2005-9

TOSHIBA

PRODUCT GUIDE

Visible Laser Diodes

semiconductor

http://www.semicon.toshiba.co.jp/eng

CONTENTS

1. Overview of the Laser Diode

1. Principles of Operation

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 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 respectively termed either a stimulated or a spontaneous emission.

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 illustrated schematically in Figure 1.

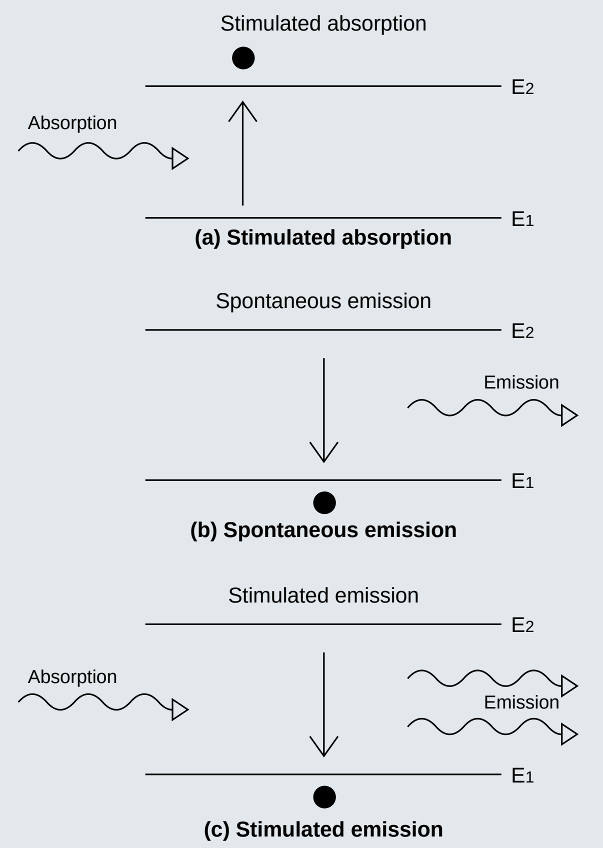


Fig. 1 Absorption and emission of radiation

2 LASER – light amplification by stimulated emission of radiation

Unlike an LED, a laser produces light radiation that is coherent (i.e., light that is highly directional, of a single wavelength and in-phase). The operation of a laser is based on the setting up of an optical oscillator, which is used to amplify light by some inherent gain mechanism.

The fundamental structure of any laser, whether 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", in which the reflectors feed back the optical signal into the active medium many times and the signal is amplified during each pass. Since the end mirrors are 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 and give off energy in the form of light radiation. Since these electrons will fall the same "energy distance", they will give off light that is coherent. Utilizing the principle of stimulated emission from semiconductor materials, with energy gaps allowing for emission of optical frequency, permits a semiconductor material to be used as the active medium and thus enables 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 LED output is incoherent whereas laser output is coherent – i.e., laser light is highly directional and of the same frequency and phase. It is this characteristic of lasers that has sustained the development of many of today's optical applications.

4 Semiconductor lasers (laser diodes)

Semiconductor laser structures

In its simplest form, a semiconductor laser is a p–n junction of a single crystal semiconductor material; the wavelength of the output light is determined by the material used. A semiconductor laser consisting of a p-n junction and is called a 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 by roughening the side edges to prevent leakage of light from the sides of the device. This structure is known as a homojunction laser.

Using the interface between two single crystal semiconductors with different bandgap energies (i.e., 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 bandgap energies of the materials used, the heterojunction structure can considerably increase device efficiency. Using a heterojunction on either side of the active layer (a double heterojunction structure) improves both optical and carrier confinement.

The double-hetero structure provides for optical confinement perpendicular to the junction; however, 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.

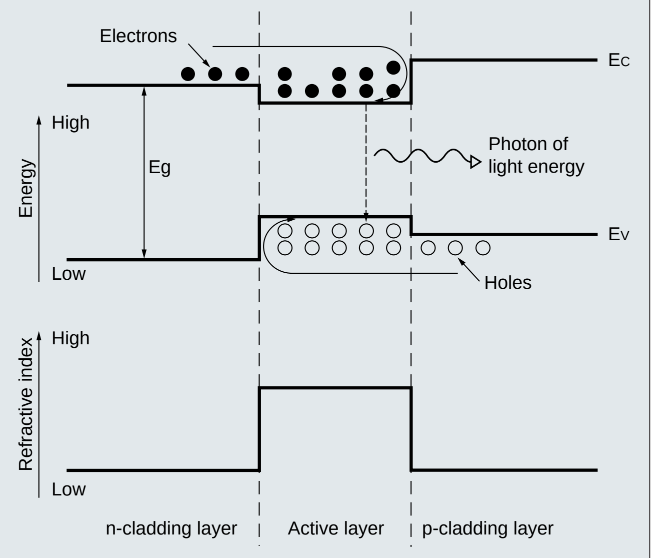


Fig. 3 Double heterostructure energy levels and refractive indices

5 Chip structures

The Toshiba semiconductor laser uses a index-guided multi-quantum well structure, as described in Figure 4.

Refractive index-guided type

To control the oscillation of laser between horizontal mode and single mode effectively, a cladding layer is formed, as shown in Figure 4, to direct the refractive index in a horizontal direction onto the active layer. Because a wave guide is formed by the differential refractive index in this structure, the laser is referred to as being of "a refractive index-guided type".

Effectively to control horizontal laser oscillation in single mode, a stripe was created in the laser structure, as shown in Figure 4. This directs the refractive index differential in a horizontal direction to the active layer. Because in this structure a wave guide is formed by the refractive index differential, this is known as a "refractive index-guided type" structure. With the structure in Figure 4, however, light is absorbed in the n-GaAs current blocking layer. Accordingly, using a non-light absorbing material, such as InAℓP, in the current blocking layer will prevent loss from light absorption and result in a laser diode with high luminous efficiency. This structure is known as a "real refractive index-guided" structure and is effective for reducing operating current in laser diodes.

Another alternative is the "gain-guided" structure, which limits the area that conducts current in the active layer and uses the gain from the current to form a wave guide. However, because this results in a large operating current, it is not used in Toshiba laser diodes. In addition, a so-called "gain-guided" structure controls the current-conducting area in the active layer to form a wave guide using the gain from that current. However, because the operating current is high and the laser characteristics (including the oscillating spectrum and astigmatism) deteriorate, Toshiba does not use a gain-guided structure in laser diodes.

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 are known as multi-quantum wells (MQW).
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.

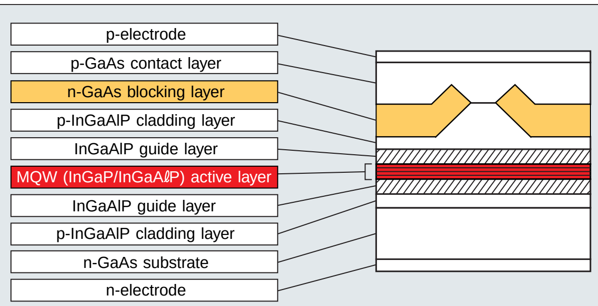


Fig. 4 Index-guided MQW structure

6 Longitudinal modes and transverse modes

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:

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

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

L: cavity length
λ: wavelength
n: refractive index of amplifying medium at λ

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.

Transverse modes

Oscillation may also occur transverse to the axis of the cavity, i.e., transverse to the direction of propagation. These transverse modes will affect the radiation pattern of the output.

7 Gain profile

Although many longitudinal modes may exist in the laser cavity, the modes which exist in the laser output will be dictated by the gain profile of the active medium. The gain profile is determined by the carrier distribution in the active layer and will influence the output as shown below:

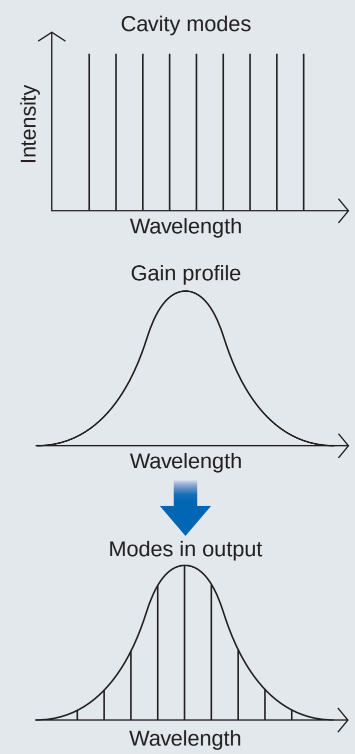


Fig. 5 Gain profile and lasing wavelength

8 Mode hopping

As the case temperature (and hence the junction temperature) of the semiconductor laser increases, the wavelength will 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. Stabilization of the wavelength can be achieved by close control of the laser's 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 Lasing wavelength of the VLD

The lasing wavelength of an LD is determined by the size of the bandgap in the active layer. Consequently, it is possible to obtain a laser beam of a desired wavelength by selecting an appropriate crystal material. In practice, however, the choice of available materials is rather limited because it is necessary to achieve good lattice matching between the material layers when having the crystal grow.

Toshiba adopts InGaP and InGaAℓP for its 650-nm Visible Laser Diodes (VLDs); and, for the infrared side (780-nm band) of its dual-wavelength laser diodes, GaAℓAs and a material that has a good lattice matching with the GaAs substrate and that is most suitable for the respective wavelengths.

10 Metal-organic chemical vapour deposition

Toshiba VLDs are grown using the 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 homogeneity 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 susceptor surface, the metal alkyls and hydrides decompose into their Group III and Group V elemental species, which then move to find available lattice sites, causing growth to occur.

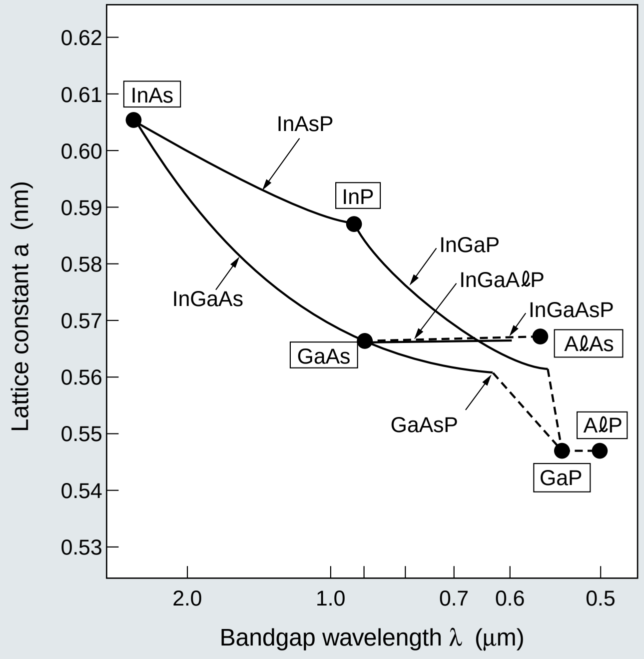


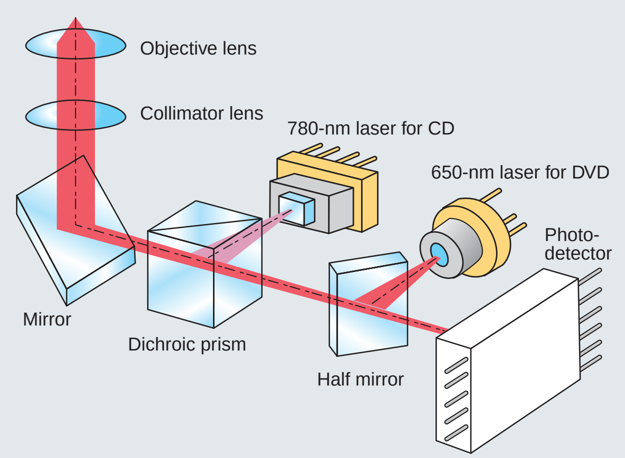
Fig. 6 Relationship between lattice constant and bandgap wavelength for III−V group semiconductor

11 Dual-wavelength laser diodes

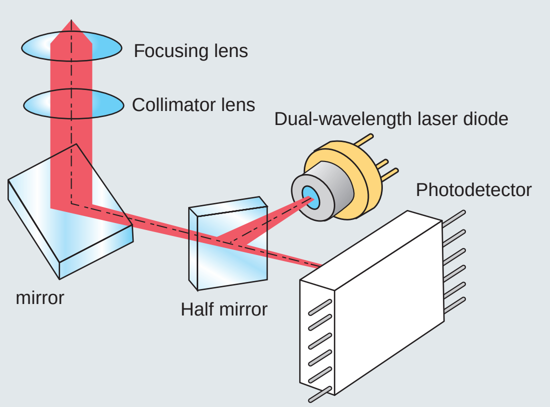
DVD-ROM and DVD-Video require a 650-nm laser for DVD reading and a 780-nm laser for CD (CD-R) reading. In conventional optical pickup heads, each laser diode was mounted separately. However, Toshiba use a dual-wavelength laser diode to incorporate both lasers in a single package. Figure 9b shows the internal structure of the dual-wavelength laser diode.

Advantages of dual-wavelength laser diodes

Figure 7 compares the structure of a conventional optical pickup head with the structure of a DVD optical pickup head using a dual-wavelength laser diode. Because conventional optical pickup heads featured a 650-nm laser for DVDs and a 780-nm laser for CDs separately mounted (as in Figure 7a), they required a larger number of components and greater complexity. Use of a dual-wavelength laser diode reduces the number of components (as shown in Figure 7b), which allows miniaturization and simplification of the optical pickup head and reduces costs. In addition, whereas the optical axis of 650-nm lasers and 780-nm lasers had to be adjusted separately in the past, the same adjustment can now be accomplished in one operation, simplifying the assembly process.



a: Conventional Structure



b: Using a Dual-Wavelength Laser Diode

Fig. 7 Optical Pickup Head Structure

Monolithic type

As shown in Figure 8, dual-wavelength laser diodes come in two types: a monolithic type and a multi-chip type. The accuracy of the lasing point interval of the 650-nm laser and 780-nm laser is paramount during adjusting of the optical axis in the optical pickup head. With the monolithic type, the lasing point distance is highly accurate because it is determined by the mask interval set when the LD chip is manufactured. With multi-chip-type dual-wavelength laser diodes, because the LD chips are mounted separately, the lasing point distance is determined by the accuracy of the manufacturing device equipment, and variations can be large.

Because Toshiba's dual-wavelength laser diode is of the monolithic type, the lasing point distance in the optical pickup head can be adjusted easily.

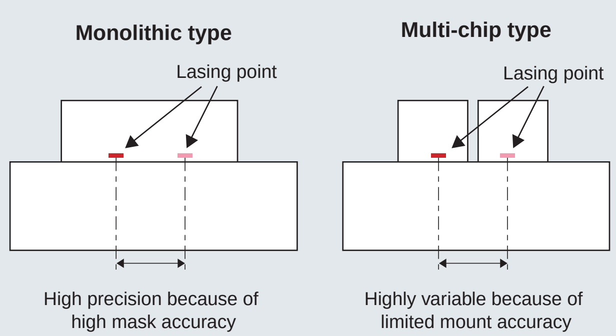


Fig. 8

Lasing point position

Optical pickup heads with a dual-wavelength laser diode use one objective lens for the DVD and CD. However, because there is some distance between the 650-nm and 780-nm lasing points, an optical design that minimizes lens aberration is required. When using the objective lens, the CD is likely to be subject to aberration caused by the diagonal incidence of the laser beam. Accordingly, 780-nm laser beams should be designed so as to avoid diagonal incidence of the laser beam.

Toshiba's dual-wavelength laser diode easily solves the problem by adjusting the lasing point on the center of the package.

12 Classifying semiconductor lasers by lasing mode

Semiconductor lasers can be classified into single-mode lasers having only one longitudinal mode, self-sustained pulsation lasers having multiple longitudinal modes, and gain-guided multi-mode lasers.

Single-mode laser

Laser beams output from a single-mode laser are characterized by a strong coherence.

If a single-mode laser is used as a light source in an optical disk reader without its strong coherence being suppressed, the laser output beams interfere with those reflected from the optical disk, resulting in the laser output fluctuating. The laser noise induced by the fluctuation is called relative intensity noise. Reducing relative intensity noise requires lowering the coherence of laser beams by increasing the number of longitudinal modes in the laser to two or more.

This goal can be achieved by superimposing a high-frequency current at several hundred MHz on the laser diode bias current (DC current) to turn laser beams on and off at short intervals. This requires a high-frequency modulator, but the operating current is low; and even if the temperature or optical output changes, a stable, low-noise level laser beam is obtained.

Superimposing a high-frequency current is effective in reducing the coherence of single-mode lasers, as stated above. However, using a high-frequency current leads to undesired electromagnetic interference (EMI). Suppressing EMI requires mounting anti-EMI components, such as ferrite beads, on the circuit board; or surrounding the high-frequency modulator with metal shields.

Self-sustained pulsation laser

A self-sustained pulsation laser has a region called a saturable absorber around its active layer.

The saturable absorber absorbs and releases laser beams generated in the active layer. As a result, the output laser beams go on and off at short intervals. To put it another way, an effect equivalent to what is attained by superimposing a high-frequency current on the output of single-mode lasers occurs in the self-sustained pulsation laser with no additional component. However, this method has some demerits: the self-sustained pulsation laser requires a large operating current compared with single-mode lasers; and its temperature and optical output ranges where laser noise level remains stable are limited.

Gain-guided multi-mode laser

A gain-guided multi-mode laser already has multiple longitudinal modes. Therefore it can be used as a light source in an optical disk without the installation of additional components. However, it requires a large operating current compared with single-mode and self-sustained pulsation lasers, and noise increases when the temperature rises or when changes occur in the optical output.

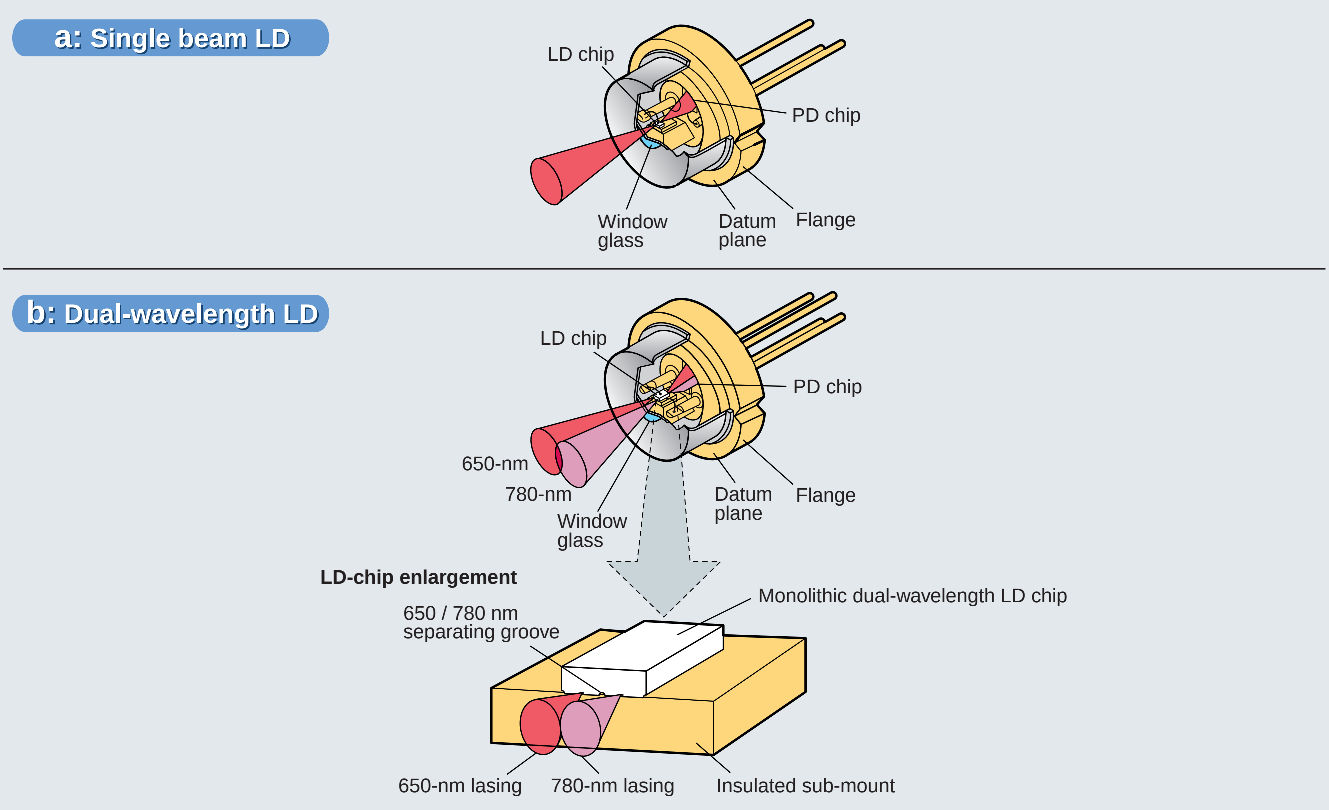


Fig. 9 Interior diagram of package

2. Symbols in Detail

Symbol	Term	Description
APC	Auto power control	Drive circuit with feedback loop to ensure that the optical output power is kept constant
AR	Aspect ratio	Ratio of $\theta_\perp$ to $\theta_{//}$ (Fig. 12)
As	Astigmatism	Difference between the focal point for the output parallel to and that for the output perpendicular to the junction, when the laser output is focused (Fig. 12)
$C_{T(PD)}$	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. 10)
$I_{D(PD)}$	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. 11)
I_m	Monitor current	Current through a reverse-biased built-in photodiode used to monitor the optical output power from the laser diode
I_{OP}	Operation current	Forward current necessary to obtain standard operation power (Fig. 11)
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. 11)
NFP	Near-field pattern	Intensity profile of the light output measured at the laser chip facet (Fig. 10)
P_O	Optical power	Optical output power from the laser diode (Fig. 11)
RIN	Relative intensity noise	C/N per laser beam unit frequency
R_{th}	Thermal resistance	Temperature difference per unit of input electrical power
SE	Slope efficiency	Optical output power increase with unit increase in forward current
Ta	Ambient temperature	Temperature of the environment in which the laser is operating
Tc	Case temperature	Actual temperature of the VLD package
TE/TM	Polarization ratio	Ratio of the output polarised parallel to the junction to the output polarized perpendicular to the junction
T_{stg}	Storage temperature	Permitted storage temperature range while the VLD is not in use
t_f	Fall time	Time taken for the optical output to fall from 90% of its maximum value to 10%
t_r	Rise time	Time taken for the optical output to rise from 10% of its maximum value to 90%
V_F	Forward voltage	Forward voltage drop across the laser diode
Vop	Operation voltage	Voltage drop across the laser diode while the laser is operating at its standard operation power
$V_{R(LD)}$	LD reverse voltage	Laser diode reverse voltage
$V_{R(PD)}$	PD reverse voltage	Photodiode reverse voltage
V_{th}	Threshold voltage	Voltage drop across the laser diode at the onset of laser oscillation
$\Delta x(1\text{-}2)$	Lasing point distance	Distance between the dual-wavelength laser diode laser's 650-nm lasing point and 780-nm lasing point
$\theta_{//}$	Beam divergence	Full width at half maximum of beam divergence parallel to the junction (Fig. 10)
$\theta_\perp$	Beam divergence	Full width at half maximum of beam divergence perpendicular to the junction (Fig. 10)
λ_p	Lasing wavelength	Lasing wavelength of peak longitudinal mode in output spectrum

■ Optical characteristics (Fig. 10)

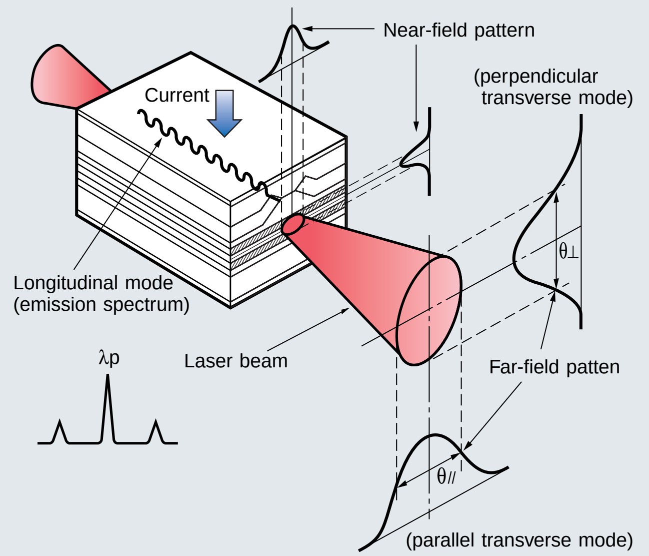


Fig. 10

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 certain 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 θ// and θ⊥ (signifying beam divergence parallel to and perpendicular to the active layer).

■ Optical and electrical characteristics (Fig. 11)

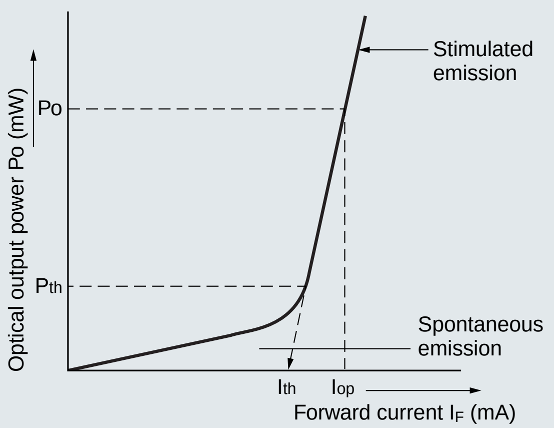


Fig. 11

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, signifying 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.

■ Astigmatism (Fig. 12)

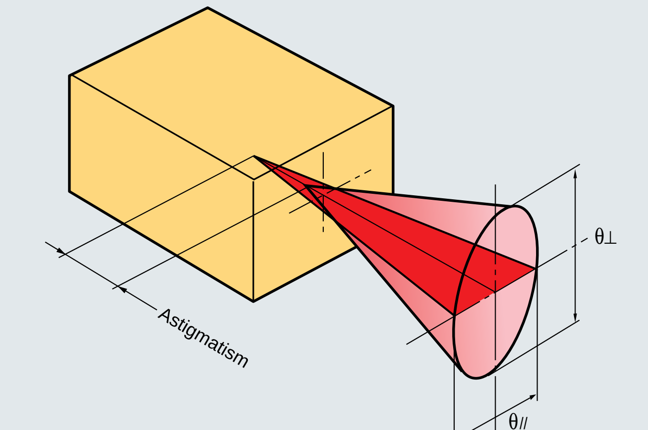


Fig. 12

When the beam from a visible laser is focused using a lens, the apparent vertical focal point differs from the apparent horizontal focal point in the active layer. This difference is referred to as astigmatism.

■ Measurement of optical output (Fig. 13)

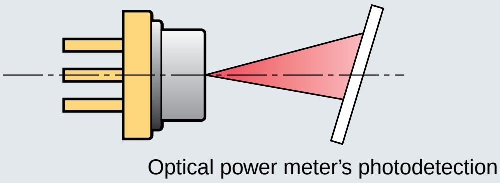


Fig. 13

Install the photodetection plane so that all the luminous flux of the laser beam is incident on the photodetection plane. Tilt the photodetection plane 5°~10° in relation to the optical axis so as to prevent light reflecting off the photodetection plane of the optical power meter and back into the lens of the visible laser.

■ Electrical characteristics (Fig. 14)

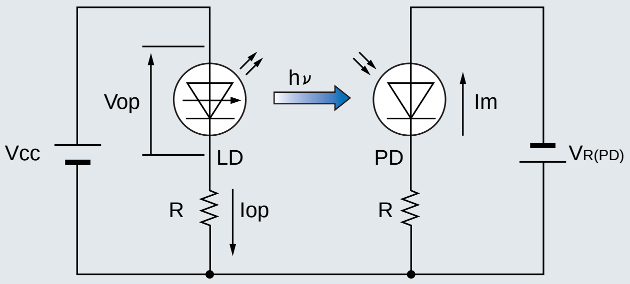


Fig. 14

V_F is the forward voltage drop across the laser diode, while I_F 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.

2. Product List

1. Main Characteristics of VLDs

<table>
<tr><th rowspan="2">Part Number</th><th colspan="2">Max Ratings</th><th rowspan="2">Lasing Wave-length (nm)</th><th rowspan="2">Threshold Current (mA)</th><th rowspan="2">Operation Current (mA)</th><th colspan="2">Beam Divergence</th><th rowspan="2">Operation Voltage (V)</th><th rowspan="2">Monitor Current (mA)</th><th rowspan="2">Marking</th></tr>
<tr><th>Po (mW)</th><th>Case Temperature (ßC)</th><th>θ‖ (ß)</th><th>θ⊥ (ß)</th></tr>
<tr><td>TOLD2000MDA</td><td rowspan="3">7</td><td rowspan="3">−10 to 70</td><td rowspan="3">*650/790</td><td rowspan="3">*25/20</td><td rowspan="3">*35/35</td><td rowspan="3">*9/10</td><td rowspan="3">*28/32</td><td rowspan="3">*2.2/2.2</td><td rowspan="2">*0.12/0.35</td><td>AN</td></tr>
<tr><td>TOLD2000SDA</td><td>B</td></tr>
<tr><td>TOLD2000FDA</td><td>*0.05/0.10</td><td>A</td></tr>
<tr><td>TOLD2003SDA</td><td>7</td><td>−30 to 85</td><td>*655/790</td><td>*40/35</td><td>*50/55</td><td>*9/10</td><td>*28/32</td><td>*2.2/2.2</td><td>*0.15/0.35</td><td>E</td></tr>
</table>

* 650-nm side value / 790-nm side value

2. Application Examples and Recommended Products

■ Optical disk type, points for selecting visible laser diodes, and recommended products

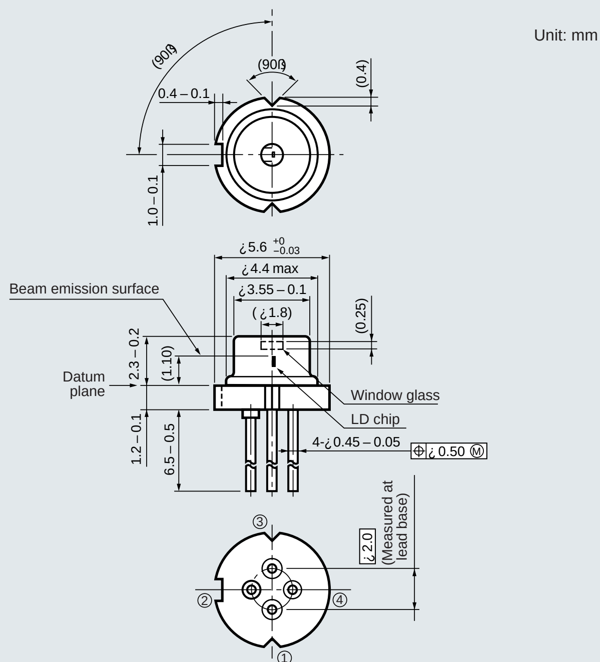
<table>
<tr><th colspan="2">Optical Disk Type</th><th>Points for Selecting Visible Laser Diodes</th><th>Recommended Product</th></tr>
<tr><td rowspan="2">Read only</td><td>DVD-Video
DVD-ROM</td><td>¥ Inhibition of heat generation as a result of low-current laser
¥ Simplification of optics system and minimization of components as a result of dual-wavelength LD</td><td>TOLD2000MDA
TOLD2000SDA
TOLD2000FDA</td></tr>
<tr><td>DVD for car navigation</td><td>¥ Expansion of use temperature range by use of high temperature operating laser</td><td>TOLD2003SDA</td></tr>
</table>

Note: For information about D-cut and I-cut packages, contact your Toshiba sales office.
In the case of non-optical disk applications, contact your Toshiba sales office.

3. Package Dimensions

4-pin package for dual-wavelength (MDA type)

Unit: mm

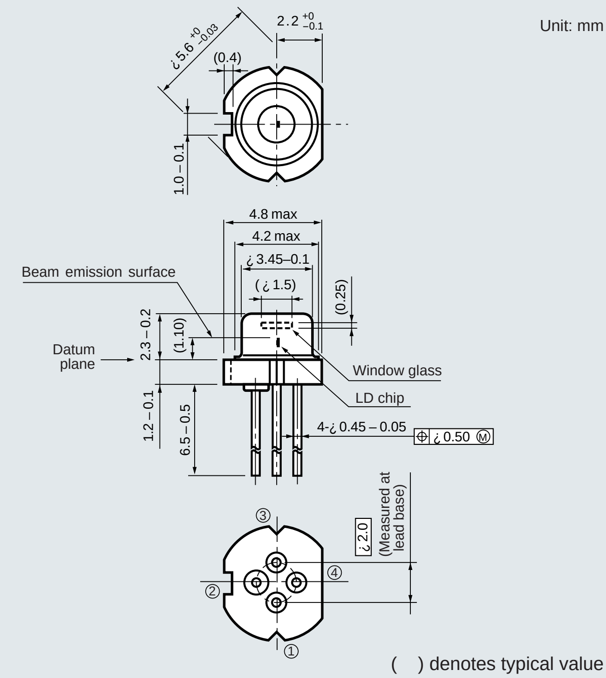


( ) denotes typical value

Part No. for 4-pin packag	TOLD2000MDA

4-pin D-cut package for dual-wavelength (SDA type)

Unit: mm

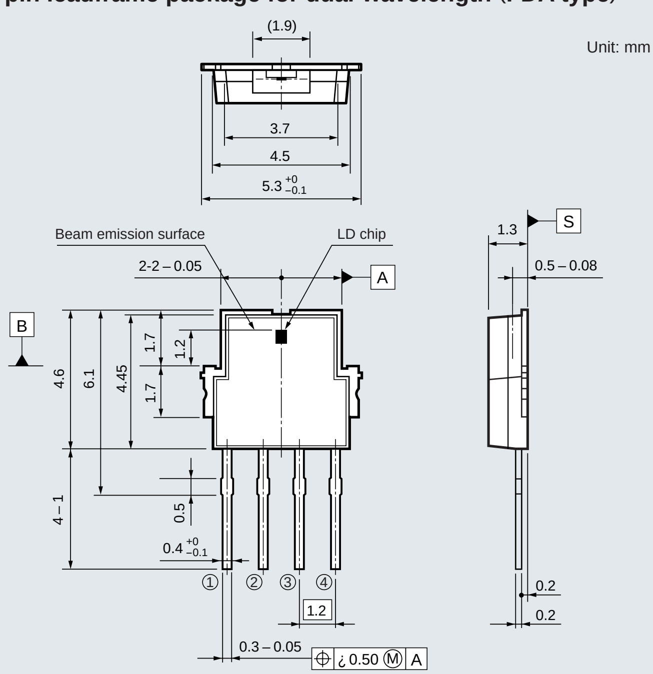


( ) denotes typical value

Part No. for 4-pin packag	TOLD2000SDA TOLD2003SDA

4-pin leadframe package for dual-wavelength (FDA type)

Unit: mm



( ) denotes typical value

Part No. for 4-pin packag	TOLD2000FDA

Note: Please refer to pages 16 to 23 for the pin connections.

3. Measurement of Main Characteristics

1. I–L Characteristic

Equipment: Optical power meter (with analog output), current sweeper, XY-recorder, thermal controller

The I-L curve is a plot of the forward current against the optical output power. It shows 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 the threshold current.

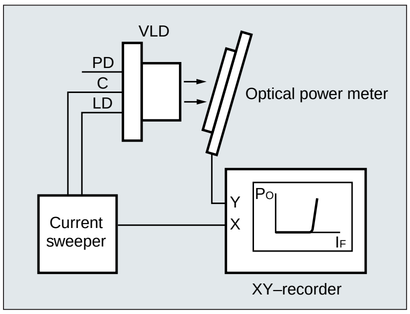


Fig. 15

2. Monitor Current vs. Optical Output Power

Equipment: Optical power meter (with analog output), current sweeper, bias voltage source, 1-kΩ resistor, ammeter (with analog 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.

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

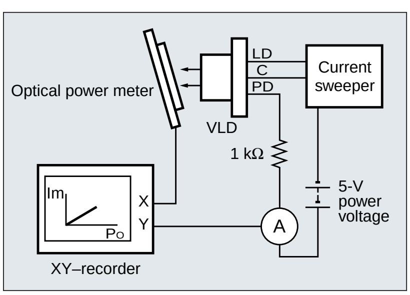


Fig. 16

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 its rated power.

Using a thermal controller allows the VLD temperature to be changed and the resulting change in voltage drop to be measured.

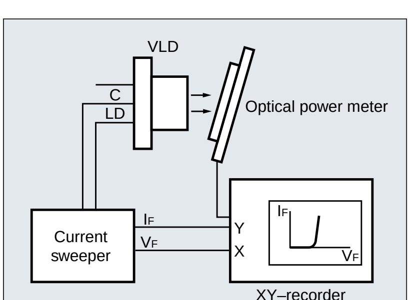


Fig. 17

4. Lasing Spectrum

Equipment: APC driver, focusing lens, optical fiber, spectrum analyser

With the VLD operating in APC Mode, the laser output is focused into an optical fiber. The spectrum of this light can then be observed using a spectrum analyser.

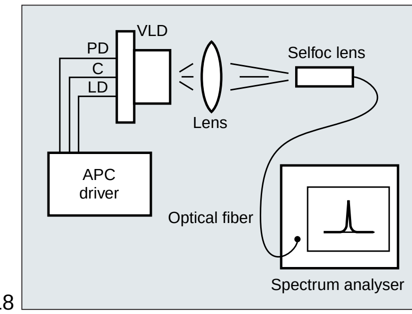


Fig. 18

5. Far-Field Patterns

Equipment: APC driver, photodiode (on rotatable axes)

While the VLD is operated 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.

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

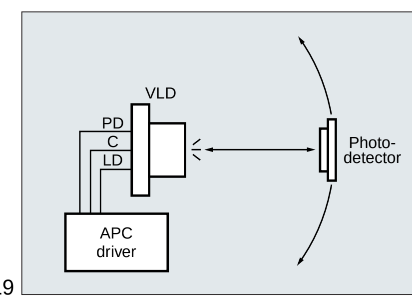


Fig. 19

6. Polarization Ratio vs. Optical Output Power

Equipment: APC driver, focusing lens, Gran-Thompson prism, optical power meter

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

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

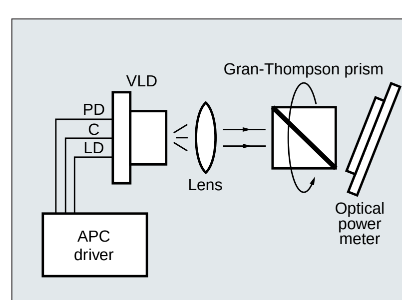


Fig. 20

4. Measurement Methods for Other Characteristics

1. Frequency Characteristics

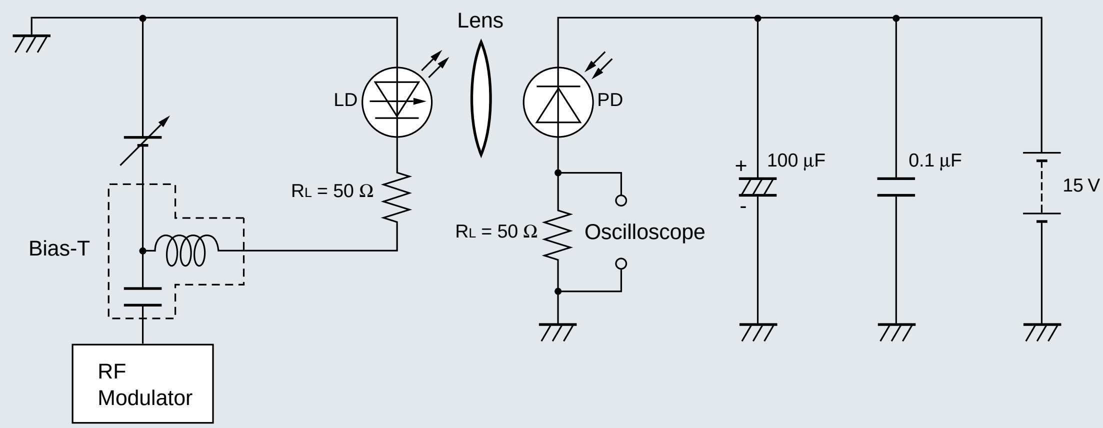


Fig. 21

Measurement method

With a VLD operation under the CW mode, a modulating power is applied through a bias-T. In this state, change the oscillation frequency of the RF modulator and plot the peak value of the optical output at every frequency. The frequency characteristic shows in the diagram in Figure 22 will be obtained.

■ Sample data: TOLD2000MDA (650 nm)

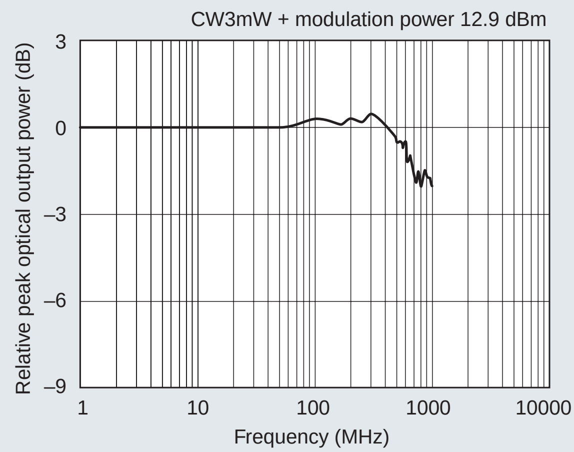
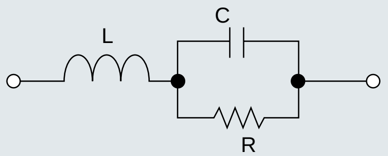


Fig. 22

2. L, C, R Characteristics

To measure the semiconductor laser L, C, and R characteristics by the parameter analyzer, use the following AC equivalent circuit.



AC equivalent circuit

■ Typical values:

Part Number	Test conditions	L (nH)	C (pF)	R (Ω)
TOLD2000MDA	$f \leqq 500$ MHz, $I_F \fallingdotseq I_{th}$	*5.5/5.5	*35/25	*8/10
TOLD2000SDA				
TOLD2000FDA				
TOLD2003SDA		*5.5/5.5	*15/10	*10/13

* 650 nm side value / 780 nm side value

4. Measurement Methods for Other Characteristics

3. Visibility

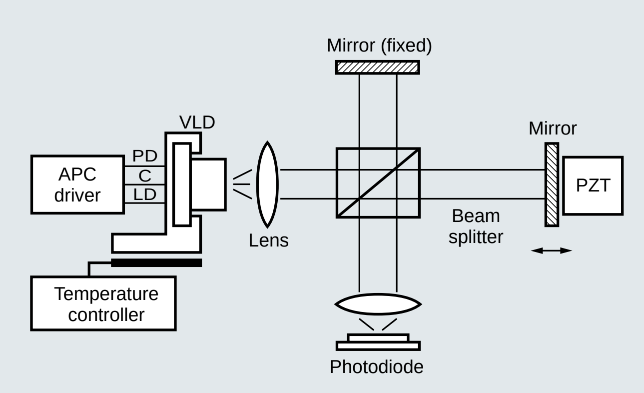


Fig. 23

Unity visibility implies full temporal coherence, whereas zero visibility corresponds to complete incoherence (i.e., absence of fringes $I_{max} = I_{min}$).

If we designate the ratio of peak Ia and the next peak Ib of optical path 0 as γ, this can be expressed as:

$$\gamma = I_b / I_a,$$

where γ is the damping ratio of V. If $\gamma = 1$, the light is fully coherent. If $\gamma = 0$, the light is incoherent.

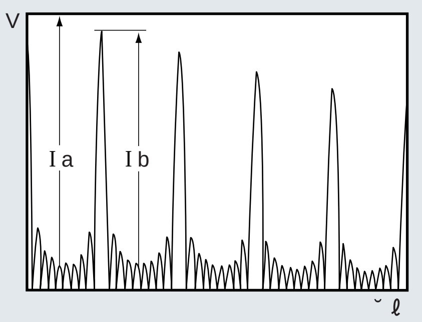


Fig. 24

Definition:

$$V = \frac{I_{max} - I_{min}}{I_{max} + I_{min}}$$

V = visibility
I_{max} = maximum observed fringe intensity
I_{min} = minimum observed fringe intensity

Measurement:

As the non-fixed mirror of the Michelson interferometer is moved, a pattern of fringes will result.
The visibility (γ) of these fringes is given by the above definition, where Imax is the maximum observed fringe intensity and Imin is the minimum observed fringe intensity.

4. Relative Intensity Noise (RIN)

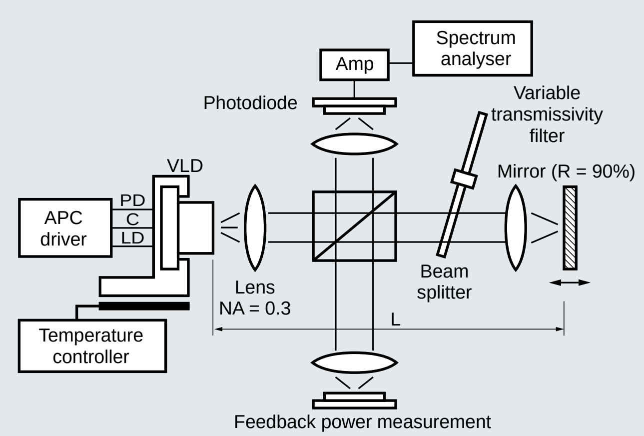


Fig. 25

Measurement:

With the VLD being operated in APC Mode, the laser output is split using a beam splitter. One part of the laser output is directed towards a vibrating mirror of 90% coating and reflected back towards the laser.
The reflected light is again split by the beam splitter, enabling measurement of the amount of light feedback. The amount of feedback can be adjusted using a variable transmissivity filter.
As the amount of feedback is varied, the signal noise is measured using the spectrum analyzer, and the maximum and minimum noise levels are recorded. Alternatively, sweeping the VLD operation temperature allows the mode-hopping noise to be measured.

Definition:

$$RIN = 10 \log \left\{ \frac{(P_{AC})^2}{(P_{DC})^2} \times \frac{1}{BW} \right\}$$

RIN = relative intensity noise
P_{AC} = measured AC optical output
P_{DC} = measured DC optical output
BW = measured band width

Test Conditions

NA: 0.3
L: 50 mm
f: 1 MHz
BW: 10 kHz
Feedback: 0.001 %~10 %

* 650-nm side value / 780-nm side value

5. Astigmatism (As)

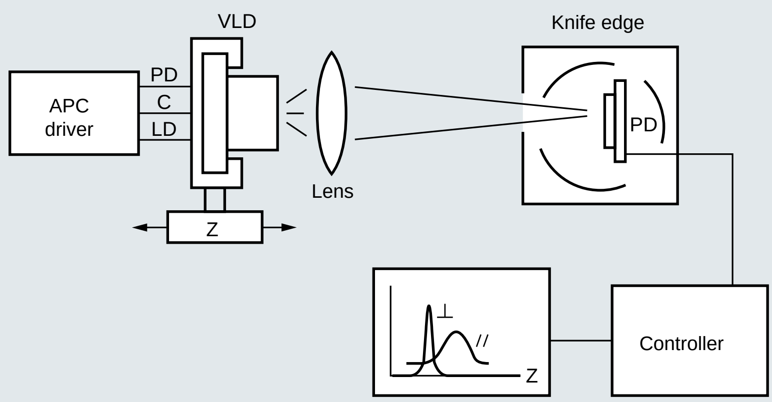


Fig. 26

Definition:

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

As = astigmatism
M = magnification
f = focal length
b = distance between focal points

Measurement:

With the VLD being operated 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 laser diode position is swept (in the Z-direction), the size of the spot falling on the photodiode will change. By differentiating the output from the photodiode, the slope of the transition from minimum light entering the photodiode (i.e., when the knife edge completely blocks the light) and maximum light entering the photodiode (i.e., when the knife edge is not interrupting the light at all) 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 so that both are perpendicular and then both are parallel to the junction, the actual focal points of the perpendicular and parallel light can be measured.

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

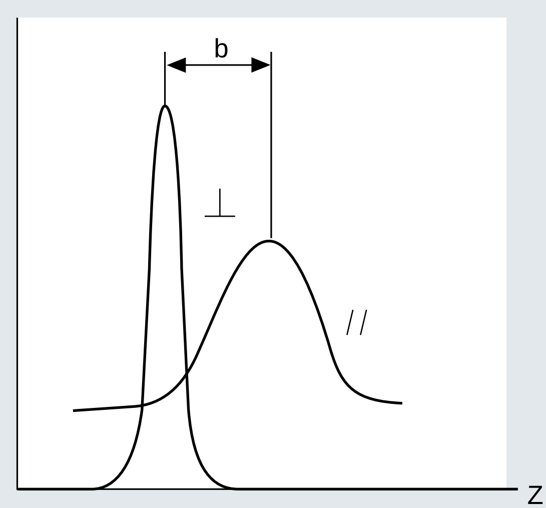


Fig. 27

■ Typical values:

Part Number	Test Power Po (mW)	Astigmation As (m)
TOLD2000MDA	3	*6 / 6
TOLD2000SDA		
TOLD2000FDA		
TOLD2003SDA	3	*7 / 7

5. Technical Datasheets

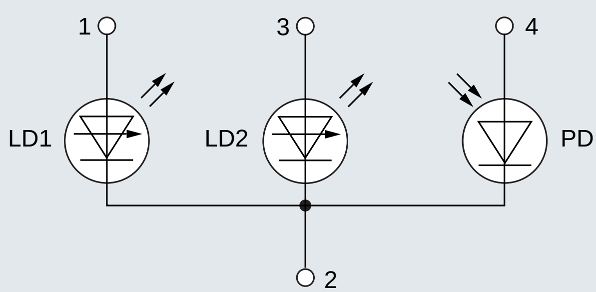
1. TOLD2000MDA/SDA/FDA

■ Features

- Dual-wavelength laser diode
- Use of a monolithic chip implements high-precision lasing point distance.
- Low current consumption.
- A 4.8-mm D-cut packaged product (SDA type) designed for a slim optical pickup head and the industry's first leadframe packaged dual-wavelength laser diode (FDA type) are available. These types are suitable for the downsizing and slimming down of optical pickup heads.

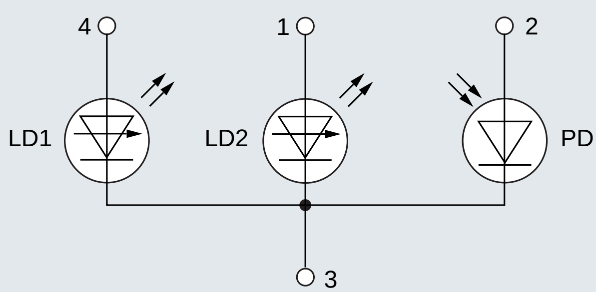
■ Pin connection

MDA/SDA Type



1. Laser diode (650 nm) anode
2. Laser diode (650 nm / 780 nm) cathode
   Photodiode cathode
3. Laser diode (780 nm) anode
4. Photodiode anode

FDA Type



1. Laser diode (780 nm) anode
2. Photodiode anode
3. Laser diode (650/780 nm) cathode
   Photodiode cathode
4. Laser diode (650 nm) anode

■ Maximum ratings (T_C = 25°C)

Parameter	Symbol	Rating	Unit
Optical Output Power (650 nm)	Po1	7	mW
Optical Output Power (780 nm)	Po2	7	mW
LD Reverse Voltage (650 nm)	$V_{R(LD)}1$	2	V
LD Reverse Voltage (780 nm)	$V_{R(LD)}2$	2	V
PD Reverse Voltage	$V_{R(PD)}$	30	V
Operation Case Temperature	Tc	−10 to 70	°C
Storage Temperature	Tstg	−40 to 85	°C

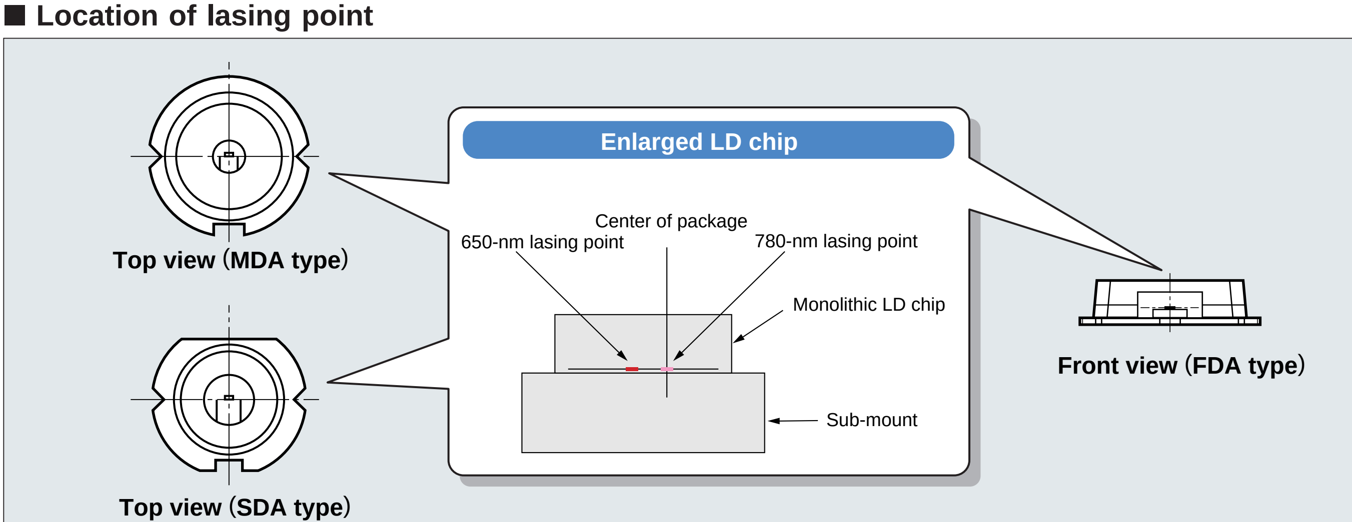
Warning: Do not attempt to use these products to emit both 650-nm and 780-nm lasers simultaneously.

■ Optical and electrical characteristics (T_C = 25°C)

Parameter		Symbol	Test Condition	Min	Typ.	Max	Unit
650 nm	Threshold Current	Ith1	CW operation	—	25	45	mA
	Operation Current	Iop1	Po = 5 mW	—	35	55	mA
	Operation Voltage	Vop1	Po = 5 mW	—	2.2	2.5	V
	Lasing Wavelength	λp1	Po = 5 mW	640	650	660	nm
	Beam Divergence	θ∥1	Po = 5 mW	7	9	13	°
		θ⊥1	Po = 5 mW	24	28	32	°
	Monitor Current	Im1	Po = 5 mW	0.06*	0.12*	0.30*	mA
				0.02**	0.05**	0.10**	mA
780 nm	Threshold Current	Ith2	CW operation	—	20	40	mA
	Operation Current	Iop2	Po = 5 mW	—	35	55	mA
	Operation Voltage	Vop2	Po = 5 mW	—	2.2	2.5	V
	Lasing Wavelength	λp2	Po = 5 mW	775	790	805	nm
	Beam Divergence	θ∥2	Po = 5 mW	7	10	15	°
		θ⊥2	Po = 5 mW	25	32	39	°
	Monitor Current	Im2	Po = 5 mW	0.12*	0.35*	0.60*	mA
				0.05**	0.10**	0.25**	mA
Lasing Point Distance		ΔX (1-2)	Numerical value specified in mask design	107	110	113	μm
PD Dark Current		$I_{D(PD)}$	V_R = 5 V	—	—	100	nA
PD Total Capacitance		$C_{T(PD)}$	V_R = 5 V, f = 1 MHz	—	—	20	pF

* These values apply to the **TOLD2000MDA/SDA**.
** These values apply to the **TOLD2000FDA**.

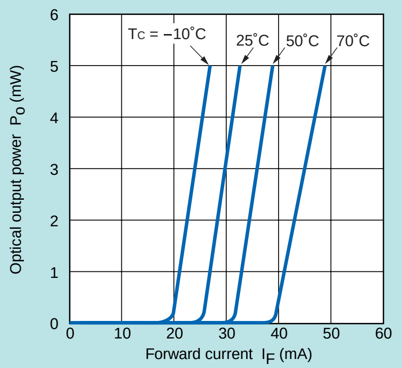
■ Location of lasing point



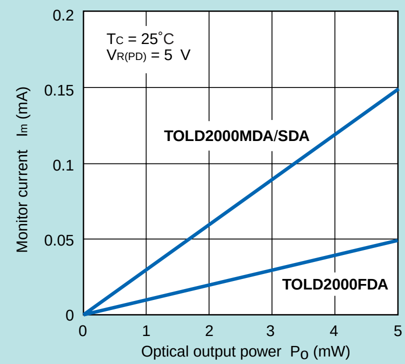
This product is designed to remedy the side-beam reflection on the sub-mount surface that may result from the CD 3-beam method, which is normally used to detect CD tracking errors.

■ Characteristics (650 nm)

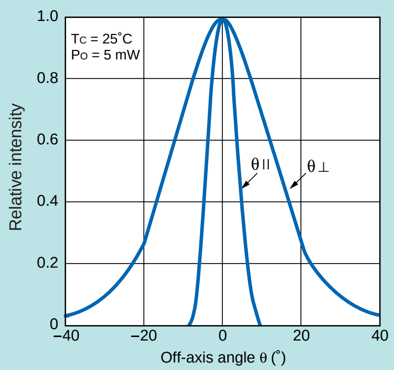
Optical output power vs. forward current



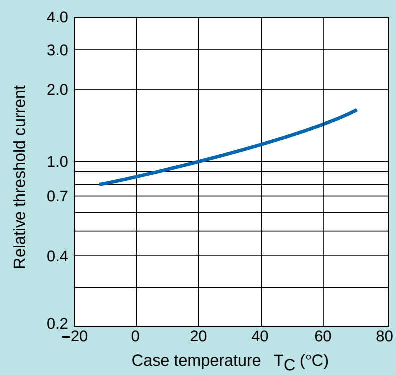
Monitor current vs. optical output power



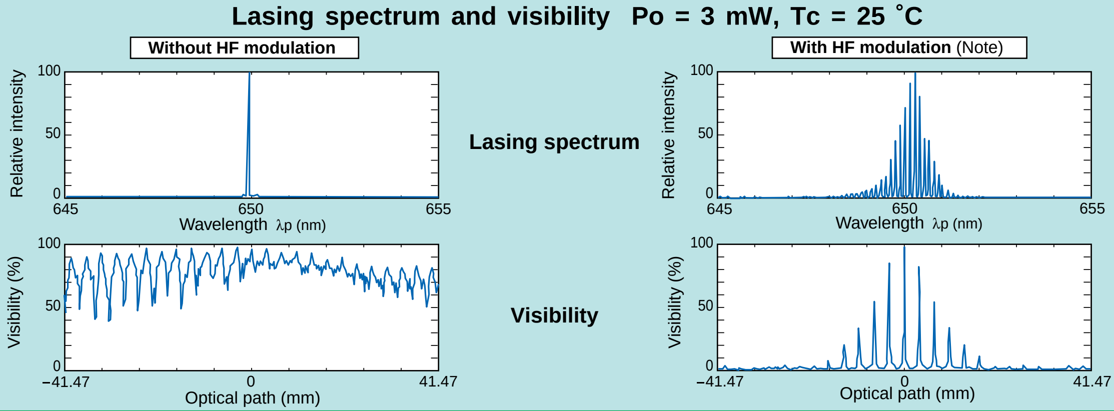
Far-field patterns



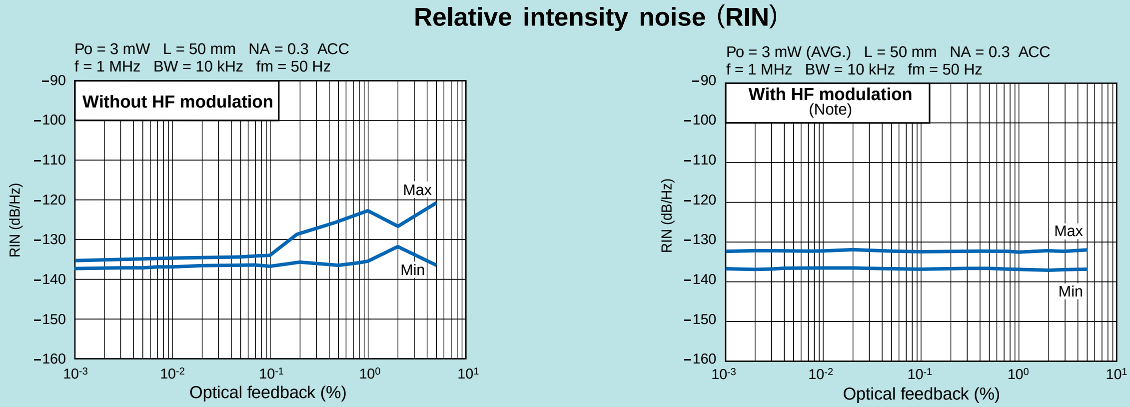
Case temperature dependence of threshold current



Lasing spectrum and visibility Po = 3 mW, Tc = 25 ˚C



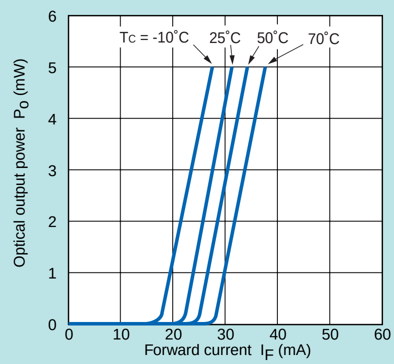
Relative intensity noise (RIN)



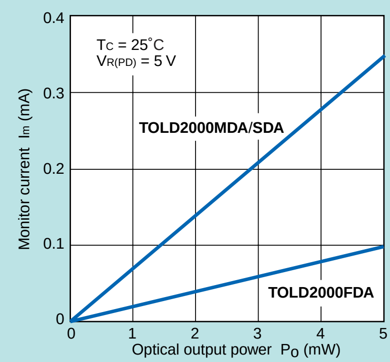
Note: Toshiba modulation IC (TC93A02FUG) operating conditions:
Vcc = 5 V, frequency adjusting resistance = 3.3 kΩ, amplitude adjusting resistance = 4.7 kΩ

■ Characteristics (780 nm)

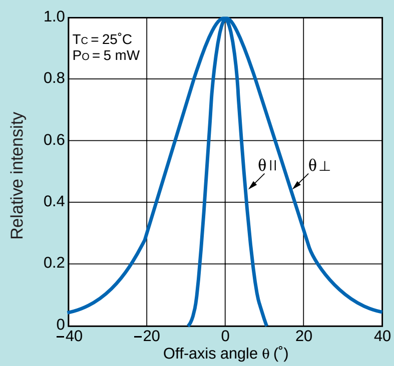
Optical output power vs. forward current



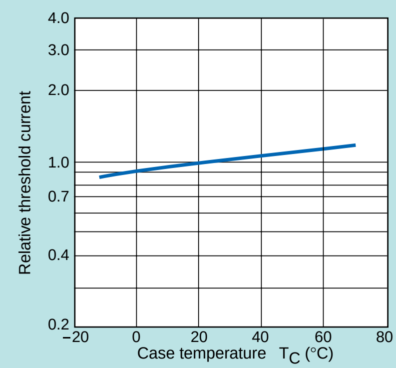
Monitor current vs. optical output power



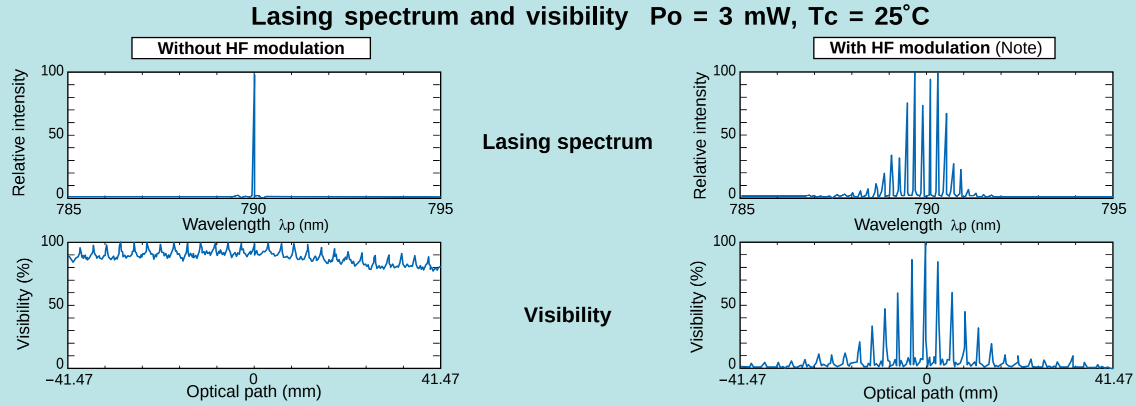
Far-field patterns



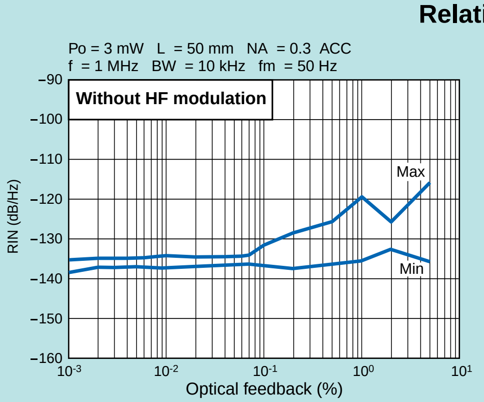
Case temperature dependence of threshold current

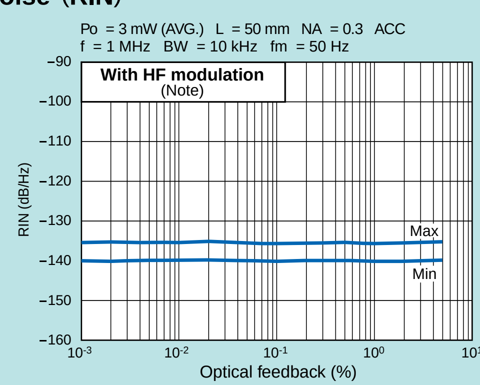


Lasing spectrum and visibility Po = 3 mW, Tc = 25˚C



Relative intensity noise (RIN)





Note: Toshiba modulation IC (TC93A02FUG) operating conditions:
Vcc = 5 V, frequency adjusting resistance = 3.3 kΩ, amplitude adjusting resistance = 4.7 kΩ

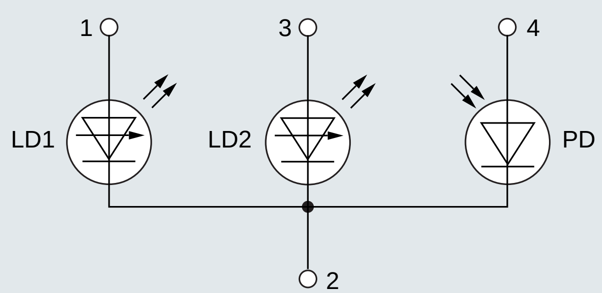
2. TOLD2003SDA

Features

- Dual-wavelength laser diode
- Use of a monolithic chip implements high-precision lasing point distance.
- Has succeeded in 85˚C operation for the first time as a dual-wavelength laser diode. Suitable for use in DVD car navigation and other applications where high-temperature operation is required.

Pin connection

SDA Type



1. Laser diode (650 nm) anode
2. Laser diode (650 nm / 780 nm) cathode
   Photodiode cathode
3. Laser diode (780 nm) anode
4. Photodiode anode

Maximum ratings (T_C = 25°C)

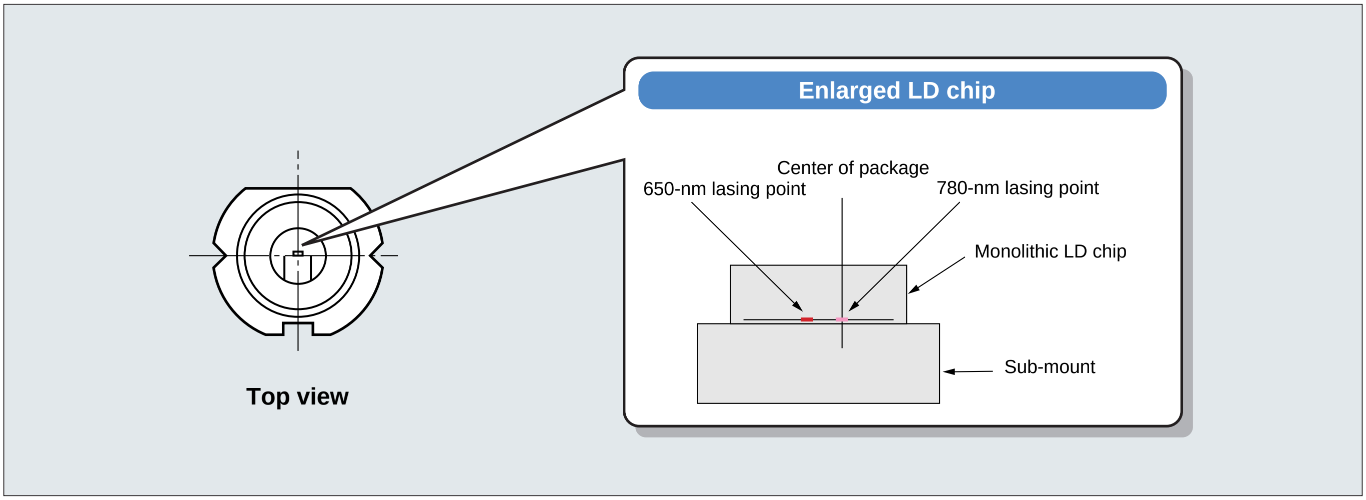
Parameter	Symbol	Rating	Unit
Optical Output Power (650 nm)	Po1	7	mW
Optical Output Power (780 nm)	Po2	7	mW
LD Reverse Voltage (650 nm)	$V_{R(LD)}1$	2	V
LD Reverse Voltage (780 nm)	$V_{R(LD)}2$	2	V
PD Reverse Voltage	$V_{R(PD)}$	30	V
Operation Case Temperature	Tc	−30 to 85	°C
Storage Temperature	Tstg	−40 to 85	°C

Warning: Do not attempt to use these products to emit both 650-nm and 780-nm lasers simultaneously.

■ Optical and electrical characteristics (Tc = 25°C)

Parameter		Symbol	Test Condition	Min	Typ.	Max	Unit
650 nm	Threshold Current	Ith1	CW operation	—	40	65	mA
	Operation Current	Iop1	Po = 5 mW	—	50	75	mA
	Operation Voltage	Vop1	Po = 5 mW	—	2.2	2.5	V
	Lasing Wavelength	$\lambda p1$	Po = 5 mW	640	655	660	nm
	Beam Divergence	$\theta_{\parallel}1$	Po = 5 mW	7	9	13	°
		$\theta_{\perp}1$	Po = 5 mW	24	28	32	°
	Monitor Current	Im1	Po = 5 mW	0.06	0.15	0.30	mA
780 nm	Threshold Current	Ith2	CW operation	—	35	55	mA
	Operation Current	Iop2	Po = 5 mW	—	55	75	mA
	Operation Voltage	Vop2	Po = 5 mW	—	2.2	2.5	V
	Lasing Wavelength	$\lambda p2$	Po = 5 mW	775	790	805	nm
	Beam Divergence	$\theta_{\parallel}2$	Po = 5 mW	7	10	15	°
		$\theta_{\perp}2$	Po = 5 mW	25	32	39	°
	Monitor Current	Im2	Po = 5 mW	0.12	0.35	0.6	mA
Lasing Point Distance		ΔX (1-2)	Numerical value specified in mask design	107	110	113	µm
PD Dark Current		$I_{D(PD)}$	V_R = 5 V	—	—	100	nA
PD Total Capacitance		$C_{T(PD)}$	V_R = 5 V, f = 1 MHz	—	—	20	pF

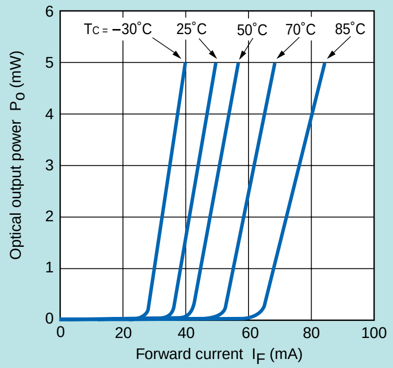
■ Location of lasing point



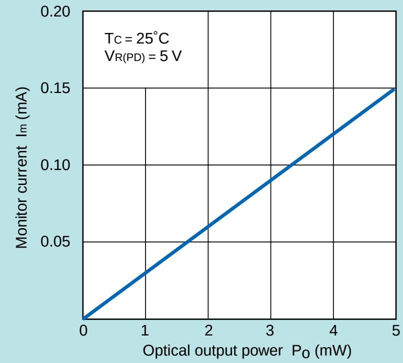
This product is designed to remedy the side-beam reflection on the sub-mount surface that may result from the CD 3-beam method, which is normally used to detect CD tracking errors.

■ Characteristics (650 nm)

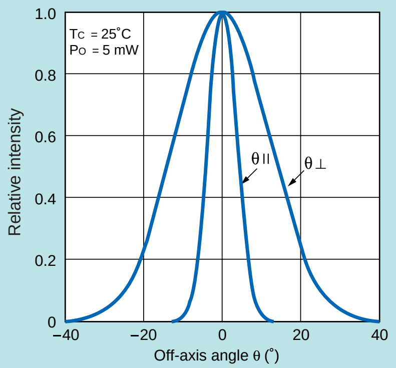
Optical output power vs. forward current



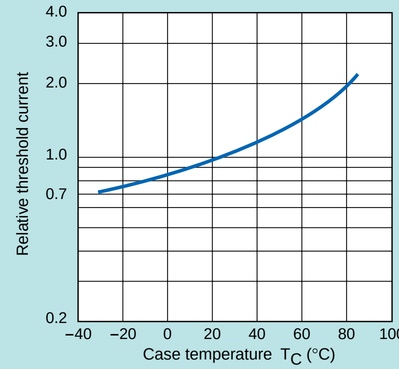
Monitor current vs. optical output power



Far-field patterns



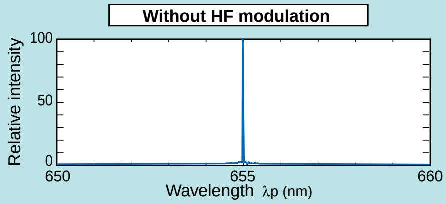
Case temperature dependence of threshold current

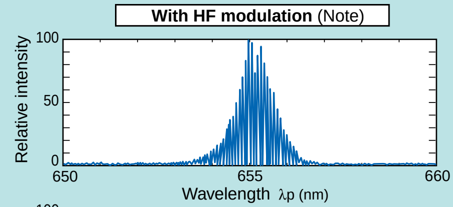


Lasing spectrum and visibility Po = 3 mW, Tc = 25 ˚C

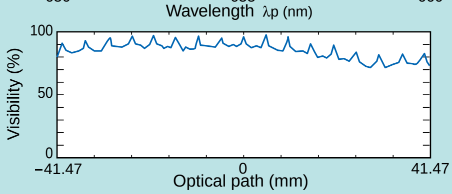
Without HF modulation | **With HF modulation** (Note)

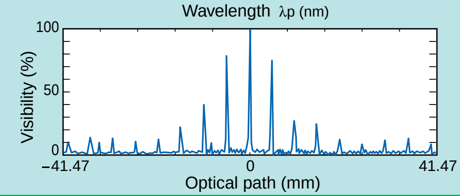
Lasing spectrum



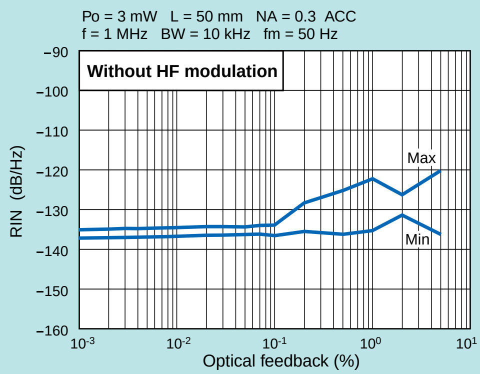


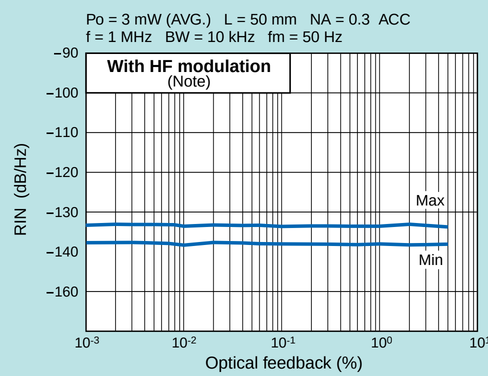
Visibility





Relative intensity noise (RIN)

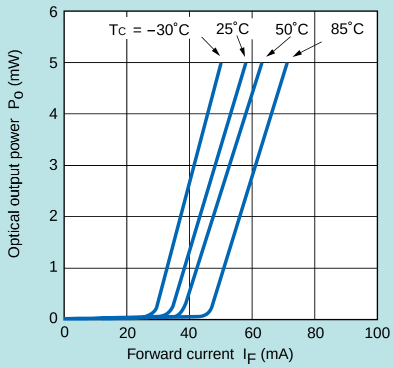




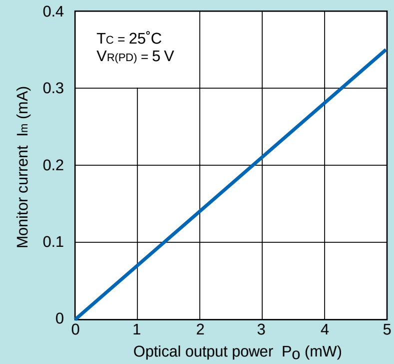
Note: Toshiba modulation IC (TC93A02FUG) operating conditions:
Vcc = 5 V, frequency adjusting resistance = 3.3 kΩ, amplitude adjusting resistance = 4.7 kΩ

■ Characteristics (780 nm)

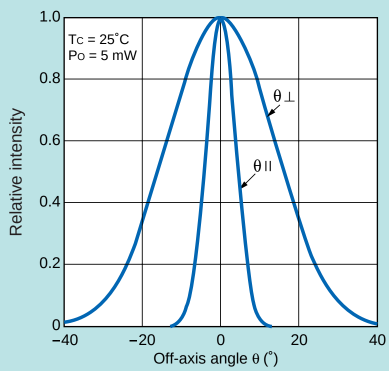
Optical output power vs. forward current



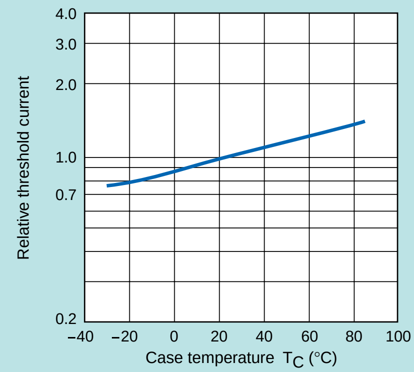
Monitor current vs. optical output power



Far-field patterns



Case temperature dependence of threshold current

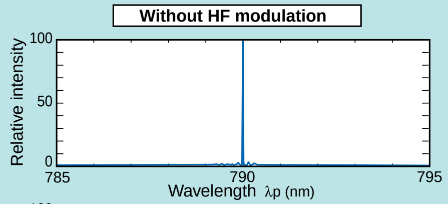


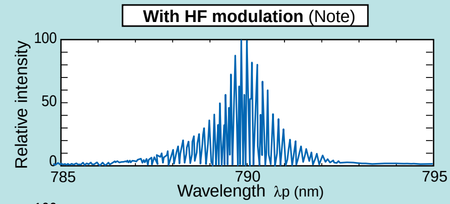
Lasing spectrum and visibility Po = 3 mW, Tc = 25 ˚C

Without HF modulation

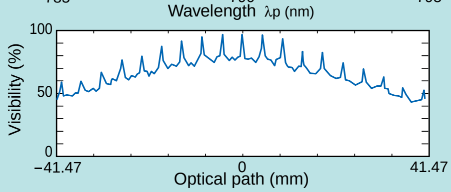
With HF modulation (Note)

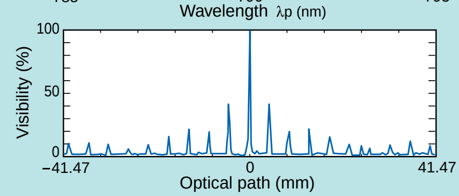
Lasing spectrum





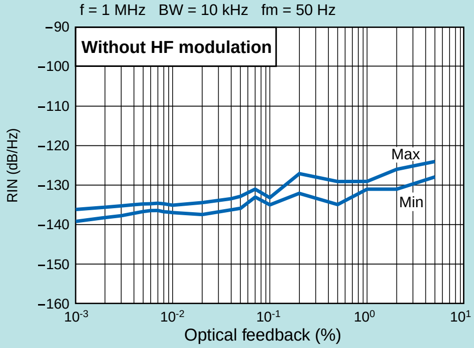
Visibility



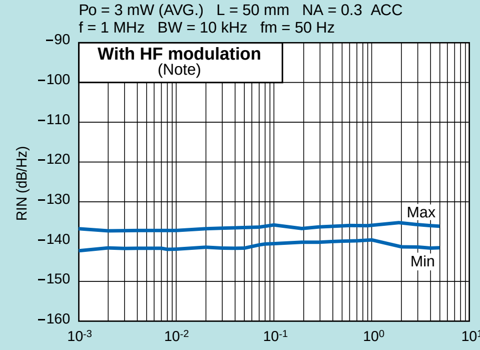


Relative intensity noise (RIN)

Po = 3 mW L = 50 mm NA = 0.3 ACC
f = 1 MHz BW = 10 kHz fm = 50 Hz



Po = 3 mW (AVG.) L = 50 mm NA = 0.3 ACC
f = 1 MHz BW = 10 kHz fm = 50 Hz



Note: Toshiba modulation IC (TC93A02FUG) operating conditions:
Vcc = 5 V, frequency adjusting resistance = 3.3 kΩ, amplitude adjusting resistance = 4.7 kΩ

6. High-Frequency Modulation ICs

When using a single-mode laser diode as the DVD reading optical source, set up a high-frequency modulation IC to reduce the laser beam noise. Toshiba offer high-frequency modulation ICs suitable for the characteristics of Toshiba laser diodes.

■ Features

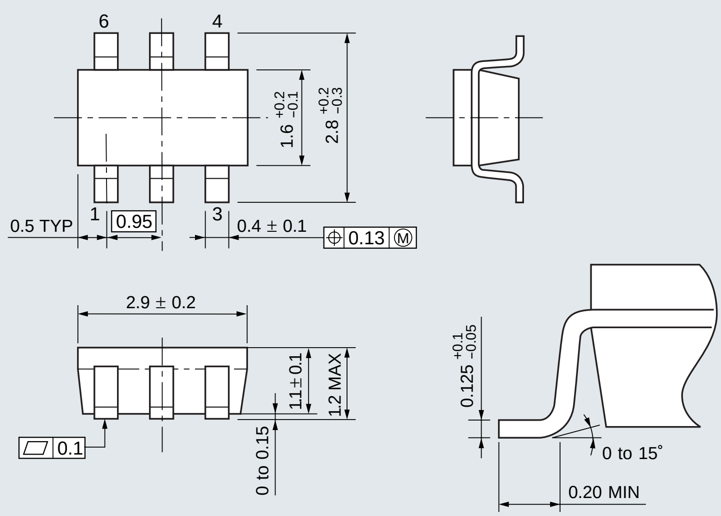
- 5-V single-source operation
- Modulation frequency and amplitude programmable by changing the resistance of the external resistor
- Push-pull type output ensures low power consumption
- Circuit operation automatically stopped when the LD is not in use (power save mode)
- Ultracompact packages (SSOP6-P-0.95B). Most suitable for use in optical pickup heads where miniaturization is advancing.

Part Number	Power Supply Voltage	Function	Characteristic	Package
TC93A02FUG	5 V	High-frequency modulation IC for optical disks (for dual-wavelength laser diodes)	Modulation amplitude: Programmable Modulation frequency: 250 to 450 MHz Accuracy of setting frequency: ± 10 %	SSOP6-P-0.95B

■ Package Dimensions

SSOP6-P-0.95B

Unit: mm



■ Precautions to be taken when using a modulation IC

1. Distance between the LD and the high-frequency modulation IC
   Keep the cable connecting between the LD and the LDA pin of this IC as short as possible. A high-frequency current of several hundreds of frequency will flow out of the LDA pin of this IC. Consequently, if the cable between the LD and the IC is too long, the output from the LDA pin may become lower than necessary due to the wiring inductance.
2. Printed traces of the Vcc and GND pins
   Keep the printed traces of the Vcc and GND pins as wide as possible. Install bypass capacitors across the Vcc and GND pins as close to the Vcc and GND pins of the IC as possible.

Note: For detailed technical data, contact your Toshiba sales office .

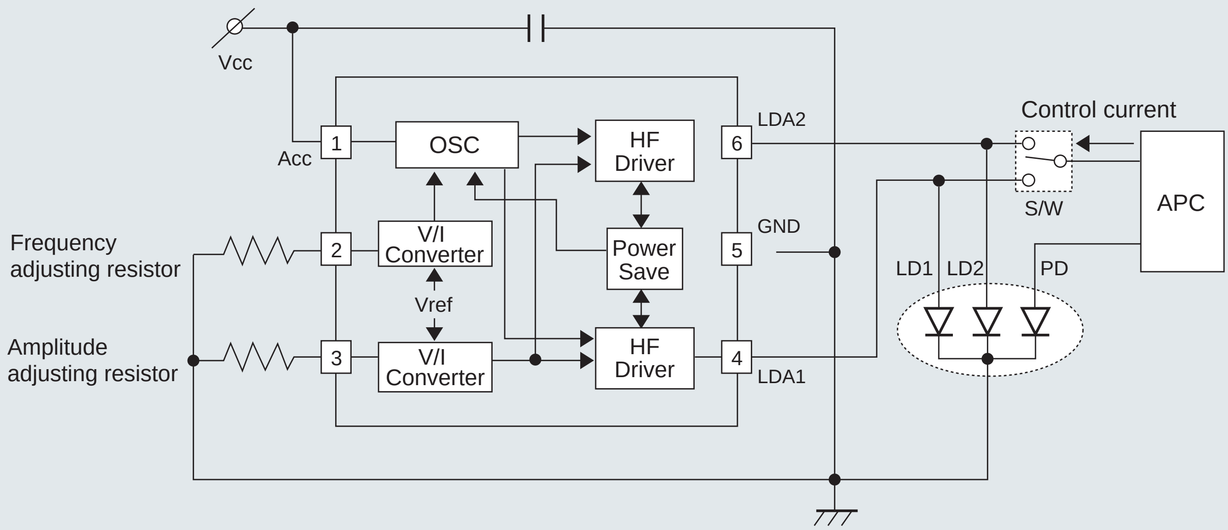
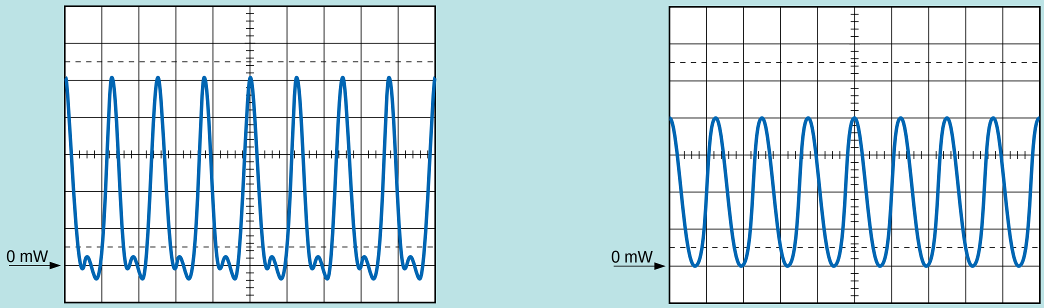


Fig. 28 TC93A02FUG Block Diagram

■ Sample data

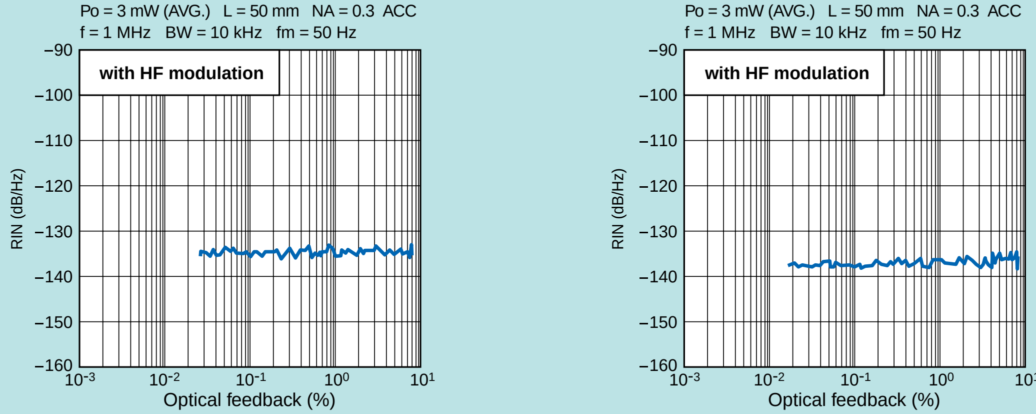
Optical output waveform (Note)

x-axis: 2 ns/div
y-axis: 2 mW/div



TOLD2000MDA + **TC93A02FUG** (650 nm)   **TOLD2000MDA** + **TC93A02FUG** (780 nm)

Relative intensity noise (RIN) (Note)



TOLD2000MDA + **TC93A02FUG** (650 nm)   **TOLD2000MDA** + **TC93A02FUG** (780 nm)

Note: Toshiba modulation IC (TC93A02FUG) operating conditions:
Vcc = 5 V, frequency adjusting resistance = 3.3 kΩ, amplitude adjusting resistance = 4.7 kΩ

6. Usage Precautions

1. Damage to Laser Diodes

If 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. 29.
The decrease occurs when 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.

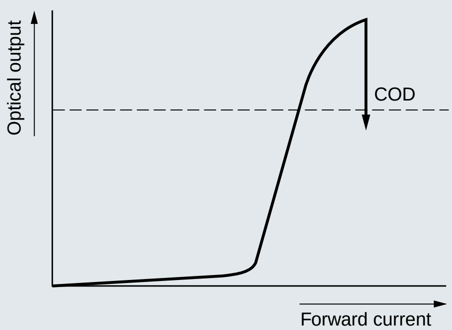


Fig. 29 COD

In Fig. 30 the center of the near-field pattern on the facet of the laser chip at which COD occurred is partly darkened.

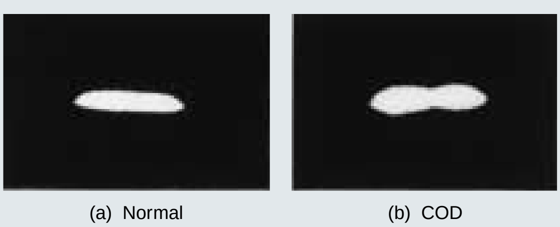


Fig. 30 Near-field patterns

The characteristics of a laser damaged in this way will deteriorate: the specified optical output will no longer be achieved or the far-field pattern will become fragmented. In the worst case, no laser beam will be generated at all (see Fig. 31 and 32).
Therefore, when handling laser diodes, care must be taken not to cause COD.

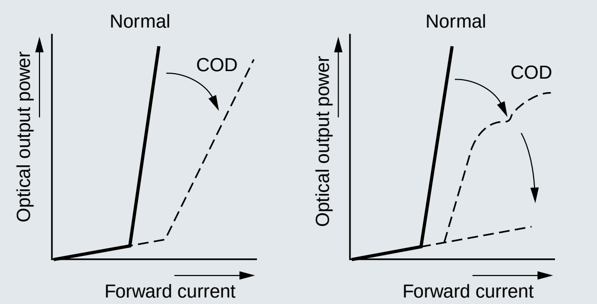


Fig. 31 Optical output power vs. forward current characteristics

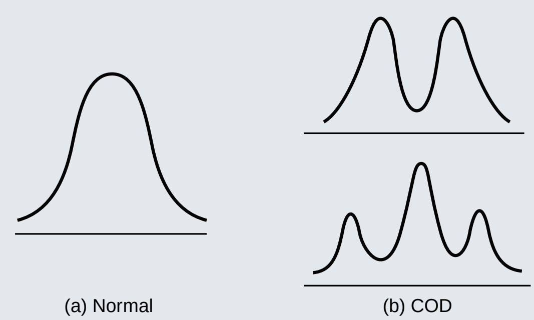


Fig. 32 Far-field patterns

2. Handling Precautions

1 Precautions when setting optical output

Design so that the maximum ratings will not be exceeded even momentarily.
For normal operation, set the optical output power to below the test condition values for the electrical and optical characteristics.
Confirm before use that spike current generated at driver ON/OFF does not cause the device to exceed the maximum ratings.
If excessive spike current is applied to the laser, characteristics such as optical output deteriorate. In the worst case, the laser may be damaged.

2 Precautions against electrostatic discharge

Laser diodes can be driven using a low operation voltage and low operation current.
In addition, these devices feature quick response. As a result, small surges, such as surges due to electrostatic discharge, can easily affect laser diodes.

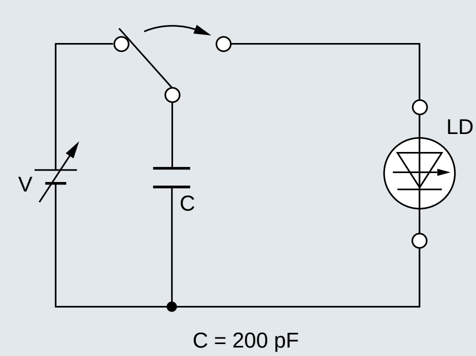


Fig. 33 Electrostatic damage test circuit

Fig. 34 shows an example of a test for electrostatic discharge damage to a laser diode.
An electrostatic surge of as little as several tens of volts can cause deterioration in device characteristics.

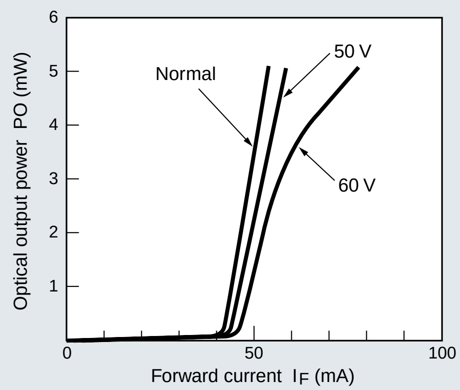


Fig. 34 Example of electrostatic damage testing

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.

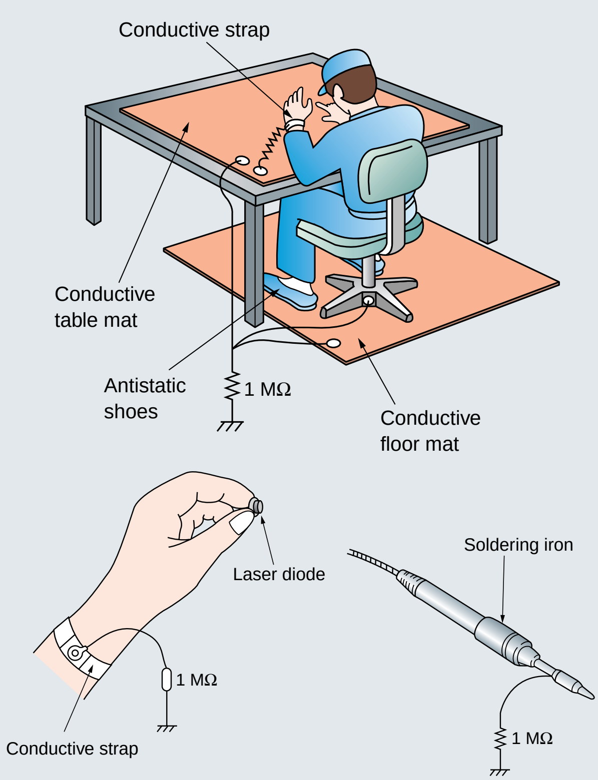


Fig. 35 Antistatic measures

3 Precautions for drive circuits

Before operation, check that the absolute maximum ratings of the device 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. 36).

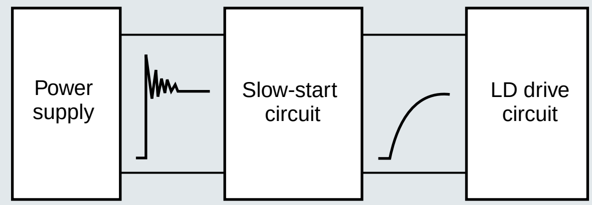


Fig. 36

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 absolute maximum rating value (see Fig. 37).

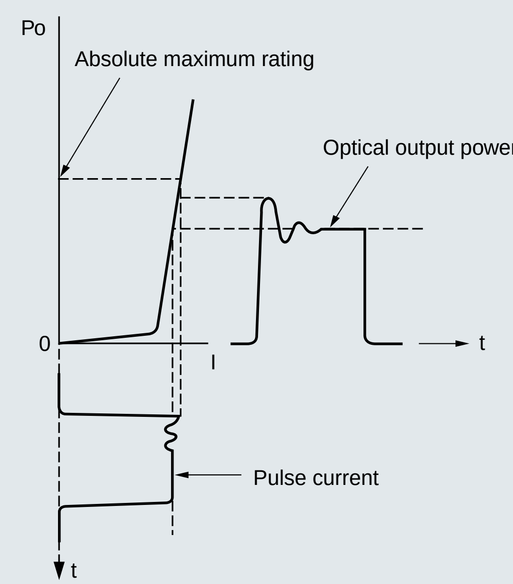


Fig. 37

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.

4 Soldering precautions

- Soldering must be performed after the leads have been formed.
- Soldering temperature ≤ 260˚C
- Soldering time ≤ 5 s
- Soldering must be performed 2 mm below the package base.

5 Heat dissipation (can package)

- Laser diodes must always be used attached to a heatsink.
- To fit the heatsink, press the flange of the package into the heatsink or secure with a firm connection as in Figure 38.
- When attaching the heatsink, avoid subjecting the cap to mechanical stress. Otherwise the glass may get cracked or, in the worst case, the cap may come off.
- Do not directly solder the visible laser diode onto the heatsink.
- When using silicon grease, avoid getting grease on the window glass.

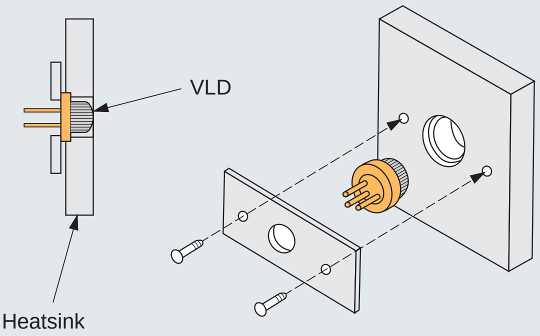


Fig. 38
Heatsink attachment method

■ Example of heatsink Selection

The following equation shows the relationship between the case temperature, Tc, the ambient temperature, Ta, and the thermal resistance of the heatsink, θf:

$$\theta f \fallingdotseq \frac{Tc - Ta}{Iop \times Vop} - (\theta s + \theta c),$$

where θs = insulated sink thermal resistance,
θc = contact thermal resistance

With the TOLD2000MDA (650 nm):

The thermal resistance of the heatsink is expressed by the following equation:

$$\theta f \fallingdotseq \frac{70 - 65}{0.05 \times 2.2} - 5 \fallingdotseq 40,$$

Where case temperature, Tc, is 70˚C; the ambient temperature, Ta, is 65˚C; the operating current, Iop, is 50 mA; and the operating voltage, Vop, is 2.2 V (when Po = 5 mW); and assuming that no insulated sink is used (θs = 0) and that the worst possible contact conditions apply (θc = 5˚C/W).
Accordingly, the thermal resistance of the heatsink should be no higher than 40˚C/W. When a 2-mm thick aluminum plate for the sink is used, the plate should have an area of at least 3.5 cm^2, as based on Figure 39.

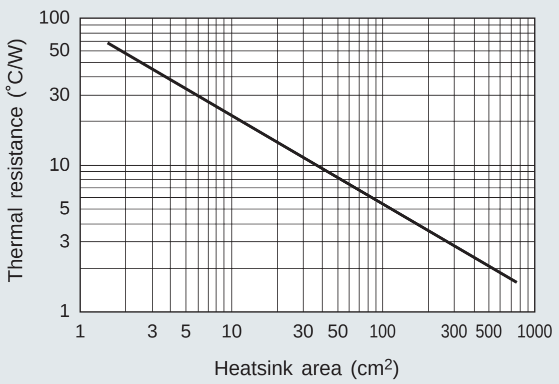


Fig. 39
The relationship between the area of
a 2-mm thick aluminum heatsink and thermal resistance θf.

6 Handling lead-frame packages

Precautions for use

- Do not use a lead-frame package with dew condensation on it, because it is not hermetically sealed. Not only is there a risk that the optical characteristics may be lowered; the device may also be damaged by short-circuits in the package.
- If it is anticipated that the product will be used in a high-temperature, high-humidity environment for a long time, do not apply a bias voltage to the internal monitor PD.

Precautions against dust

- Keep the LD chip facet free from dust.
- Keep the LD chip facet free from silicone grease, which may be used with a heatsink.

Precautions in securing the product and releasing heat from it

- When using the product, keep the heat-releasing surface at its bottom in close contact with a heatsink made of aluminum or copper. To increase its heat-releasing capability, place a load of about 5 N uniformly on the cap at the top. Carefully assess and determine the load beforehand because the material and surface state of the heatsink can affect the heat-releasing characteristic.

Table Recommended range of load on the cap

	Min	Typ.	Max
Recommended load (N)	2	5	8

- Do not put an excessive load on the cap on the top of the product. Also, avoid concentrating a load on a single point. Doing so may result not only in changes in the monitor current but also in distortion to or breakage of the cap.
- Before attaching a heatsink, avoid subjecting the product to excessive twisting or shock.
- To secure the product, fasten its wings with adhesive or screws in addition to placing a load on its cap.
- Ensure that no gas fumes released from the product-securing adhesive enter or remain in the product.

Precautions in designing and positioning a heatsink

- Keep the front edge of the heatsink between the front-end surface of the product's lead frame and the bottom surface of the concave portion at the center of the frame (Fig. 40 a). If the front edge of the heatsink projects too far from the product, it may interfere with output beams. If it is too far behind the product, the heat releasing characteristic of the device will be impaired.
- Do not round the front edge of the heatsink (Fig. 40 c). If it is rounded, the heatsink will be unable to touch the heat releasing surface directly underneath the laser chip, leading to a lowered heat-releasing characteristic.

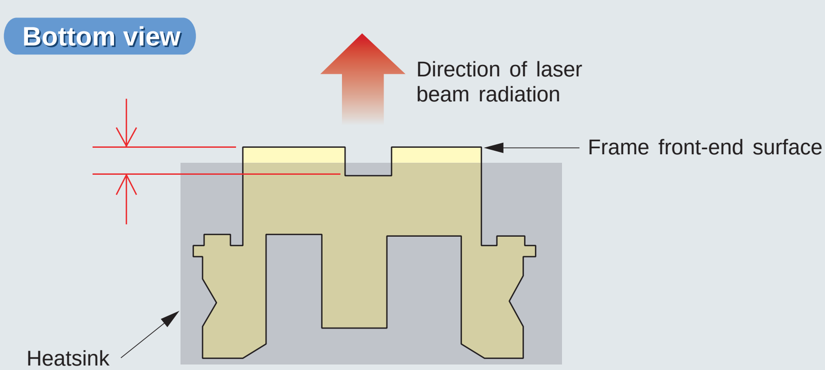


Fig. 40 a Position of the heatsink front-end surface

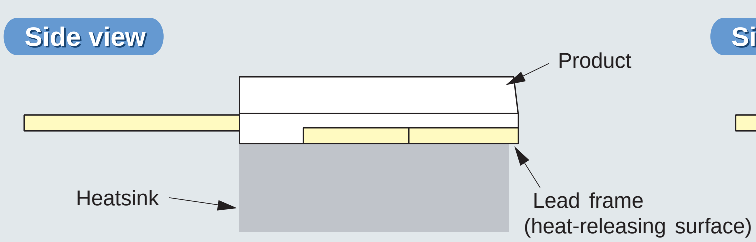


Fig. 40 b Mounting a heatsink (example of acceptable mounting)

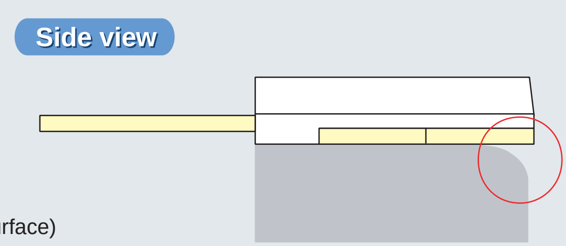


Fig. 40 c Mounting a heatsink (example of unacceptable mounting)

7 Safety considerations

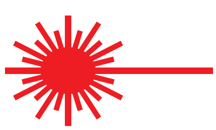
The laser beam emitted by the laser diode is harmful if aimed directly into the human eye. Never look directly into the laser beam or into a laser beam that is collimated (i.e., parallel) with the optical axis.

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, 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 laser diode cartons.

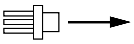


⚠CAUTION

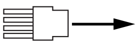
Laser radiation can cause hazard eyes and skin.
Avoid direct exposure to the beam.

CLASS 3B LASER PRODUCT

TYPE I



TYPE II



Laser radiation emits this direction.

TYPE I or TYPE II is contained in this package.

NOTE

ESD can cause damage to the product.
Treat prevention to the ESD.

PEAK POWER 250 mW
WAVELENGTH 600～805 nm
CLASS 3B LASER PRODUCT

⚠CAUTION

GaAs is used in this product.
The dust or vapor can be dangerous to humans.
Do not break, cut, crush or dissolve chemically.

TOSHIBA CORPORATION

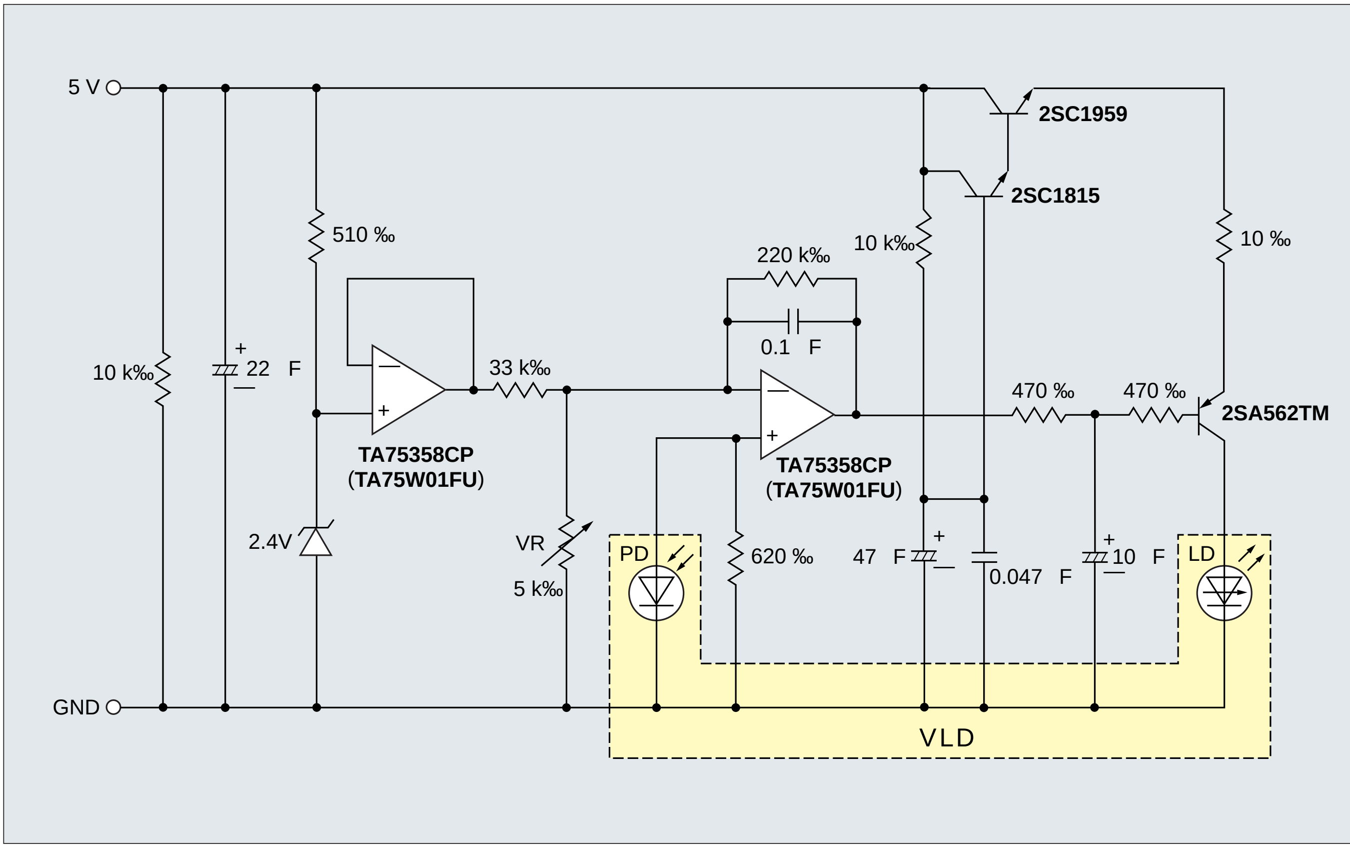
CERTIFICATION

This Product Complies with
21 CFR 1040.10 and 1040.11

MANUFACTURED TOSHIBA CORPORATION
1-1-1. SHIBAURA MINATOKU TOKYO 105-8001. JAPAN

7. Sample Drive Circuits

1. Example Featuring an APC Drive Circuit for a Visible Laser Diode



Note: This APC drive circuit is an example only.
Values of resistors may vary depending on the laser diodes used and on the operating conditions.
Check the operation of any APC drive circuit thoroughly before use.

8. How to Order

8-1 Toshiba VLD Order Codes

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

TR — tray carton (200 items)
TRK — tray carton (200 items x 5 trays)

TOLD**M*(TR)**
Tray carton/200 laser diodes

TOLD**M*(TRK)**
Tray carton/200 laser diodes x 5 trays = 1000 laser diodes

Because Toshiba visible laser diodes are used for optical storage disks, they cannot be sold individually. Please contact a Toshiba sales office if you require a small number of samples for test evaluation.

OVERSEAS SUBSIDIARIES AND AFFILIATES

(As of April 1, 2005)

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Buffalo Grove (Chicago)
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Buffalo Grove, IL 60089, U.S.A.
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Duluth, GA 30096, U.S.A.
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Beaverton/Portland, OR
8323 SW Cirrus Drive, Beaverton,
OR 97008, U.S.A.
Tel: (503)466-3721 Fax: (503)629-0827

Raleigh, NC
3120 Highwoods Blvd., #108, Raleigh,
NC 27604, U.S.A.
Tel: (919)859-2800 Fax: (919)859-2898

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Tel: (972)480-0470 Fax: (972)235-4114

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1060 Rincon Circle, San Jose, CA 95131, U.S.A.
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MA 01880-6229, U.S.A.
Tel: (781)224-0074 Fax: (781)224-1095

Wixom (Detroit)
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MI 48393 U.S.A.
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