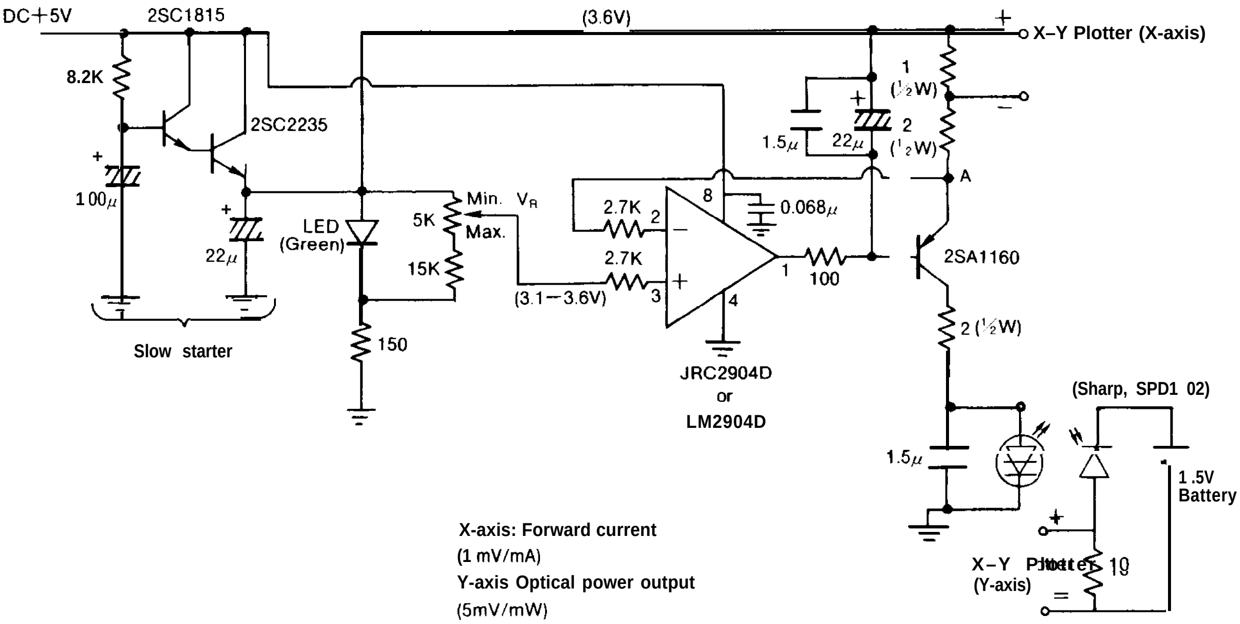
Optical Power Output vs. Forward Current Characteristics

Fig. 24-1 P_O-I_F (Optical Power Output va. Forward Current) Measurement System



X-axis: Forward current
(1 mV/mA)
Y-axis Optical power output
(5mV/mW)

Fig. 24-1 shows the measurement circuit used to determine optical power output vs. forward current characteristics. This is an automatic current control (ACC) circuit used to gradually increase the current through the laser diode. The slow starter section on the left side of the circuit protects the laser diode from DC power surges and should always be included. After setting the level control (5kΩ potentiometer) to the minimum setting, the 5 volt power supply may be switched on. Under no circumstances should the laser diode be inserted or removed while power is on.

Feedback is applied in such a way that the voltage at point A corresponds to the forward current selected by the level control. A constant current will be applied to the laser diode so long as the level control setting is not changed.

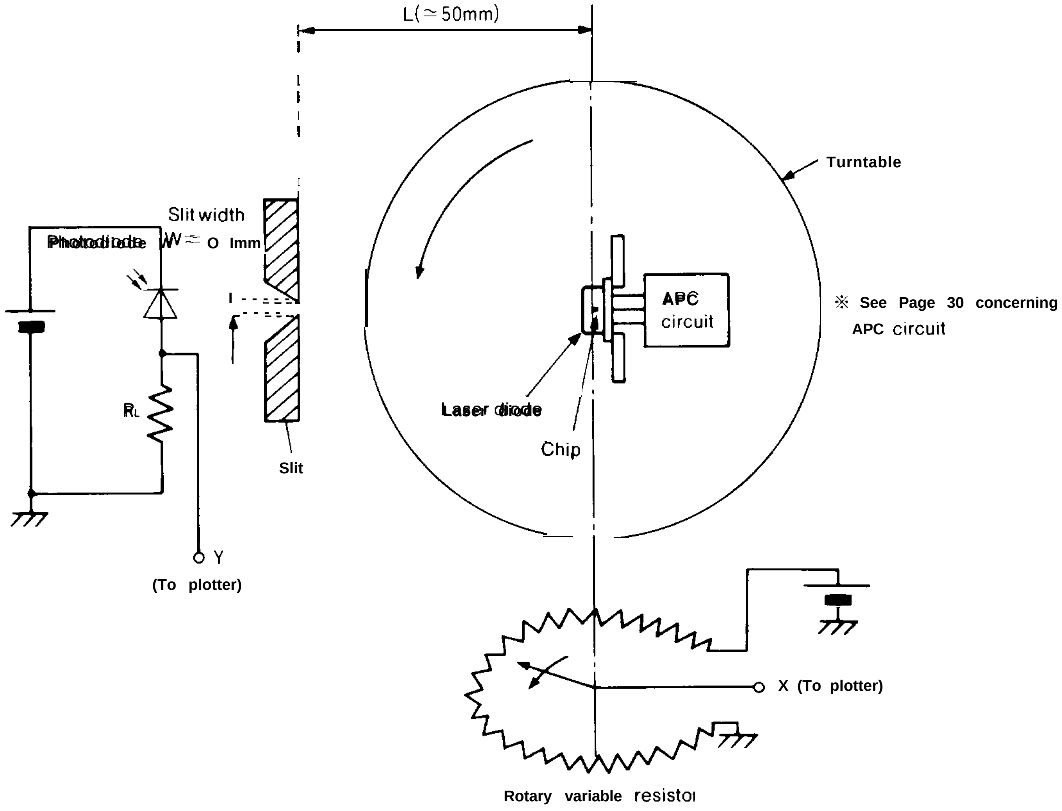
The photodiode should have the largest possible light acceptance area so that the full power output of the laser diode will be measured.

Sharp's SPD102 is recommended. The photodiode should have a sensitivity of approximately 0.5 mA/mW for a 750 to 830 nm wavelength GaAlAs laser diode, Reverse bias is applied with a 1.5 volt battery. Load resistance, R_l, should be as small as possible (5 to 10Ω)

For a circuit built as shown in Fig. 24-1 the P. vs. I_F characteristics maybe displayed on the X-Y plotter by gradually Increasing the ACC circuit level control. Care must be taken to insure that the maximum rated power output of the laser diode is not exceeded.

Radiation Characteristics (Far-Field Pattern, FFP)

Fig. 25-1 Far-Field Pattern Measurement System



※ See Page 30 concerning APC circuit

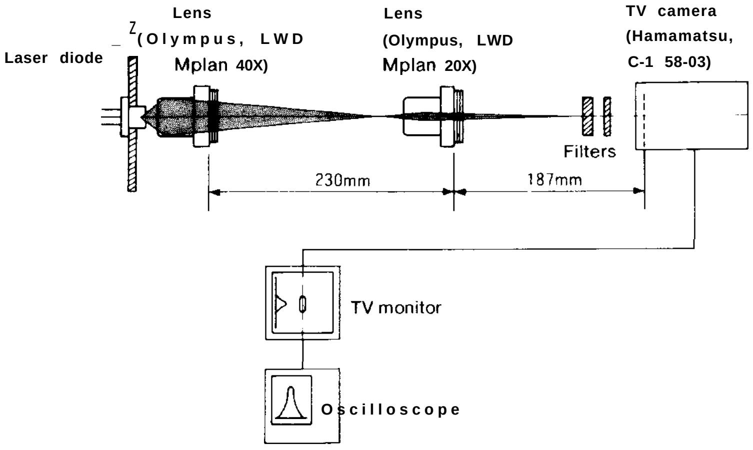
The radiation characteristic is measured by rotating the laser diode as shown in Fig. 25-1 A rotary variable resistor is attached to the turntable to enable measurement of the angular position of the laser diode. The laser diode is fixed to the turntable so that the light emitting point of the chip is in the center, and the laser diode is driven with an automatic power control (APC) circuit to obtain a constant power output.

A slit is positioned in front of the photodiode to increase the resolution of the radiation measurement, The resolution, $\Delta\theta$, is determined by the following formula.

$\Delta\theta\,(\mathrm{deg}) \approx \tan^{-1}(W/L)$

Radiation Pattern (Near-Field Pattern, NFP)

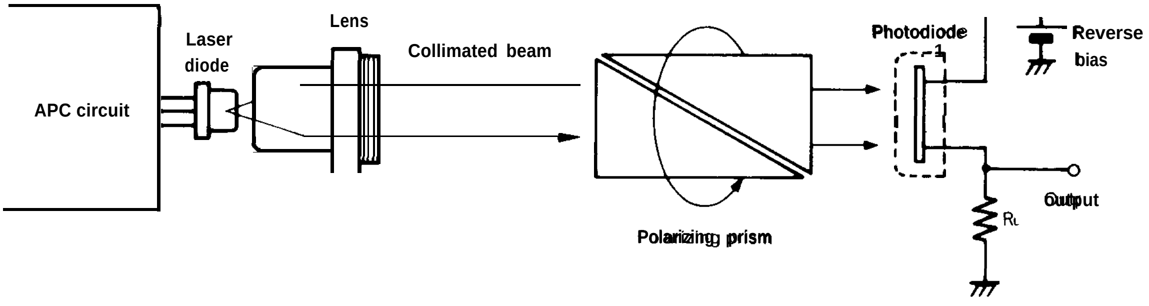
Fig. 25-2 Radiation Pattern Measurement System



As shown in Fig. 25-2, the radiation pattern (near-field pattern) is observed by focusing a lens on the light emitting surface of the laser diode. The radiation pattern is enlarged several hundred times and projected onto a screen by means of an infrared TV camera. The TV camera is protected from damage by the use of filters which limit the amount of light striking the camera.

Polarization Ratio

Fig. 26-1 Polarization Ratio Measurement System



The polarization measurement system is shown in Fig. 26-1 Light emitted by the laser diode is collimated and then passed through a polarizing prism. The prism is rotated and maximum and minimum transmission levels are measured by a photodiode. The polarization ratio is the ratio of the maximum output level to the minimum output level. A polarizing prism with a high extinction ratio (> 103), such as a Glan-Thompson prism, should be used

Thermal Resistance

Fig. 26-2 (a) Thermal Resistance Measurement System

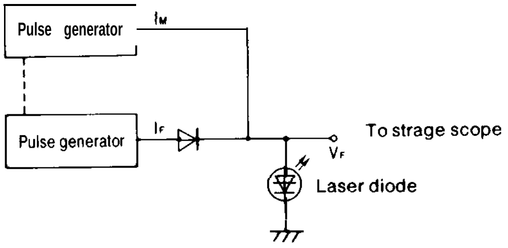
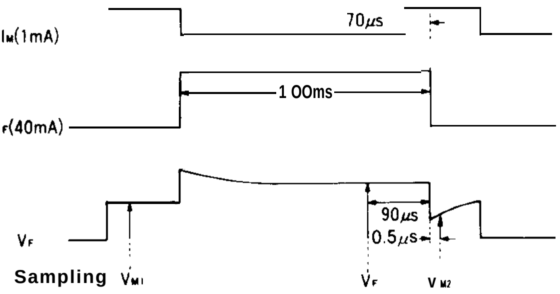


Fig. 26-2 (b) Timing Chart



The system shown in Fig 26-2(a) is used to measure thermal resistance of the laser diode. The temperature dependence of the forward voltage at a specific forward current level is used to measure temperature variations at the junction. These measurements are converted to determine the thermal resistance of the device. As shown in Fig, 26-2 (b) a current, I_M (Approximately 1 mA), is applied in the forward direction and the forward voltage, V_{M1}, is measured. The small Increase in temperature caused by this current is ignored. A forward current, I_F (~40 mA), is then applied for 1 msec and the forward voltage, V_F, is measured. Following this 1 msec pulse, a forward current equivalent to the initial forward current, I_M, is again applied and the forward voltage, V_{M2}, is measured Thermal resistance is calculated using the following formula:

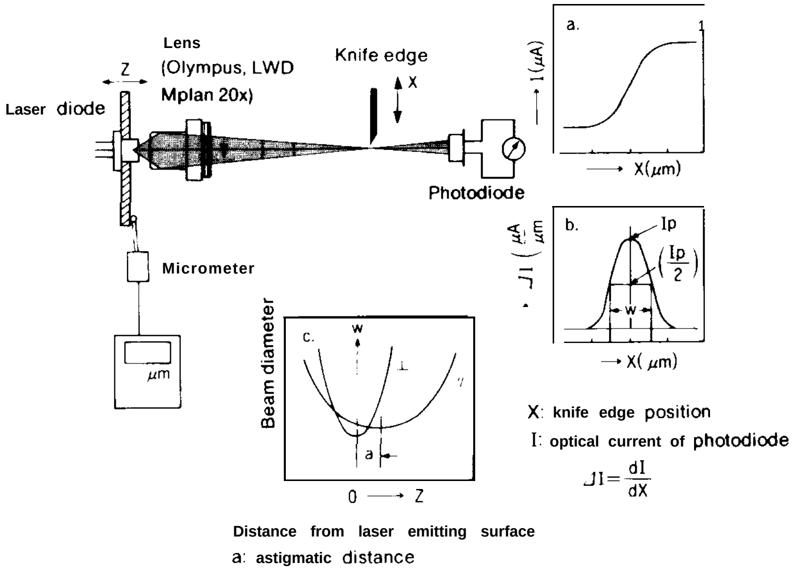
$$\text{Thermal Resistance} = \frac{(V_{M1} - V_{M2})/m}{I_F \cdot V_F} \quad [^\circ\text{C/W}]$$

Where m, the temperature Coefficient (dV_F/dT) of the junction voltage, is measured independently.

To more accurately determine the thermal resistance, the process is repeated at various temperatures.

Astigmatic Distance

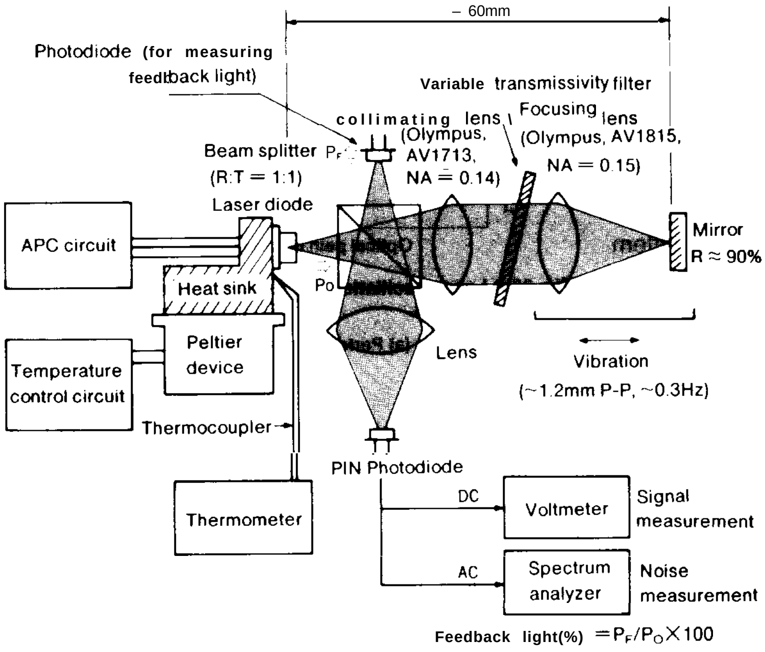
Fig. 27-1 Astigmatic Distance Measurement System



The astigmatic distance is measured using the knife edge technique shown in Fig. 27-1. In this method, a straight knife edge is moved across the beam, traveling perpendicular to its edge. By plotting the total optical power passing the knife edge vs. the knife edge position, an integrated power profile of the laser beam is obtained (Fig 27-1 a,). Differentiation reveals the actual power profile, from which the beam diameter (full width, half maximum) can be determined (Fig 27-1 b.). A beam diameter profile (Fig 27-1 c.) is produced by measuring the beam diameter while varying the distance between the laser diode and the focusing lens Two plots of this type are produced, one for knife edge travel in the direction perpendicular to the junction plane of the laser diode, and the other for travel parallel to the junction plane. The astigmatic distance is defined as the displacement between the minima of these two plots (Fig. 27-1 c.).

Noise

Fig. 27-2 Noise Measurement System



Laser diode noise Includes 1) mode competition noise which is variations in oscillation wavelength caused by fluctuations in current and temperature and 2) optical feedback noise (complex resonator noise) resulting from the partial reflection of the laser beam back into the laser source.

The system shown in Fig. 27-2 will permit measurement of both types of noise. To measure mode competition noise, the mirror and variable filter of the external resonator are fixed in place, and the S/N ratio is measured while varying the temperature of the laser diode with a Peltier device.

To measure optical feedback noise, the amount of feedback light is regulated by varying the transmissivity of the variable filter

The photodiode used to measure noise should be a high speed PIN photodiode or an avalanche photodiode. The application will determine the frequency range to be measured. For compact disc players, a 720-kHz center frequency and 10-kHz bandwidth are standard, The noise level can be expressed as the signal-to-noise level or as the relative Intensity noise (RIN). These are expressed by the two following equations

$$S/N = 10 \log \left(\frac{\delta P}{P}\right)^2 (\mathrm{dB})$$

$$RIN = 10 \log \left\{\left(\frac{\delta P}{P}\right)^2 \frac{1}{\Delta f}\right\} (\mathrm{dB/Hz})$$

Where, P is the optical power output, δP is the fluctuation in the optical power output and Δf is the bandwidth being measured,

Coherence (γ)

The Michelson interferometer described in Fig 28-1 can be used to measure the coherence of a laser beam. The laser beam is split into two by the beam splitter The two beams are reflected off mirrors Ml and M_2 and returned to the beam splitter, where they are recombined and interfere. By observing the change in the interference pattern while moving one mirror in the parallel direction, coherence can be measured, The optical path difference $A\ell$ of the two beams reflected off mirrors M_1 and M_2 is described by

$$\Delta\ell=2(\ell_2-\ell_1)\ \cdots\cdots(1)$$

Where, ℓ_1 and ℓ_2 are the respective distances from the beam splitter to mirrors Ml and M_2. The light intensity I entering the photodiode is given by

$$I=A_0^2+A_0^2\cos(2\pi/\lambda)\Delta\ell$$

(λ= light wavelength) . . ····(2)

Where A_0 is the amplitude of the beam Intensities, 1_0. Equation (2) shows that each time the optical path difference A ℓ increases or decreases by $\lambda/2$, the light intensity cycles between maximum and minimum values (Fig, 28-2). When the optical path difference A ℓ is changed by moving mirror M_2, in the parallel direction, the intensity of the light cycles at wavelength λ and demonstrates sine wave oscillation. To quantitatively express the clarity of the interference stripe, we define its visibility, V, as

$$V=\frac{I\max-I\min}{I\max+I\min}\ \cdots\cdots(3)$$

Where, Imax and Imin are the intensities of the wave crests and troughs in the Interference pattern, as shown in Fig, 28-2. In a perfectly coherent laser beam such as that shown in Fig. 28-3a, visibility V is 1 even if the optical path difference A ℓ is long, But actual laser beams are not perfectly coherent so as A ℓ Increases, V becomes smaller. The maximum optical path difference at which visibility does not decrease is called the coherence length, By plotting the envelope of the interference pattern as in Fig. 28-2the coherence length can be obtained,

In laser diodes, there are side modes in the oscillation spectrum (longitudinal mode), so peaks appear in the envelope (Fig. 28-3 b, c).

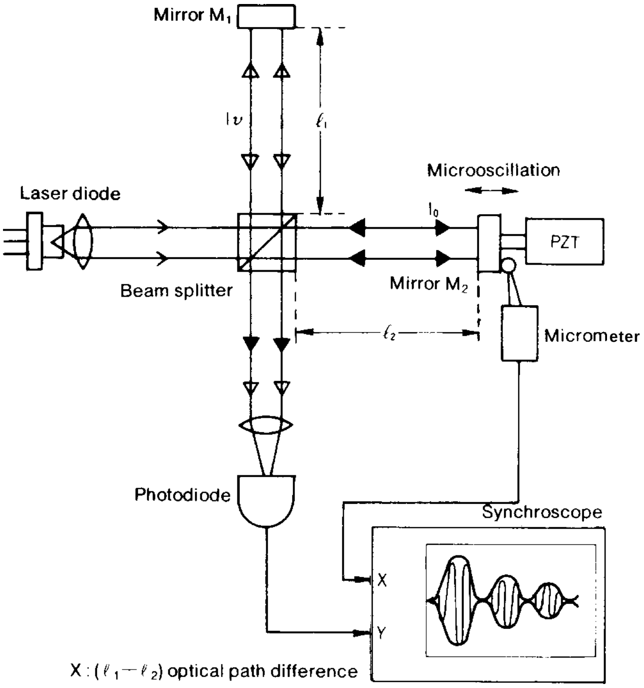
γ, the attenuation factor of the visibility, is defined as the ratio of the intensity of the pattern at zero path difference, I_A, to the intensity of the next peak in the envelope, I_B.

$$\gamma=I_B/I_A\ .\ .\ .\ .\ ...(4)$$

If γ= 1, the light is perfectly coherent, and if γ=0, the light is incoherent.

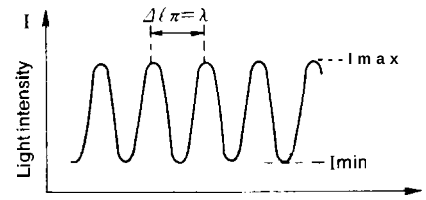
In the LT023 series, Sharp has decreased this parameter, to $\gamma\leqq 0.47$ to minimize the amount of optical feedback noise. The coherence length in this instance is about 1 mm,

Fig. 28-1 Coherence Measurement System



X : ($\ell_1-\ell_2$) optical path difference
Y : I light intensity

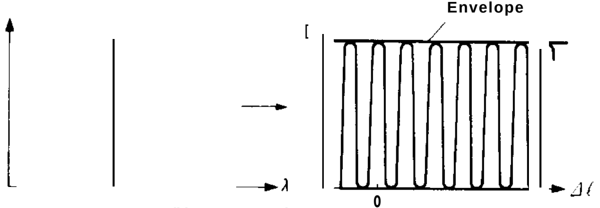
Fig. 28-2 Interference Stripe



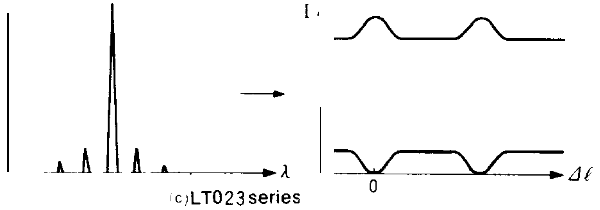
Optical path difference $A\ell$

Fig. 28-3 **Laser Oscillation** Spectra and interference Pattern Envelopes.

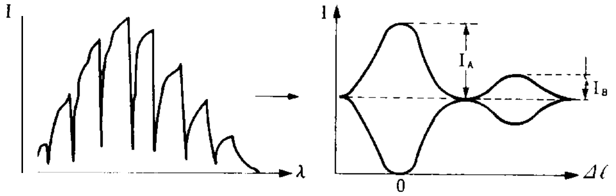
(a) Perfectly coherent laser



(b) LT026 series



(c) LT023 series

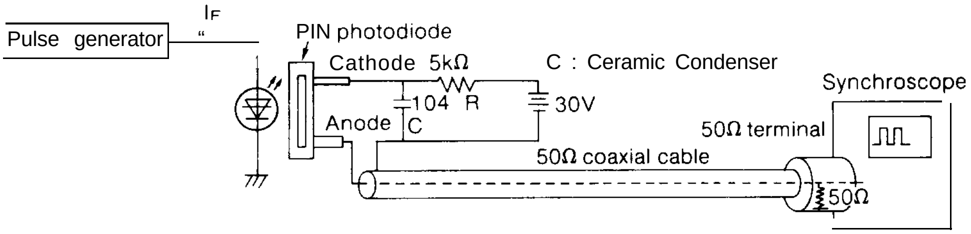


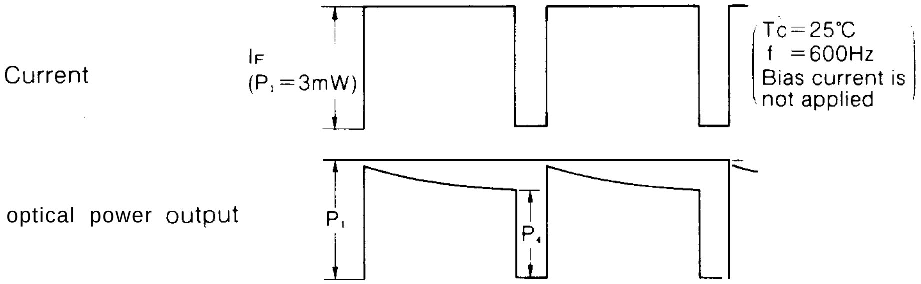
Droop rate

The droop rate measurement system is shown in Fig.29-1. The current of P_1 (Momentary optical power output on 10% duty drive,) is set 3mW. Then at the same current, the laser diode is driven with 90% duty.
At that time, the optical power output become decreasing due to thermal from laser chip. After that, the optical power output (P_4) just before the current become off is measured. The droop rate is calculated using the following formula:

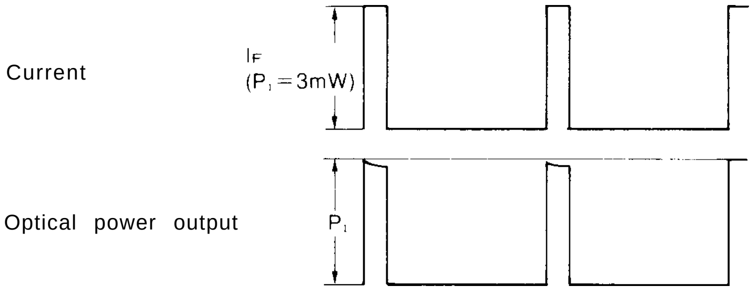
$$\text{Droop rate} = \frac{P_1 - P_4}{P_4} \times 100\ [\%]$$

Fig. 29-1 Droop Rate Measurement System





Duty 90%



Duty 10%