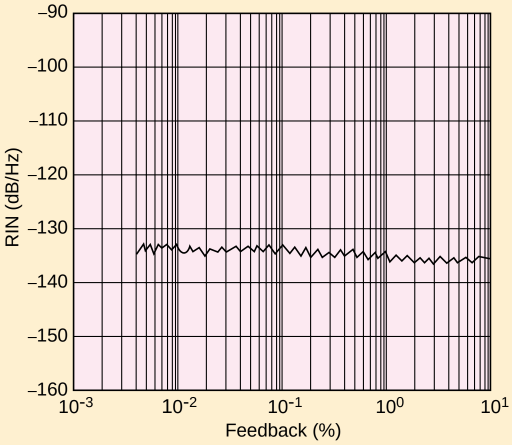
P_O (APC)	: 5 mW
NA	: 0.3
L	: 50 mm
f	: 1 MHz
BW	: 10 kHz
Feedback	: 0.001 to 10%

TOLD9441MC/MD

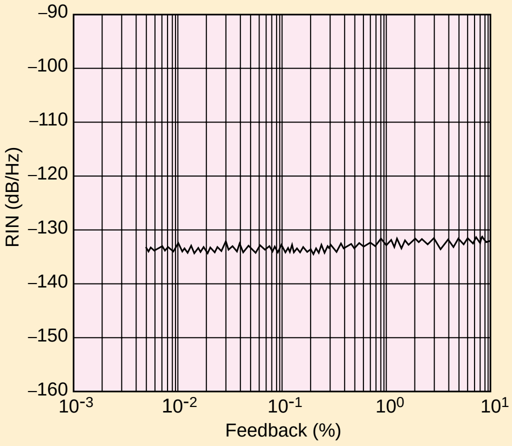
With no HF Modulation



HF Modulation 300 MHz

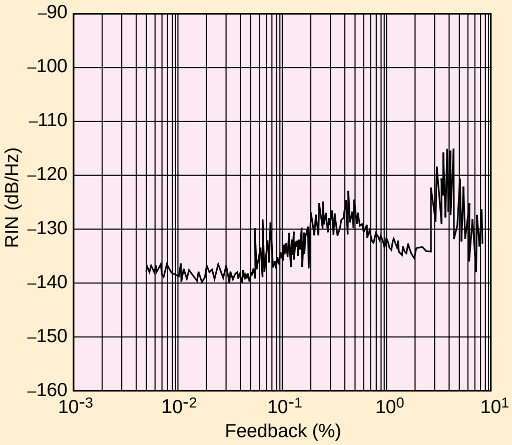


HF Modulation 500 MHz

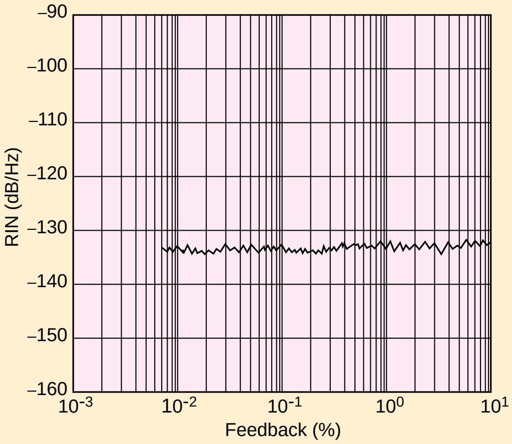


TOLD9451MB/MC

With no HF Modulation

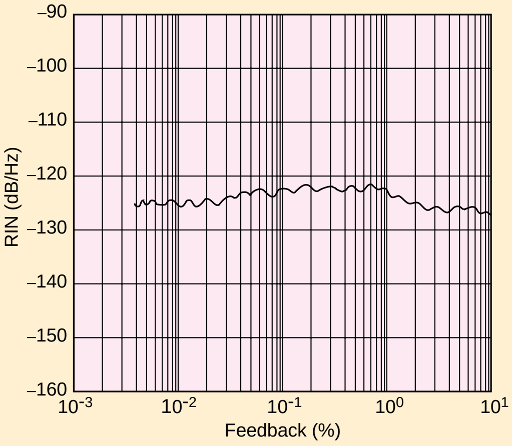


HF Modulation 300 MHz



TOLD9231M

With no HF Modulation



4. Measurement Method for Other Characteristics and Typical Data

4–4 Astigmatism (As)

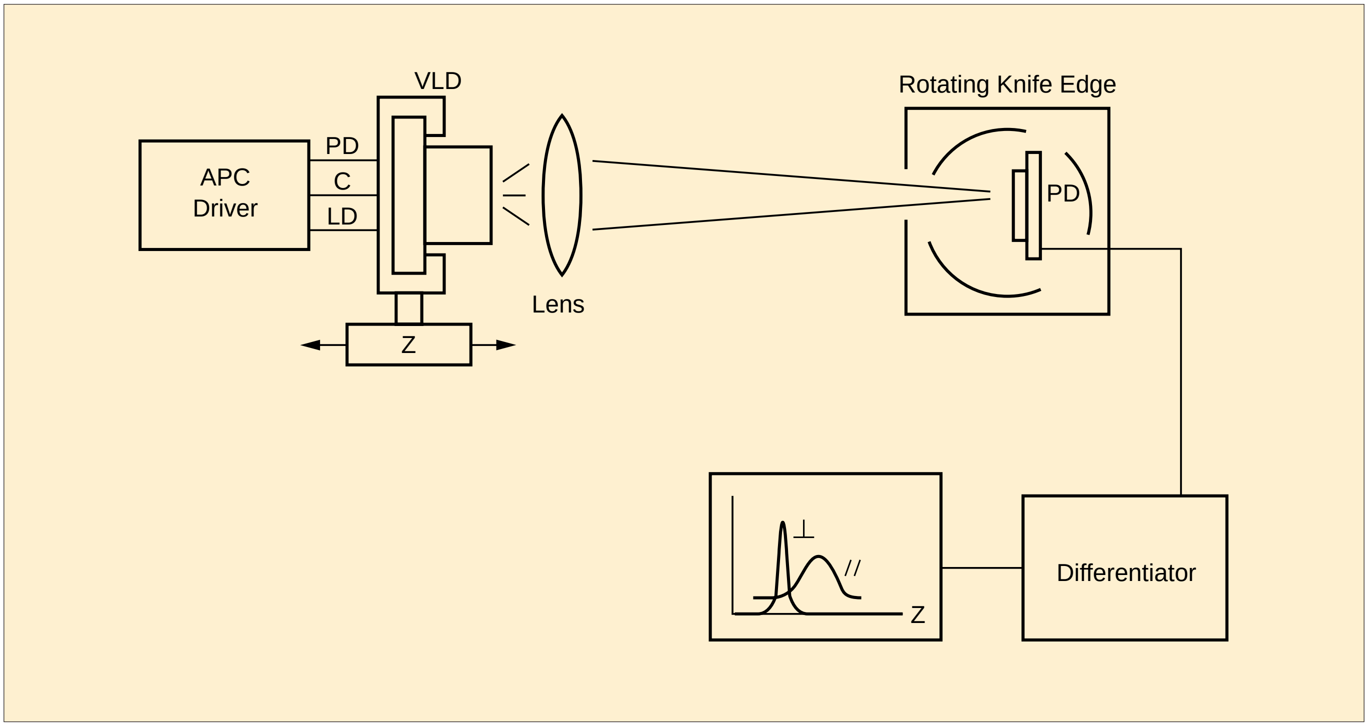


Fig. 30

Definition:

$$As = -\frac{b}{M^2 + \frac{M \cdot b}{f}}$$

As = Astigmatism
M = Magnification
f = focus length
b = difference between focal points

Measurement:

While operating the VLD in APC mode the laser output is focused onto the photodiode. This light is interrupted by a rotating knife edge in front of the photodiode. As the laserdiode position is sweeped (z-direction) the size of the spot size falling on the photodiode will change. By differentiating the output from the photodiode the slope of the transition from minimum light entering the photodiode (ie. knife edge completely blocking the light) and maximum light entering the photodiode (ie. knife edge not interrupting the light) can be obtained. The point where this slope is at a maximum represents the smallest spot size and is the focal point of the light.
By changing the direction of the rotation of the knife edges to both perpendicular and then parallel to the junction the actual focal points of the perpendicular and parallel light can be measured.

By taking into account the magnification of the lens the above equation gives the value for astigmatism, where b is the distance shown below:—

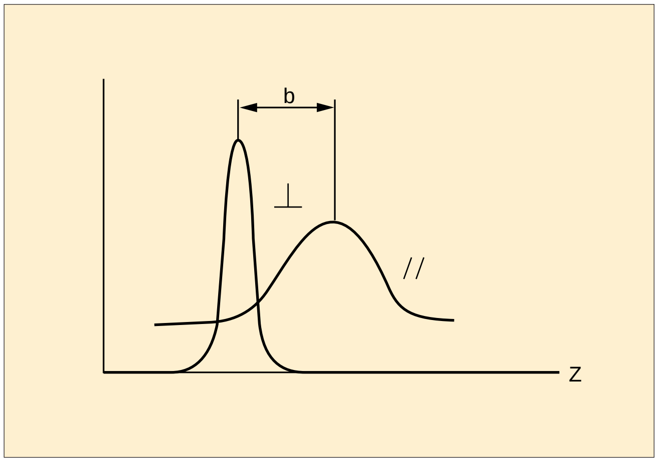


Fig. 31

Sample Data: TOLD9451MB/MC

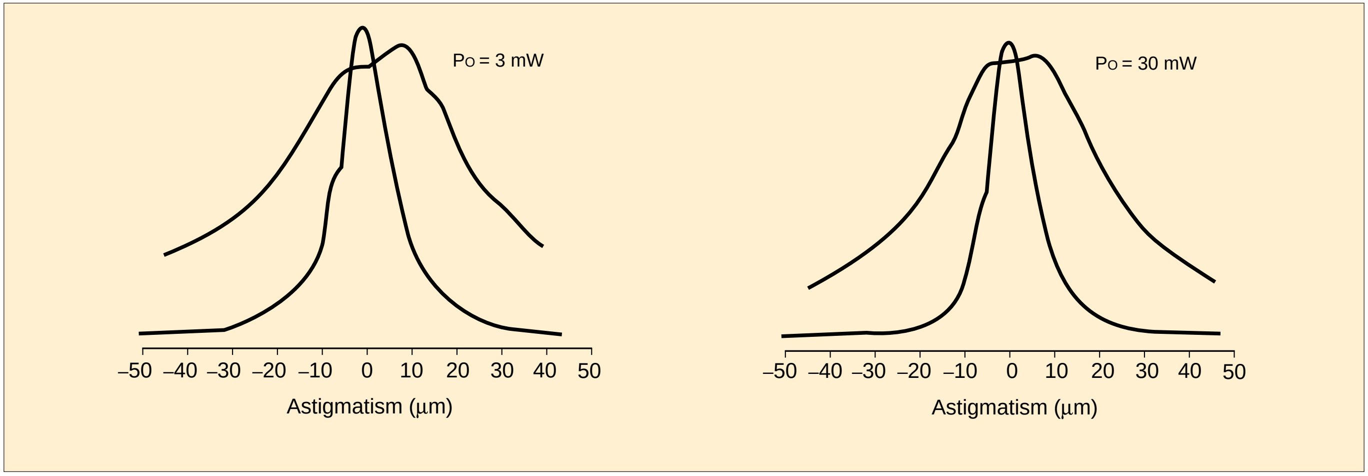


Fig. 32

Typical value:

Product No.	Test Power Po (mW)	Astigmation As (µm)
TOLD9231M	3	40
TOLD9221M	3	10
TOLD9225M	3	6
TOLD9441MC/MD	3	8
TOLD9442M/MC	3	8
TOLD9443MC/MD	3	8
TOLD9445M/MC	3	8
TOLD9451MB/MC	3	6

Table 3

Beam Waist

Since the knife edge in the set-up shown rotates at a fixed velocity the time taken to transverse the light beam can be observed using an oscilloscope (full width read at 1/e). By taking the lens into consideration the beam waist can be calculated from this data.

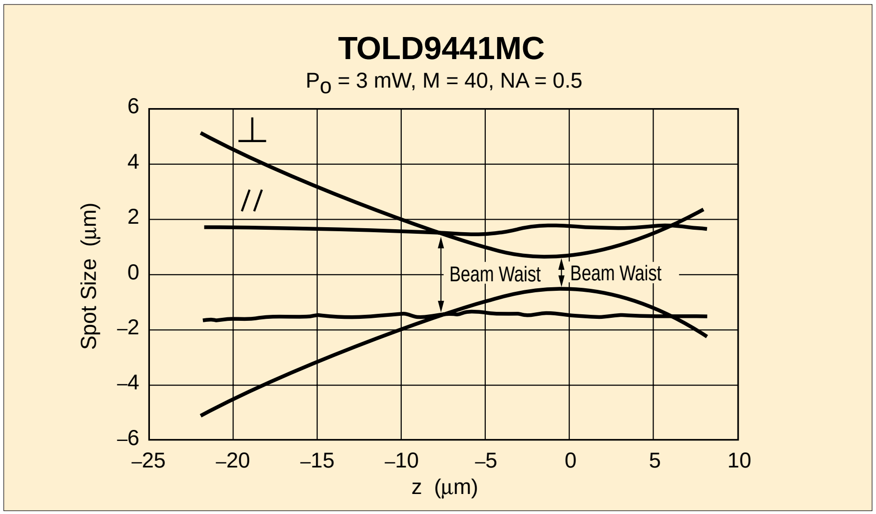


Fig. 33

5. Technical Data Sheets

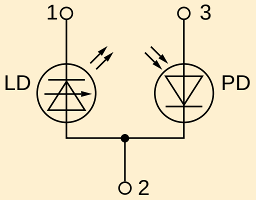
TOLD9221M

Features

- Operation current: Iop = 45 mA (typ.)
- Lasing wavelength: λp = 670 nm (typ.)
- Operation case temperature: Tc = –10 to 60˚C

Pin Connection

M Type



1. Laser diode cathode
2. Laser diode anode
   Photodiode cathode
3. Photodiode anode

Maximum Ratings/Optical-Electrical Characteristics

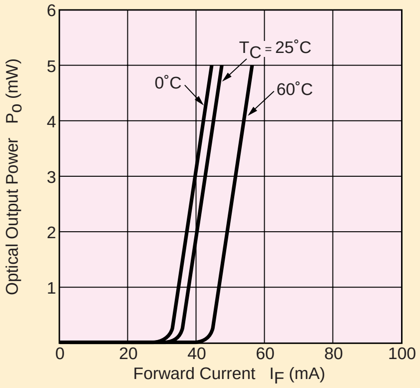
● Maximum Ratings (TC = 25˚C)

Characteristic	Symbol	Rating	Unit
Optical Output Power (CW)	P_O	5	mW
LD Reverse Voltage	$V_{R(LD)}$	2	V
PD Reverse Voltage	$V_{R(PD)}$	30	V
Operation Case Temperature	T_C	–10 to 60	˚C
Storage Temperature	T_{STG}	–40 to 85	˚C

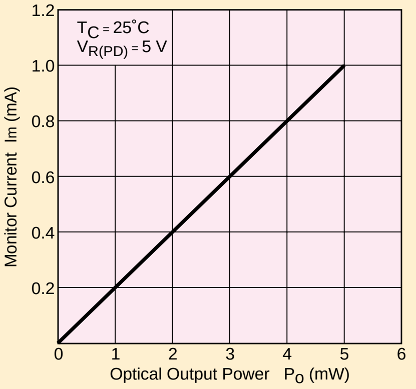
● Optical-Electrical Characteristics (TC = 25˚C)

Characteristic	Symbol	Test Condition	Min	Typ.	Max	Unit
Threshold Current	Ith	CW Operation	—	35	55	mA
Operation Current	Iop	Po = 5 mW	—	45	65	mA
Operation Voltage	Vop	Po = 5 mW	—	2.2	2.8	V
Lasing Wavelength	λp	Po = 5 mW	660	670	680	nm
Beam Divergence	$\theta_{\parallel}$	Po = 5 mW	5	8	11	°
	$\theta_{\perp}$	Po = 5 mW	24	30	35	°
Monitor Current	Im	Po = 5 mW	0.3	1.0	1.9	mA
PD Dark Current	ID(PD)	VR = 5 V	—	—	100	nA
PD Total Capacitance	CT(PD)	VR = 5 V, f = 1 MHz	—	—	20	pF

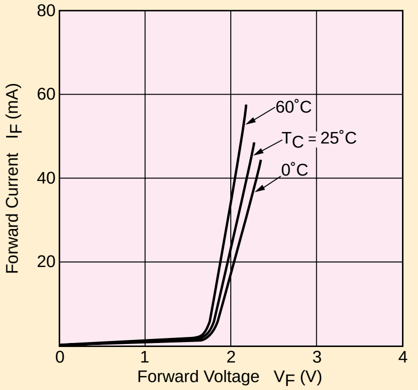
Optical Output Power vs. Forward Current



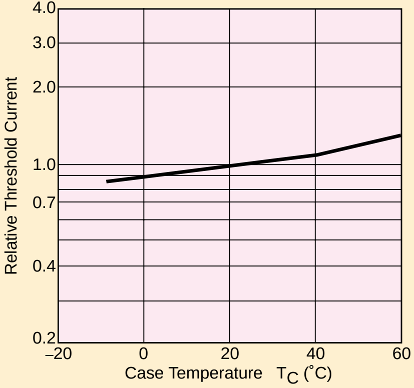
Monitor Current vs. Optical Output Power



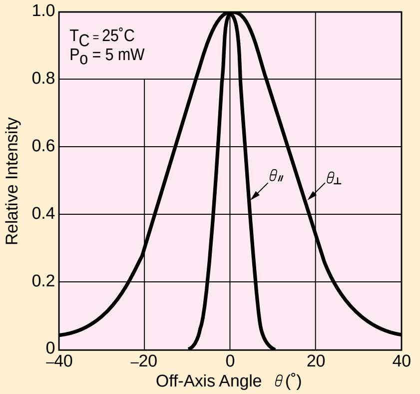
Forward Current vs. Forward Voltage



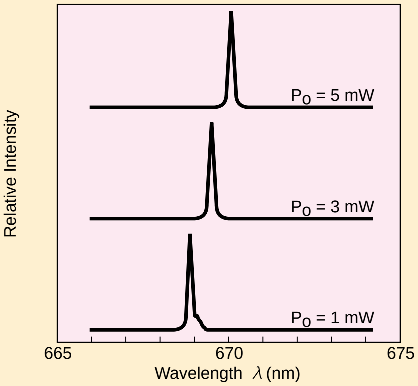
Case Temperature Dependence of Threshold Current



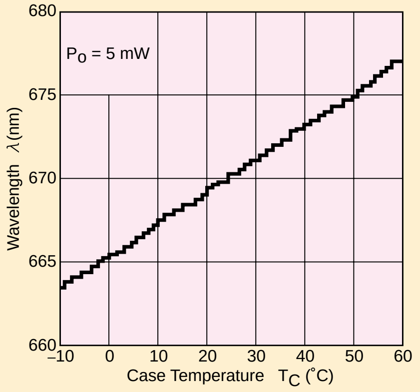
Far-Field Patterns



Lasing Spectrum



Case Temperature Dependence of Lasting Wavelength



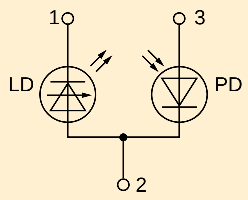
TOLD9231M

Features

- Operation current: Iop = 60 mA (typ.)
- Lasing wavelength: λp = 670 nm (typ.)
- Operation case temperature: Tc = –10 to 60˚C

Pin Connection

M Type



1. Laser diode cathode
2. Laser diode anode
   Photodiode cathode
3. Photodiode anode

Maximum Ratings/Optical-Electrical Characteristics

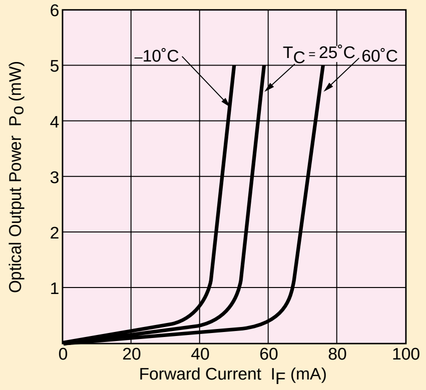
● Maximum Ratings (T_C = 25˚C)

Characteristic	Symbol	Rating	Unit
Optical Output Power (CW)	P_O	5	mW
LD Reverse Voltage	$V_{R(LD)}$	2	V
PD Reverse Voltage	$V_{R(PD)}$	30	V
Operation Case Temperature	T_C	–10 to 60	˚C
Storage Temperature	T_{STG}	–40 to 85	˚C

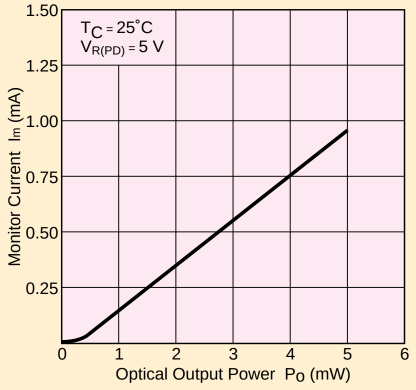
● Optical-Electrical Characteristics (T_C = 25˚C)

Characteristic	Symbol	Test Condition	Min	Typ.	Max	Unit
Threshold Current	Ith	CW Operation	—	50	75	mA
Operation Current	Iop	Po = 5 mW	—	60	85	mA
Operation Voltage	Vop	Po = 5 mW	—	2.3	3.0	V
Lasing Wavelength	λp	Po = 5 mW	660	670	680	nm
Beam Divergence	$\theta_{\parallel}$	Po = 5 mW	7	10	16	°
	$\theta_{\perp}$	Po = 5 mW	26	32	38	°
Monitor Current	Im	Po = 5 mW	0.25	0.9	1.7	mA
PD Dark Current	ID(PD)	VR = 5 V	—	—	100	nA
PD Total Capacitance	CT(PD)	VR = 5 V, f = 1 MHz	—	—	20	pF

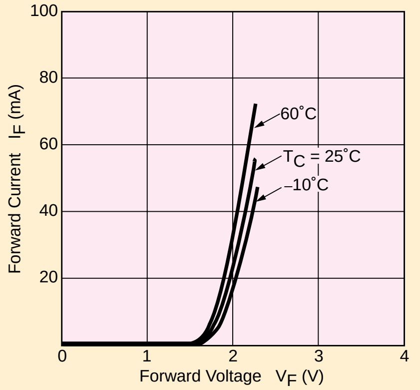
Optical Output Power vs. Forward Current



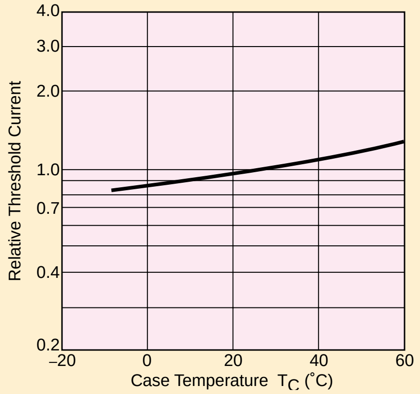
Monitor Current vs. Optical Output Power



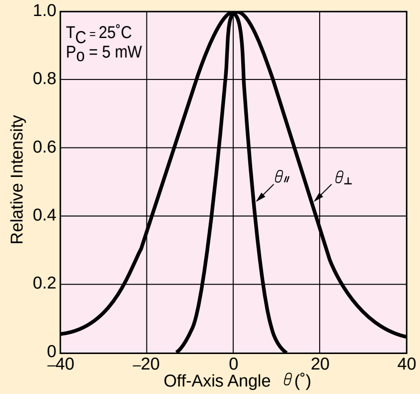
Forward Current vs. Forward Voltage



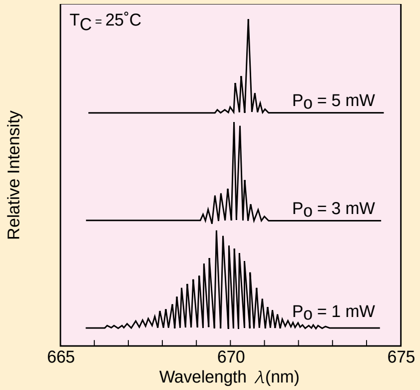
Case Temperature Dependence of Threshold Current



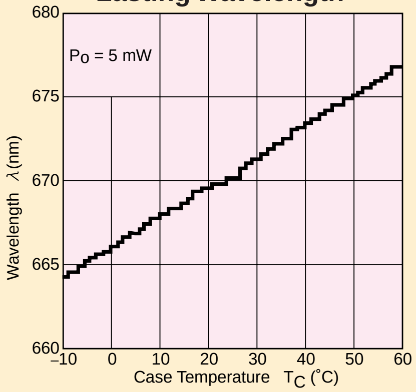
Far-Field Patterns



Lasing Spectrum



Case Temperature Dependence of Lasting Wavelength



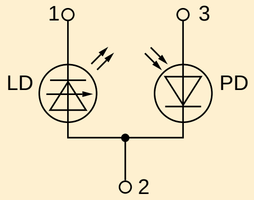
TOLD9225M

Features

- Operation current: Iop = 60 mA (typ.)
- Lasing wavelength: λp = 670 nm (typ.)
- Operation case temperature: Tc = –10 to 60˚C

Pin Connection

M Type



1. Laser diode cathode
2. Laser diode anode
   Photodiode cathode
3. Photodiode anode

Maximum Ratings/Optical-Electrical Characteristics

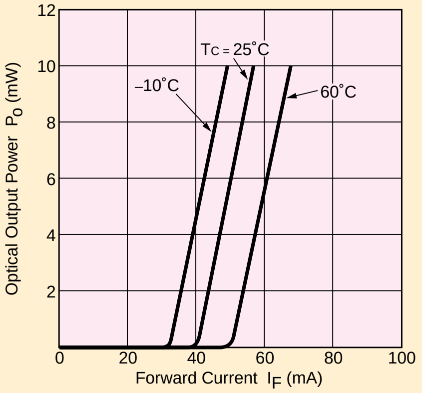
● Maximum Ratings (T_C = 25˚C)

Characteristic	Symbol	Rating	Unit
Optical Output Power (CW)	P_O	10	mW
LD Reverse Voltage	$V_{R(LD)}$	2	V
PD Reverse Voltage	$V_{R(PD)}$	30	V
Operation Case Temperature	T_C	–10 to 60	˚C
Storage Temperature	T_{STG}	–40 to 85	˚C

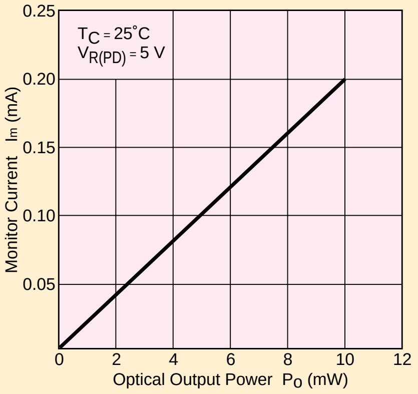
● Optical-Electrical Characteristics (T_C = 25˚C)

Characteristic	Symbol	Test Condition	Min	Typ.	Max	Unit
Threshold Current	Ith	CW Operation	—	40	60	mA
Operation Current	Iop	Po = 10 mW	—	60	80	mA
Operation Voltage	Vop	Po = 10 mW	—	2.4	3.0	V
Lasing Wavelength	λp	Po = 10 mW	660	670	680	nm
Beam Divergence	$\theta_{\parallel}$	Po = 10 mW	5	8	11	°
	$\theta_{\perp}$	Po = 10 mW	15	18	23	°
Monitor Current	Im	Po = 10 mW	0.1	0.2	0.5	mA
PD Dark Current	ID(PD)	VR = 5 V	—	—	100	nA
PD Total Capacitance	CT(PD)	VR = 5 V, f = 1 MHz	—	—	20	pF

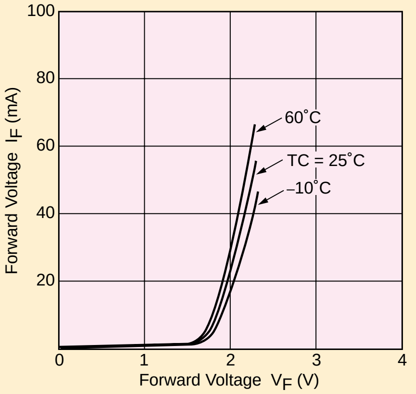
Optical Output Power vs. Forward Current



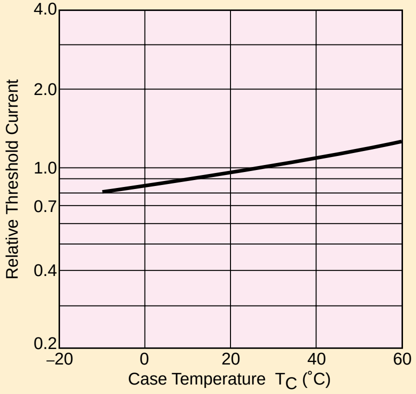
Monitor Current vs. Optical Output Power



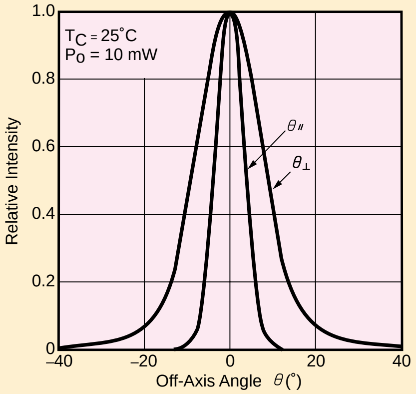
Forward Current vs. Forward Voltage



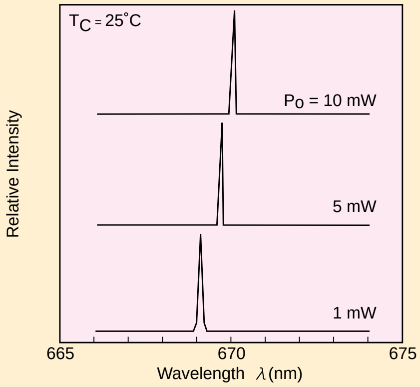
Case Temperature Dependence of Threshold Current



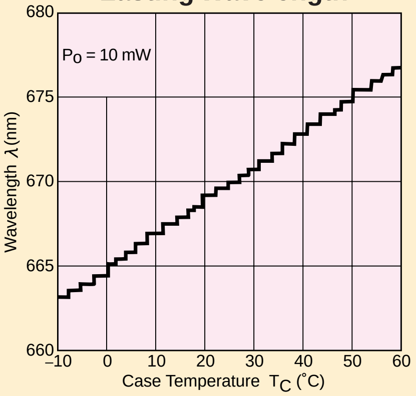
Far-Field Patterns



Lasing Spectrum



Case Temperature Dependence of Lasting Wavelength



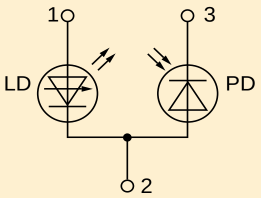
TOLD9441MC/MD

Features

- Lasing wavelength: λp = 650 nm (typ.)
- Operation case temperature: Tc = –10 to 70˚C
- Frequency characteristic has been improved because impedance is lowered.

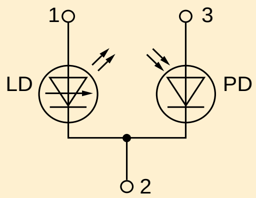
Pin Connection

MC Type



1. Laser diode anode
2. Laser diode cathode
   Photodiode anode
3. Photodiode cathode

MD Type



1. Laser diode anode
2. Laser diode cathode
   Photodiode cathode
3. Photodiode anode

Maximum Ratings/Optical-Electrical Characteristics

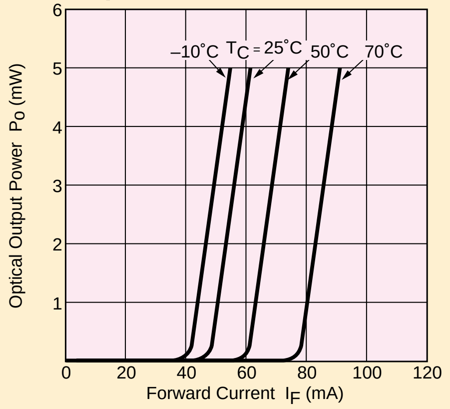
Maximum Ratings (TC = 25˚C)

Characteristic	Symbol	Rating	Unit
Optical Output Power (CW)	P_O	7	mW
LD Reverse Voltage	$V_{R(LD)}$	2	V
PD Reverse Voltage	$V_{R(PD)}$	30	V
Operation Case Temperature	T_C	–10 to 70	˚C
Storage Temperature	T_{STG}	–40 to 85	˚C

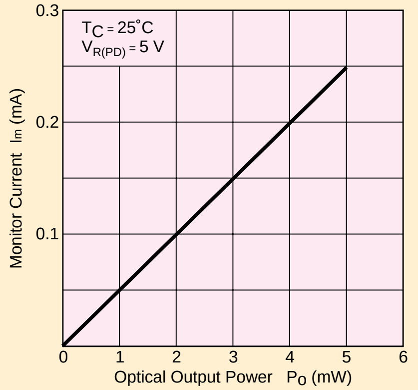
Optical-Electrical Characteristics (TC = 25˚C)

Characteristic	Symbol	Test Condition	Min	Typ.	Max	Unit
Threshold Current	Ith	CW Operation	—	40	70	mA
Operation Current	Iop	Po = 5 mW	—	50	80	mA
Operation Voltage	Vop	Po = 5 mW	—	2.2	3.0	V
Lasing Wavelength	λp	Po = 5 mW	640	650	660	nm
Beam Divergence	$\theta_{\parallel}$	Po = 5 mW	5	8	12	°
	$\theta_{\perp}$	Po = 5 mW	24	28	35	°
Monitor Current	Im	Po = 5 mW	0.07	0.25	0.5	mA
PD Dark Current	ID(PD)	VR = 5 V	—	—	100	nA
PD Total Capacitance	CT(PD)	VR = 5 V, f = 1 MHz	—	—	20	pF

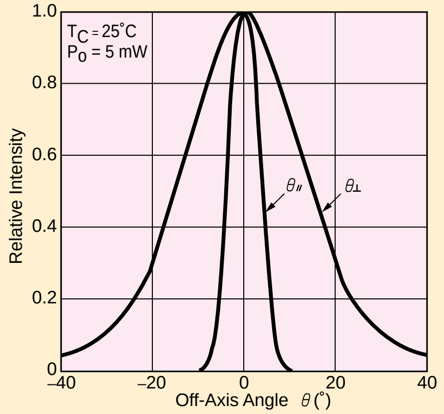
Optical Output Power vs. Forward Current



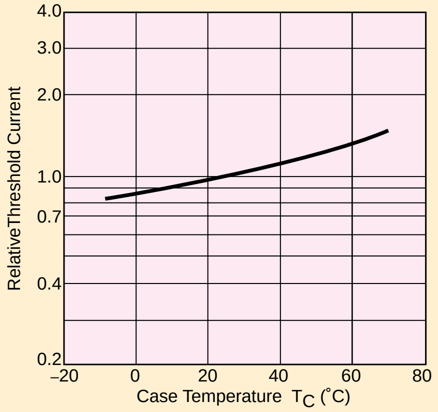
Monitor Current vs. Optical Output Power



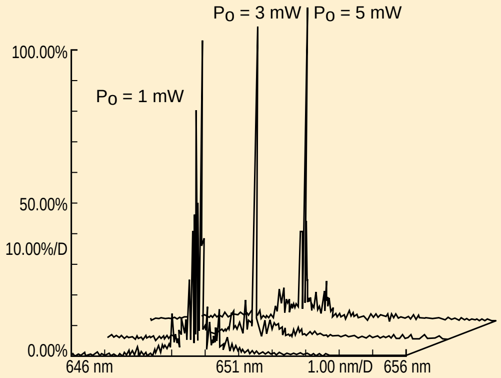
Far-Field Patterns



Case Temperature Dependence of Threshold Current

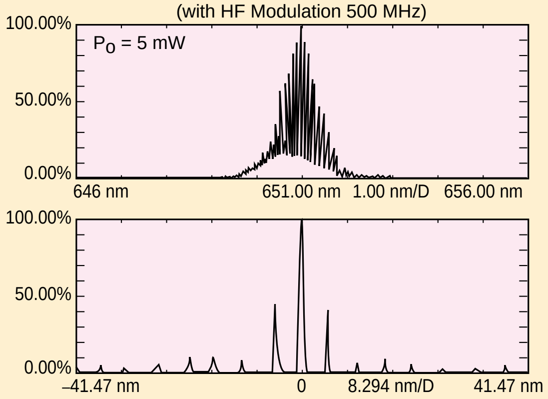


Lasing Spectrum



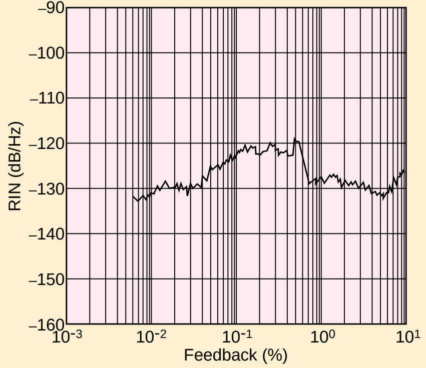
Lasing Spectrum and Visibility

(with HF Modulation 500 MHz)



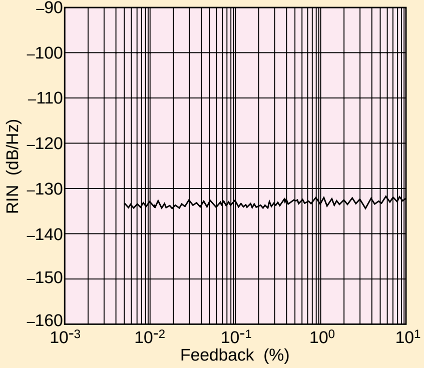
RIN (With no HF Modulation)

P_O = 5 mW L = 50 mm NA = 0.3 ACC
f = 1 MHz BW = 10 kHz fm = 50 Hz



RIN (With HF Modulation 500 MHz)

P_O = 5 mW(AVG.) L = 50 mm NA = 0.3 ACC
f = 1 MHz BW = 10 kHz fm = 50 Hz



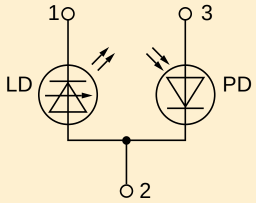
TOLD9442M/MC

Features

- Operation current: Iop = 35 mA (typ.)
- Lasing wavelength: λ_p = 650 nm (typ.)
- Operation case temperature: Tc = –10 to 60˚C

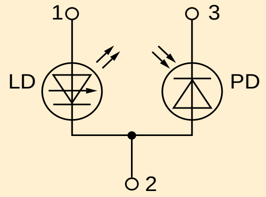
Pin Connection

M Type



1. Laser diode cathode
2. Laser diode anode
   Photodiode cathode
3. Photodiode anode

MC Type



1. Laser diode anode
2. Laser diode cathode
   Photodiode anode
3. Photodiode cathode

Maximum Ratings/Optical-Electrical Characteristics

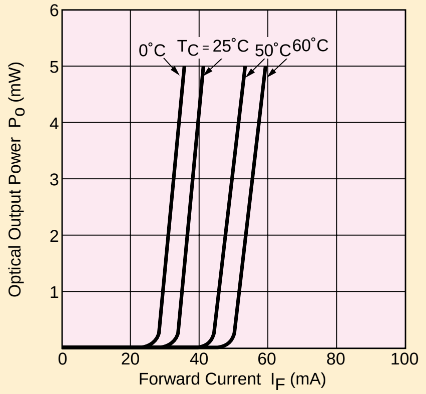
● Maximum Ratings (TC = 25˚C)

Characteristic	Symbol	Rating	Unit
Optical Output Power (CW)	P_O	5	mW
LD Reverse Voltage	$V_{R(LD)}$	2	V
PD Reverse Voltage	$V_{R(PD)}$	30	V
Operation Case Temperature	T_C	–10 to 60	˚C
Storage Temperature	T_{STG}	–40 to 85	˚C

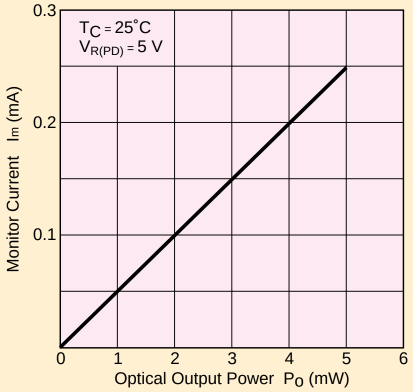
● Optical-Electrical Characteristics (TC = 25˚C)

Characteristic	Symbol	Test Condition	Min	Typ.	Max	Unit
Threshold Current	Ith	CW Operation	—	30	55	mA
Operation Current	Iop	Po = 5 mW	—	35	60	mA
Operation Voltage	Vop	Po = 5 mW	—	2.2	2.7	V
Lasing Wavelength	λ_p	Po = 5 mW	645	650	655	nm
Beam Divergence	$\theta_{\parallel}$	Po = 5 mW	5	8	12	°
	$\theta_{\perp}$	Po = 5 mW	24	28	35	°
Monitor Current	Im	Po = 5 mW	0.07	0.25	0.35	mA
PD Dark Current	ID(PD)	VR = 5 V	—	—	100	nA
PD Total Capacitance	CT(PD)	VR = 5 V, f = 1 MHz	—	—	20	pF

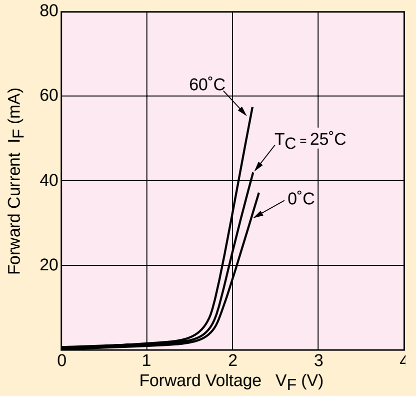
Optical Output Power vs. Forward Current



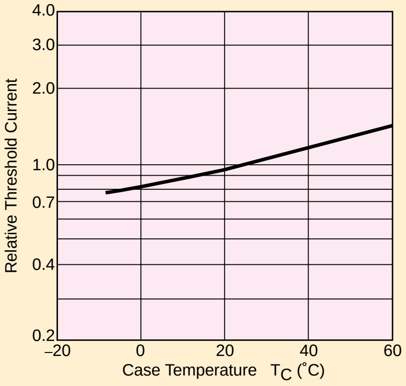
Monitor Current vs. Optical Output Power



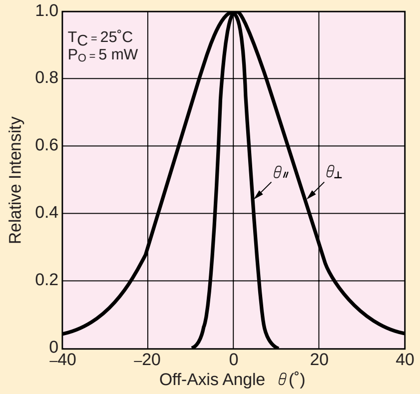
Forward Current vs. Forward Voltage



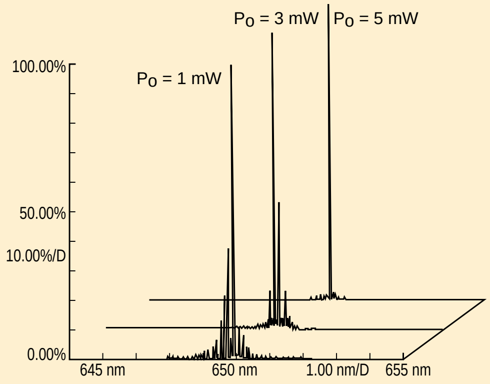
Case Temperature Dependence of Threshold Current



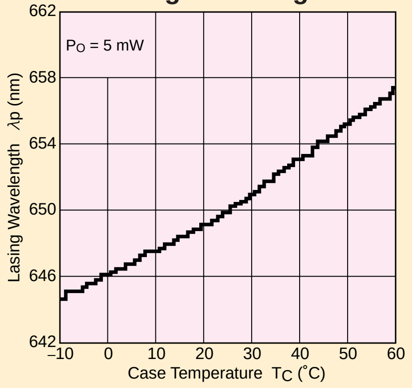
Far-Field Patterns



Lasing Spectrum



Case Temperature Dependence of Lasting Wavelength



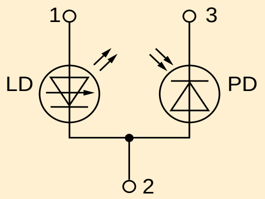
TOLD9443MC/MD

Features

- Lasing wavelength: λp = 650 nm (typ.)
- Operation case temperature: Tc = –10 to 70˚C
- Frequency characteristic has been improved because impedance is lowered.

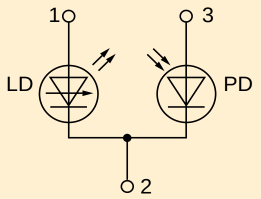
Pin Connection

MC Type



1. Laser diode anode
2. Laser diode cathode
   Photodiode anode
3. Photodiode cathode

MD Type



1. Laser diode anode
2. Laser diode cathode
   Photodiode cathode
3. Photodiode anode

Maximum Ratings/Optical-Electrical Characteristics

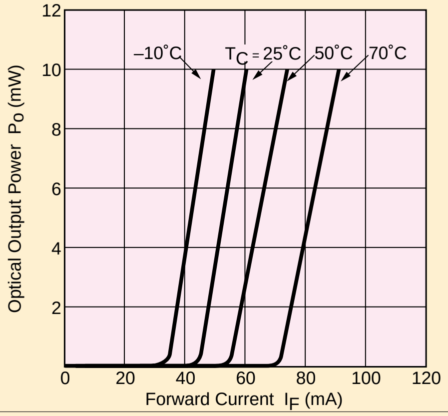
● Maximum Ratings (TC = 25˚C)

Characteristic	Symbol	Rating	Unit
Optical Output Power (CW)	P_O	10	mW
LD Reverse Voltage	$V_{R(LD)}$	2	V
PD Reverse Voltage	$V_{R(PD)}$	30	V
Operation Case Temperature	T_C	–10 to 70	˚C
Storage Temperature	T_{STG}	–40 to 85	˚C

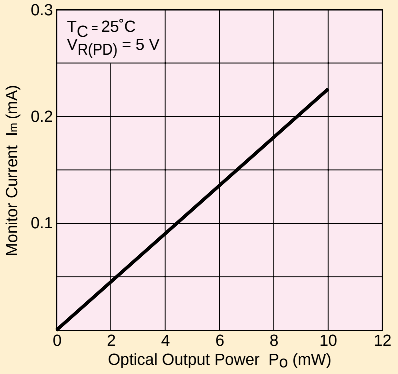
● Optical-Electrical Characteristics (TC = 25˚C)

Characteristic	Symbol	Test Condition	Min	Typ.	Max	Unit
Threshold Current	Ith	CW Operation	—	45	65	mA
Operation Current	Iop	Po = 10 mW	—	60	80	mA
Operation Voltage	Vop	Po = 10 mW	—	2.2	2.5	V
Lasing Wavelength	λp	Po = 10 mW	640	650	660	nm
Beam Divergence	$\theta_{\parallel}$	Po = 10 mW	5	8	12	°
	$\theta_{\perp}$	Po = 10 mW	24	28	35	°
Monitor Current	Im	Po = 10 mW	0.1	0.2	0.5	mA
PD Dark Current	ID(PD)	VR = 5 V	—	—	100	nA
PD Total Capacitance	CT(PD)	VR = 5 V, f = 1 MHz	—	—	20	pF

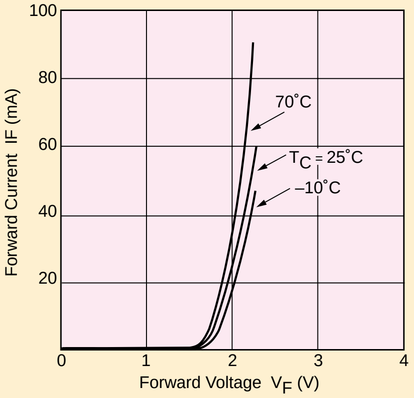
Optical Output Power vs. Forward Current



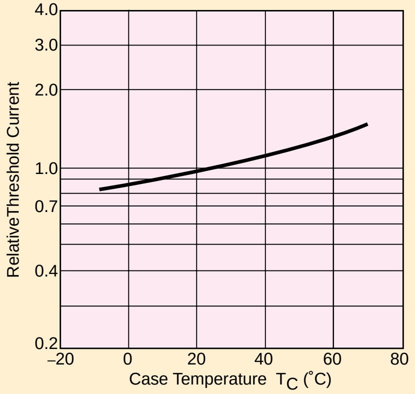
Monitor Current vs. Optical Output Power



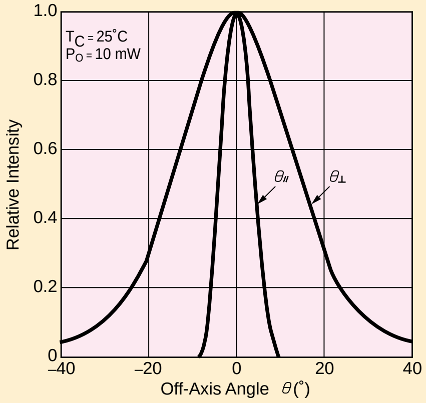
Forward Current vs. Forward Voltage



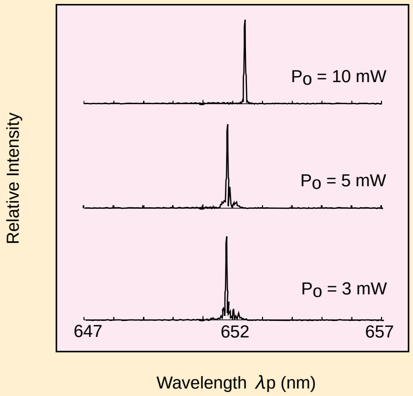
Case Temperature Dependence of Threshold Current



Far-Field Patterns

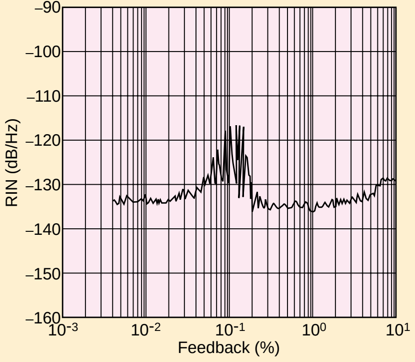


Lasing Spectrum



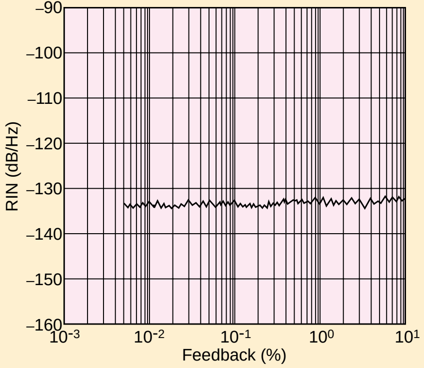
RIN (With no HF Modulation)

P_O = 5 mW L = 50 mm NA = 0.3 ACC
f = 1 MHz BW = 10 kHz fm = 50 Hz



RIN (With HF Modulation 500 MHz)

P_O = 5 mW(AVG.) L = 50 mm NA = 0.3 ACC
f = 1 MHz BW = 10 kHz fm = 50 Hz



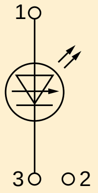
TOLD9451MB/MC

Features

- Lasing wavelength: λ_p = 658 nm (typ.)
- Optical output power: Po = 30 mV (CW)/50 mW (pulse)
- Frequency characteristic has been improved because impedance is lowered.

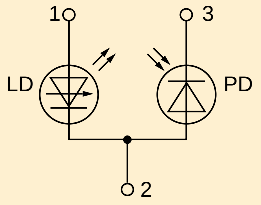
Pin Connection

MB Type



1. Laser diode anode
2. Case
3. Laser diode cathode

MC Type



1. Laser diode anode
2. Laser diode cathode
   Photodiode anode
3. Photodiode cathode

Maximum Ratings/Optical-Electrical Characteristics

● Maximum Ratings (TC = 25˚C)

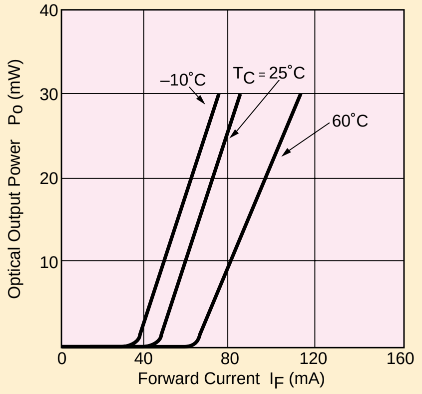
Characteristic	Symbol	Rating	Unit
Optical Output Power (CW)	P_O	30	mW
Optical Output Power (Pulse) Note (1)	P_O	50	mW
LD Reverse Voltage	$V_{R(LD)}$	2	V
PD Reverse Voltage Note (2)	$V_{R(PD)}$	30	V
Operation Case Temperature	T_C	–10 to 60	˚C
Storage Temperature	T_{STG}	–40 to 85	˚C

● Optical-Electrical Characteristics (TC = 25˚C)

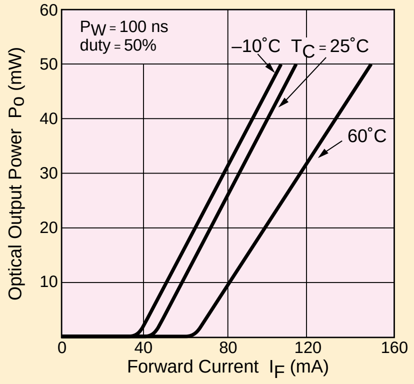
Characteristic	Symbol	Test Condition	Min	Typ.	Max	Unit
Threshold Current	Ith	CW Operation	—	45	70	mA
Operation Current	Iop	Po = 30 mW (CW)	—	85	120	mA
Operation Voltage	Vop	Po = 30 mW (CW)	—	2.4	2.8	V
Lasing Wavelength	λp	Po = 30 mW (CW)	650	658	655	nm
Beam Divergence	$\theta_{\parallel}$	Po = 30 mW (CW)	7	9	11	°
	$\theta_{\perp}$	Po = 30 mW (CW)	19	22	25	°
Monitor Current Note (2)	Im	Po = 30 mW (CW)	0.02	0.1	0.5	mA
PD Dark Current Note (2)	ID(PD)	VR = 5 V	—	—	100	nA
PD Total Capacitance Note (2)	CT(PD)	VR = 5 V, f = 1 MHz	—	—	20	pF

Note (1) Pulse Condition : Pulse Width 100 ns, Duty Cycle 50%
Note (2) For MC type only

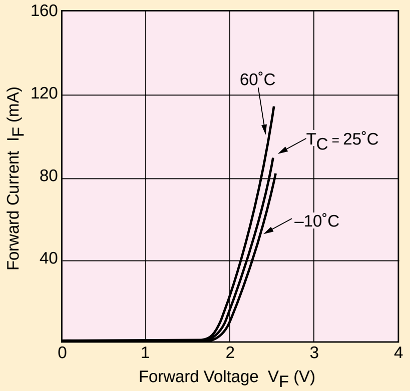
Optical Output Power vs. Forward Current (CW)



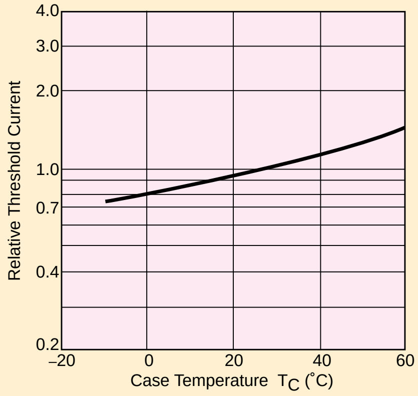
Optical Output Power vs. Forward Current (Pulse)



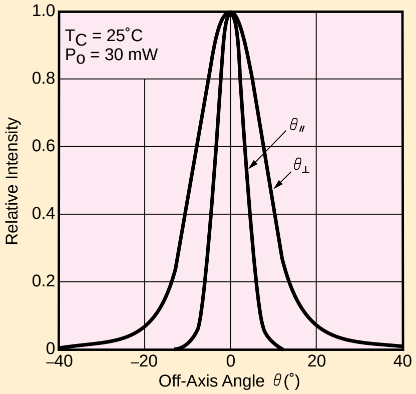
Forward Current vs. Forward Voltage



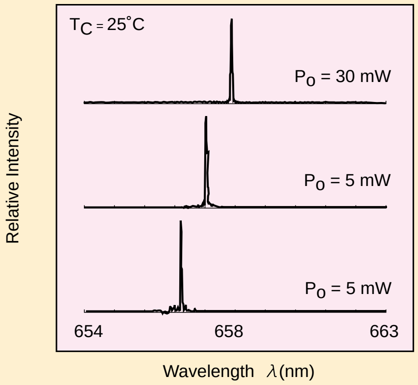
Case Temperature Dependence of Threshold Current



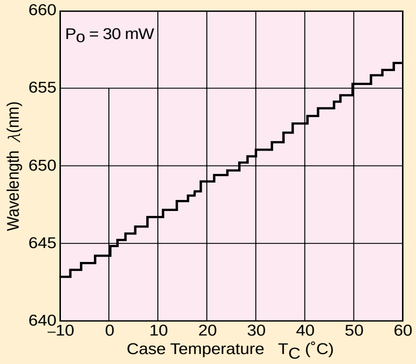
Far-Field Patterns



Lasing Spectrum

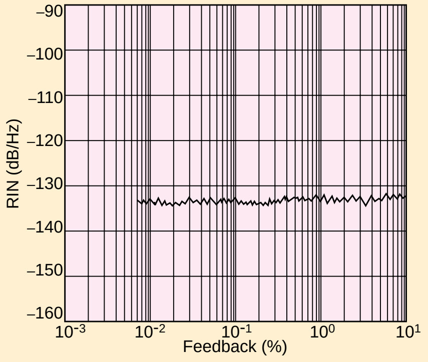


Case Temperature Dependence of Lasting Wavelength



RIN (with HF Modulation)

P_O = 5 mW (AVG.) L = 50 mm NA = 0.3 ACC f = 1 MHz
BW = 10 kHz fm = 50 Hz Vf = 100Hz HF = 300MHz



Characteristics of Internal Monitor Photodiode

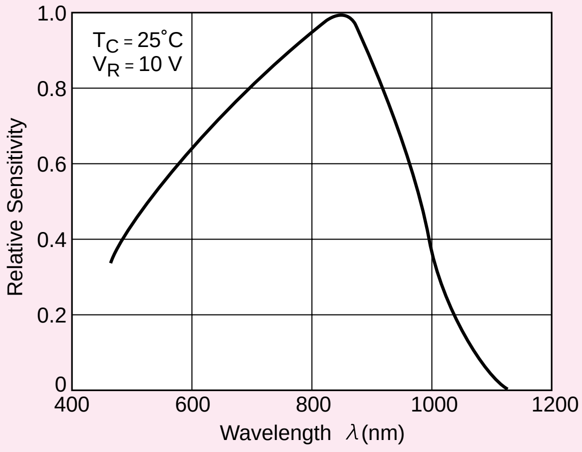
Internal Monitor Photodiode

Maximum Ratings and Electrical Characteristics (Tc = 25˚C)

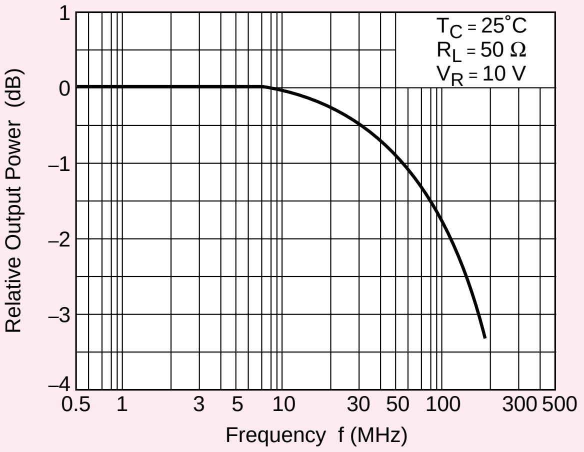
Characteristic	Symbol	Test Condition	Max	Unit
Reverse Voltage	$V_{R(PD)}$	—	30	V
Dark Current	$I_{D(PD)}$	V_R = 10 V	100	nA
Total Capacitance	$C_{T(PD)}$	V_R = 10 V, f = 1 MHz	20	pF

Examples of Typical Characteristics

■ Sensitivity vs. Wavelength



■ Frequency Response



6. Usage Precautions

6–1 Damage to Laser Diodes

When a laser diode outputs light in excess of its rated optical output, at a certain point the optical output will suddenly decrease, as shown in Fig. 34.
This is because the optical output from the facet of the chip becomes excessive, damaging the mirror surface of the Fabry-Perot cavity.
This phenomenon is called catastrophic optical damage (COD), since damage is caused to the optical part of the laser chip.

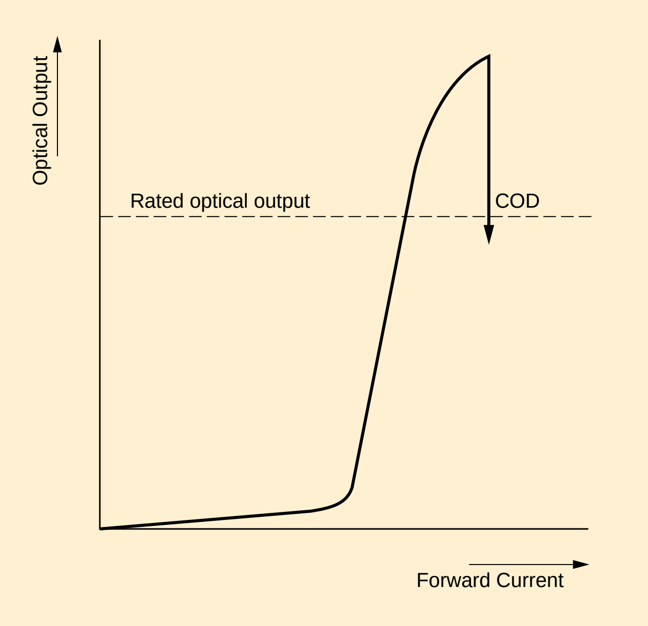


Fig. 34 COD

The center of the near-field pattern on the facet of the laser chip at which COD occurred is partly darkened (see Fig. 35).
The characteristics of a laser which has been damaged in this way will deteriorate: the specified optical output will no longer be achieved or the far-field pattern will become fragmented (see Fig. 37).
In the worst case, no laser beam will be obtained at all (see Fig. 36).

Therefore, when handling laser diodes, care must be taken not to cause COD.

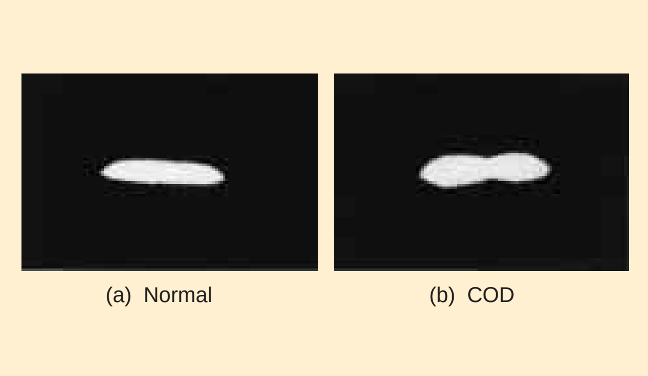

(a) Normal (b) COD

Fig. 35 Near-Field Patterns

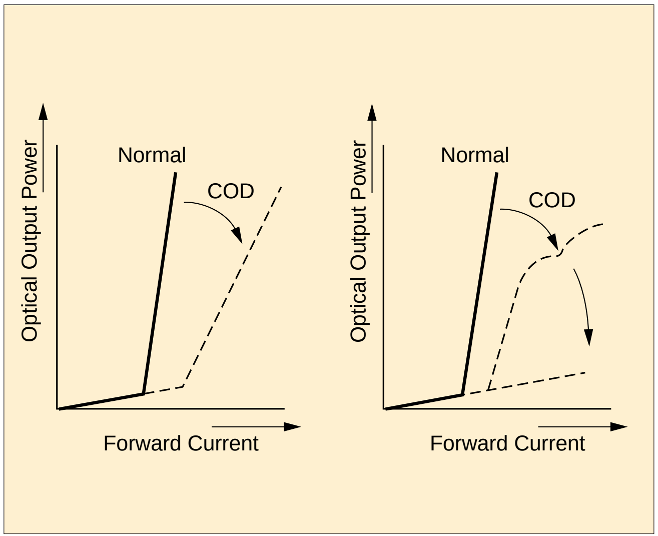


Fig. 36 Optical Output Power vs. Forward Current Characteristics

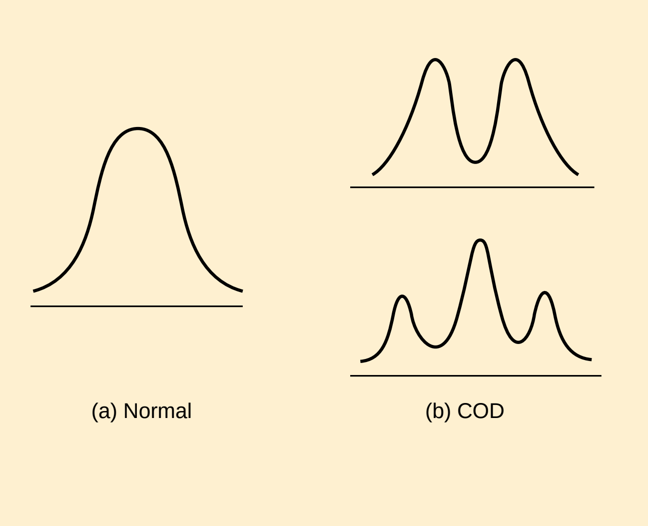

(a) Normal (b) COD

Fig. 37 Far-Field Patterns

6. Usage Precautions

6–2 Handling Precautions

1) Precautions against electro static

Laser diodes can be driven using a low operation voltage and low operation current.
Also, these devices feature quick response.
As a result, small surges, such as surges due to electro static, can easily affect laser diodes.
Fig. 39 shows an example of a test for electro static damage to a laser diode.
A electro static surge of as little as several tens of volts can cause deterioration in device characteristics.

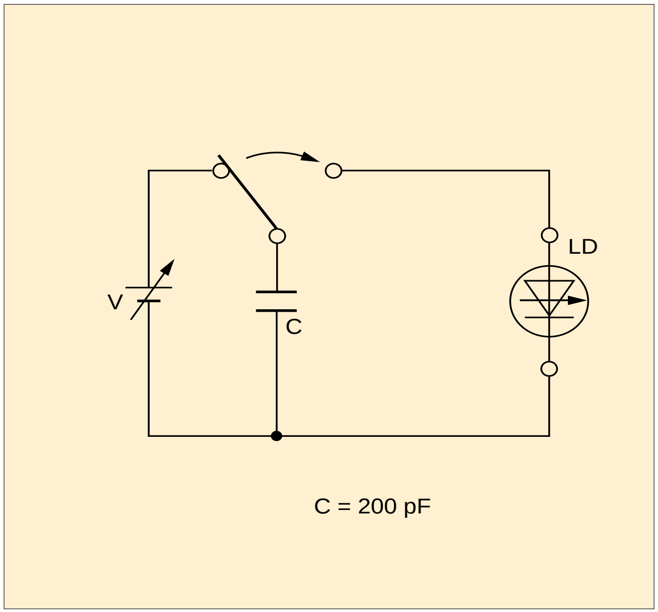


Fig. 38 Electro Static Damage Test Circuit

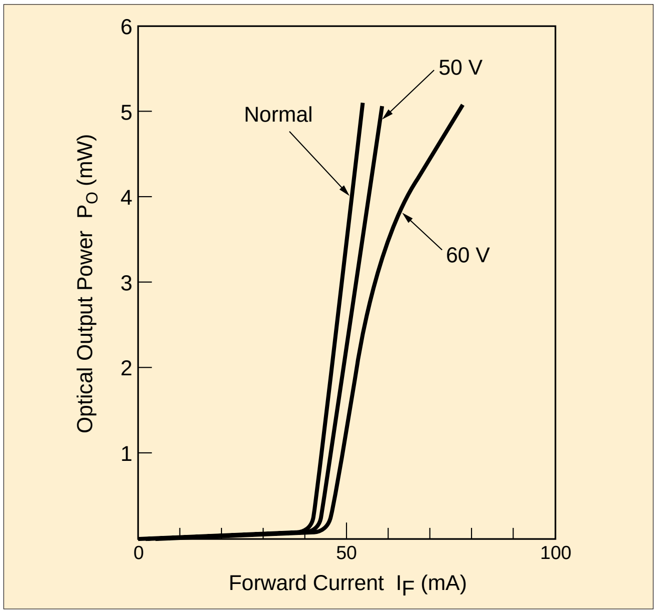


Fig. 39 Example of Electro Static Damage Testing

When handling laser diodes, take the following measures to prevent the laser from being damaged or otherwise adversely affected.

1) Use a conductive table mat and conductive floor mat, and ground the work bench and floor.
2) Operators handling laser diodes must be grounded via a high resistance (about 1 MΩ. A conductive strap is good for this purpose.
3) Ground all tools including soldering irons.

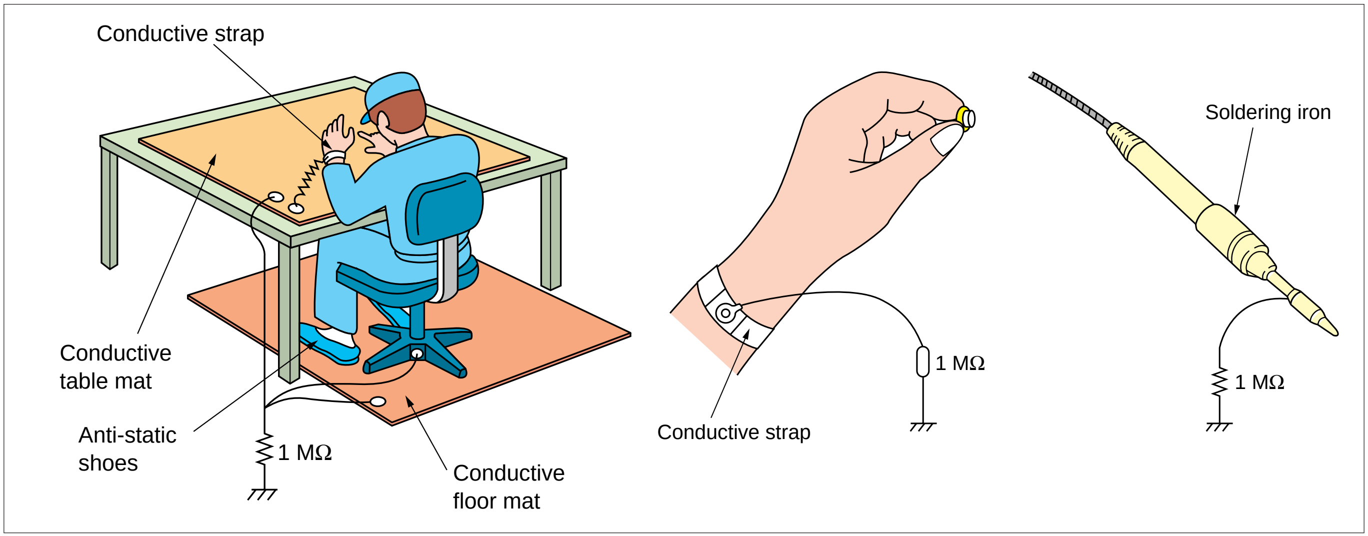


Fig. 40 Anti-Static Measures

2) Precautions for drive circuits

Before operation, check that the device's maximum ratings will not be exceeded due to spike currents caused by the power being switched on and off. If chatter or overshoot is observed, eliminate the problem by inserting a filter such as a CR circuit or a slow-start circuit (see Fig. 41).

If overshoot occurs in the optical waveform during pulse operation, either eliminate the overshoot or adjust the optical output so that the overshoot does not exceed the maximum rating (see Fig. 42).

Do not connect or disconnect an oscilloscope probe or voltmeter cable during operation.
Doing so may cause an unexpected surge, resulting in damage to the laser diode.
Eliminate any noise on the AC line using an AC line filter.

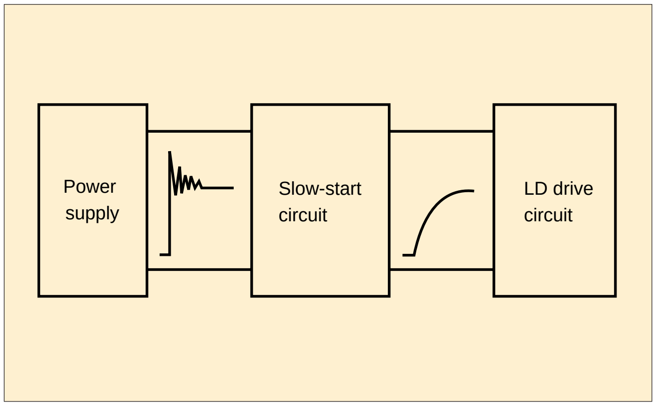


Fig. 41

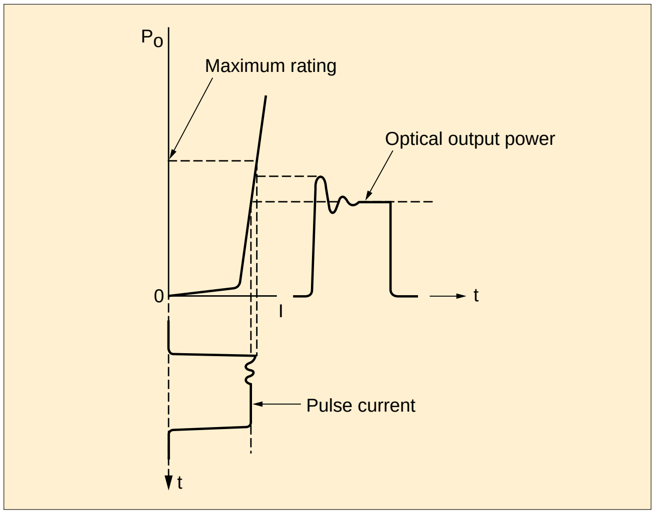


Fig. 42

3) Heat-sinking

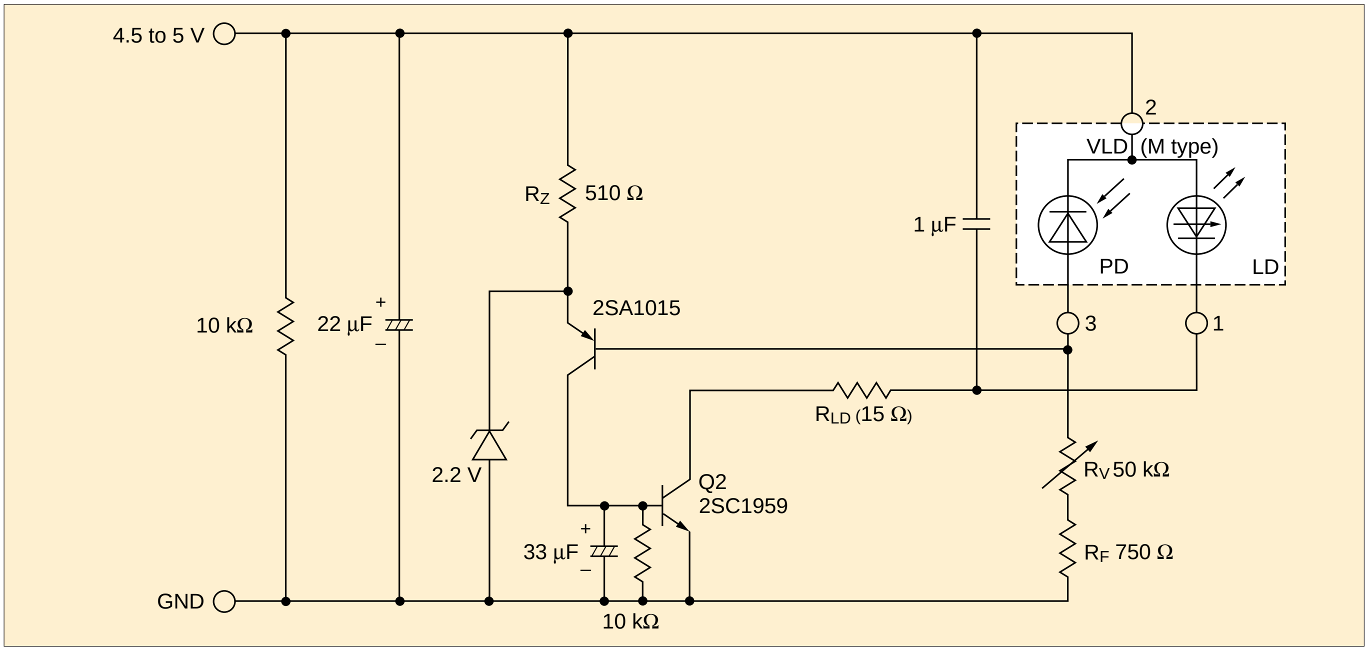
1) The PN junction of a laser diode generates considerable heat. Thus, when using laser diodes, adequate measures must be taken to disperse this heat. To disperse heat efficiently from the PN junction, mount the laser diode chip on a heat sink inside the package.
The heat sink is specifically designed to conduct heat generated in the chip to the package's flange.
Hence, attaching the heat sink to the flange disperses the heat generated by the laser diode to the outside.

2) If the heat dispersion for the laser diode is insufficient, the case temperature will increase and the optical output power will decrease.
Thus, in order for the specified optical output power to be maintained, more current must flow.
The increase in forward current triggers a further increase in case temperature, which leads to a further increase in the forward current; hence a vicious circle is created.
Excessive current may damage the laser diode.
Therefore, prevent increases in temperature and current by ensuring sufficient dispersal of heat.

3) To ensure that your design efficiently disperses heat to the outside, make sure that there is a sufficient degree of contact between the heat sink and the laser diode package's flange.
Your design should also take the heat sinkís heat dispersion characteristics into account; the heat dispersion characteristics are a function of the size and shape of the heat sink, and of the material from which it is constructed.

7. Sample Drive Circuit

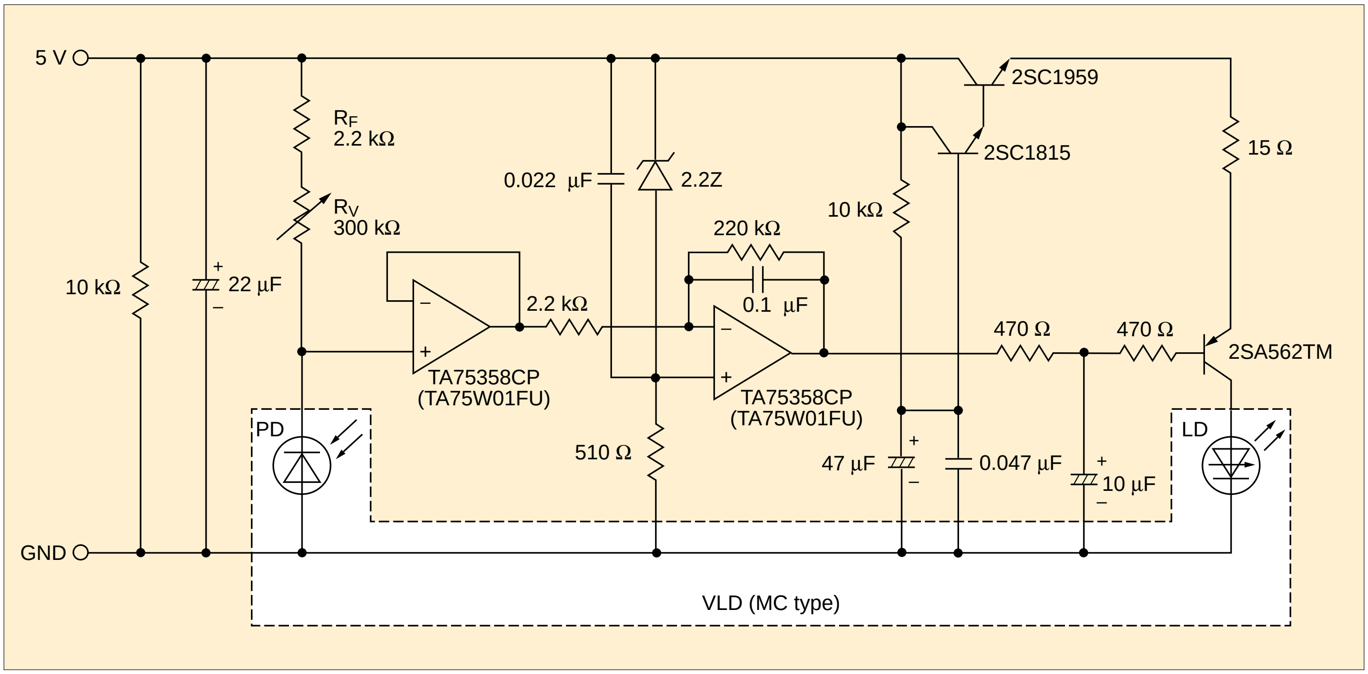
Example featuring an automatic power control (APC) drive circuit for a visible laser diode (M-type VLD)



By changing R_Z to 150 Ω, R_{LD} to 5 Ω, and the transistor Q2 to an S2C3266, the above circuit can be driven using a supply voltage of 3 V.

When a laser diode is operated using a constant current, the optical output decreases as temperature increases. However, in practice a constant optical output power which will be unaffected by changes in temperature is required. To meet this requirement, an APC circuit, which maintains a constant optical output power irrespective of temperature changes, is generally used.
An APC circuit is a feedback circuit which controls the forward current so that the optical output voltage of the built-in photodiode (PD) is always equal to the reference voltage.

Example featuring an APC driver circuit for a visible laser diode (MC-type VLD)



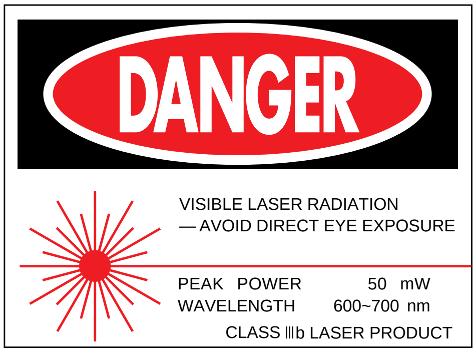
8. Safety Considerations

The laser beam emitted by the laser diode is harmful if aimed directly into the human eye.
Never look directly into the laser beam or into a laser beam that is collimated parallel with the optical axis.
The labels shown below are attached to the individual packages or containers.
These labels show that Toshiba laser diodes are certified to be in compliance with U.S. Safety Standards for laser products (21CFR 1040.10 and 1044.11).
Toshiba Visible Laser Diodes are classified as "Class Ⅲb Laser Products".

CLASS Ⅲb : This classification as applied to visible laser diodes operating in CW mode means that human access to laser radiation in excess of 5 mW but to a maximum of 500 mW is possible.
In accordance with the regulations the warning labels shown below are attached to Toshiba visible diode cartons.

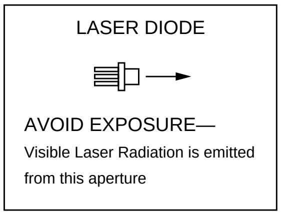
LABEL POSITION : Toshiba visible laser diodes are available in two types of carton—

1) Envelope Package (1 piece) warning labels are included on the reverse side of the individual envelope.
2) Tray package (200 pieces) warning labels are attached to the top of the external carton that contains the tray.



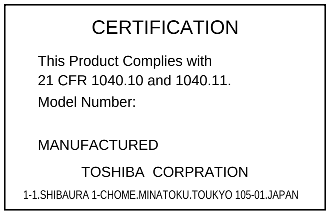
VISIBLE LASER RADIATION
— AVOID DIRECT EYE EXPOSURE

PEAK POWER 50 mW
WAVELENGTH 600~700 nm
CLASS Ⅲb LASER PRODUCT



LASER DIODE

AVOID EXPOSURE—
Visible Laser Radiation is emitted from this aperture



CERTIFICATION

This Product Complies with
21 CFR 1040.10 and 1040.11.
Model Number:

MANUFACTURED
TOSHIBA CORPRATION
1-1.SHIBAURA 1-CHOME.MINATOKU.TOUKYO 105-01.JAPAN

9. Toshiba VLD Order Codes

Please specify (DA) or (TR) after the product number when you order Toshiba visible laser diodes.

TR—tray carton (200 pieces)

The add-on code 'TR' indicates a tray carton containing 200 pieces

DA—data included with diodes

The add-on code 'DA' indicates that the following data will be included with the lasers: —

• Threshold Current	Ith	at test conditions as in this product guide
• Operation Current	Iop	
• Beam Divergence	$\theta_{\perp}$, $\theta_{\parallel}$	
• Peak Wavelength	λp	
• Monitor Current	Im	

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TOSHIBA

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