CHAPTER 4: LASER DIODE DRIVER

The laser source consists of a laser diode, a driver to operate the diode, and a power supply.

4.1 Laser Diode

The LIM requires a continuous wave (CW) laser input whose wavelength is in the visible range. A number of commercially available laser diodes were studied based on the following criteria to identify the most suitable diode for the laser system:

Wavelength: The laser diodes with output in the visible range are available in wavelengths ranging from 635 nm to 690 nm. Output of lasers with wavelengths closer to 635 nm are more visible and brighter compared to the output of lasers with wavelengths closer to 690 nm. However, the cost of shorter wavelength (wavelengths closer to 635 nm) diodes is much more compared to their longer wavelength (wavelengths closer to 690 nm) counterparts. Furthermore, the signal-to-noise ratio of a 670 nm laser diode rated at a particular power is same as that of a 635 nm laser diode of the same power as the 690 nm diode. Thus a longer wavelength laser diode with higher power output and lower cost is preferred to a shorter wavelength laser diode with a lower power output and higher cost, even though it looks brighter.

Power: The output from the laser diode, when used in the LIM, suffers several losses including the coupling loss, when the laser diode is pigtailed to the Polarization Maintaining (PM) fiber; the loss when projected on optical components like the hologram and SLM; and the loss when passed through the lens. Hence it is desirable to have a laser diode with high power output at an affordable cost.

Beam Divergence: Semiconductor diodes, in addition to several advantages (for example, smaller size) over other type of lasers, have some drawbacks. The two major disadvantages of laser diode output are their elliptical cross section and the intrinsic astigmatism [25]. Both these disadvantages are due to the rectangular shape of the end facets (mirrors) of the diode. The elliptical cross section and the astigmatism are shown in Figures 4.1 and 4.2, respectively [25].

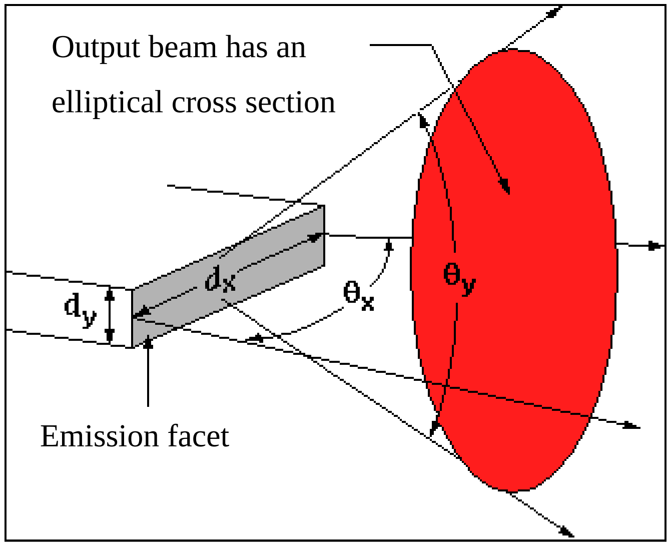


Figure 4.1 Elliptical Cross Section Of Laser Output

The rectangular shape of the facets results in an output that is not entirely collimated and consequently the output suffers divergence. The divergence θ in a particular direction is given by

$$\theta = 4\lambda / \pi d,$$

where λ is the wavelength and d is the length of the facet along a particular direction. A circular beam is obtained when the divergence is equal in both x and y directions, while an elliptical beam is obtained for unequal divergence.

Astigmatism is the phenomenon when the light output from a source appears to originate from two different points in a system. As shown in Figure 4.2, the output from the facet is equivalent to the output from a point source, which is located at a point P. Due to the rectangular shape of the facet, P_x is located farther back than P_y and consequently θ_y is greater than θ_x. Larger the difference between θx and θy, greater is the astigmatism. When astigmatism is present, it is possible to collimate the output using a standard lens in only one direction, either x or y. This is because only one of the two points P_x and P_y can be converged to the focal point of the lens.

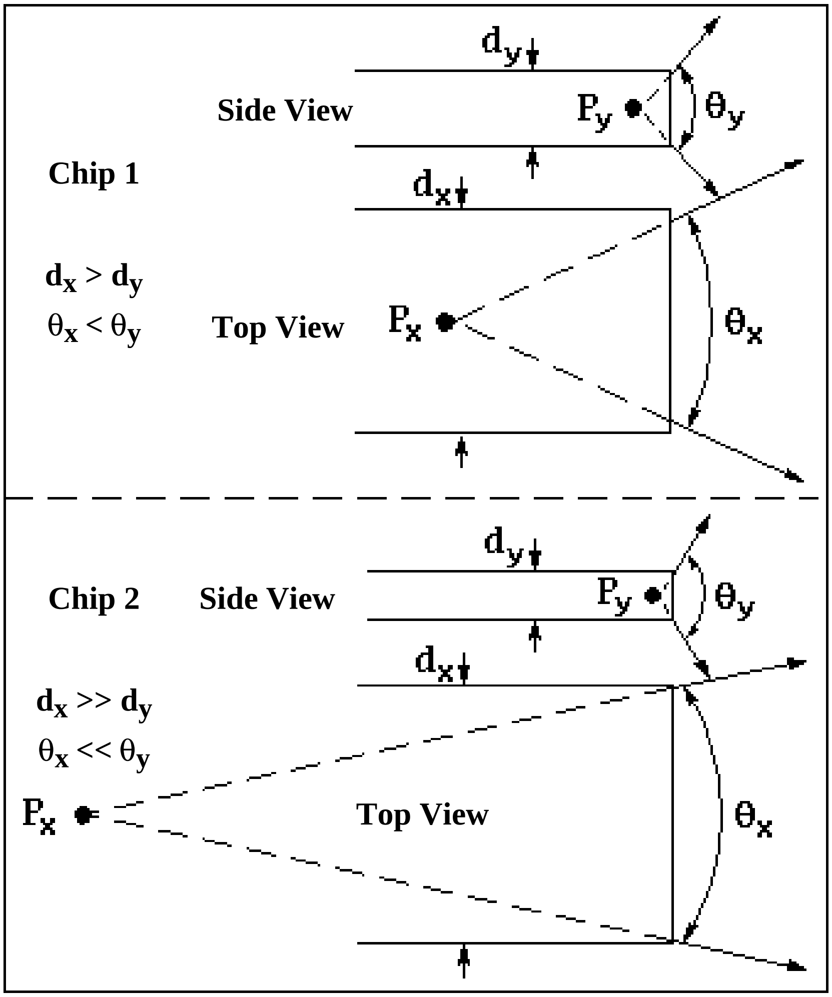


Figure 4.2 Astigmatism Of Laser Output

In order to minimize the effects of beam divergence and astigmatism on the output, laser diodes with the smallest values of the divergent angles θ_x and θ_y are preferred.

The comparison of the above parameters for a few of the commercially available diodes that were considered for the laser source is given in Table 4.1.

Table 4.1 Comparison Of Commercially Available Laser Diodes

Parameter		Hitachi HL6320G	Philips CQL806/D	Toshiba TOLD9150
Wavelength		635 nm	675 nm	690 nm
Optical Power		10 mW	20 mW	30 mW
Beam Divergence	Perpendicular	8°	8°	8.5°
	Parallel	31°	24°	18°

Based on the above comparison, the laser diode TOLD9150 from Toshiba is chosen for the laser system.

4.1.1 TOLD9150

TOLD9150 is a high power, AlGaInP, index guided, multiple-quantum-well structure visible diode. AlGaInP is a quarternary compound, which is used to build lasers with output in the visible range. GaInP lasers have an output wavelength of 670 nm. In order to obtain a different wavelength, aluminum is used in addition to gallium resulting in AlGaInP. TOLD9150 provides a coherent continuous wave output with a typical wavelength of 690 nm and a maximum power of 30 mW, at an operating temperature of 25° C. The typical threshold current is 50 mA and the operation current should not exceed 125 mA at any instant. The wavelength, threshold current, and operation current for the purchased laser diode are 691.5 nm, 44.9 mA and, 79.9 mA, respectively. The data sheet for TOLD9150 and the characteristics for the purchased diode are included in APPENDIX.

The following precautions were taken to ensure proper function of the diode:

Handling and storage precautions: Use of wrist straps and anti-static mats, while handling the diode, and shorting the leads of the diode, when the diode is not in use, are recommended.

Use of proper driver: The driver used to operate the laser diode should protect it against power supply transients and, provide accurate current and voltage for diode operation. The operation current of 79.9 mA should not be exceeded at any time, as it will result in rapid and permanent degradation of laser performance. A reverse voltage of 2 V is the maximum accepted value and any reverse voltage more than 2 V can damage the laser. The diode has fast response time and can be damaged by transients that last for less than 1μs. Hence, surge-protected outlets must be used.

Heat sink: The lifetime of the laser is inversely proportional to the operating temperature and hence a proper heat sink, if used to mount the laser, will ensure its longevity.

Reflections: A feedback photodiode is provided to ensure stability of the output power. In the presence of a flat surface, a portion of the output power is reflected back to the photodiode. This results in a wrong estimate for the photodiode current. When the reflecting surface is removed, accidentally or intentionally, the photodiode tries to compensate for the drop in current and this might result in overdriving of the laser. Hence, use of optical isolators to avoid direct feedback into the laser or use of an angled surface is advised.

4.2 Laser-Fiber Coupling

The laser diode is pigtailed to a PM fiber by OZ Optics LTD. They use a method called the Tilt Adjustment Technique to achieve maximum coupling between the diode output and the fiber. There are two versions of tilt-adjustable laser-diode-to-fiber couplers:

1. Receptacle style couplers that have a female receptacle, such as NTT-FC and AT&T-ST, at the output end, which enables the user to connect it to any optical fiber with a matching male connector.
2. Pigtail style coupler with the fiber pigtailed directly onto the coupler.

The pigtail style coupler is chosen for the Toshiba laser diode, as it provides higher coupling efficiency, better stability of output, and lower backreflection levels. The coupler diameter is 1.3”. The coupler has an operating temperature range of –25° to 60° C, and has been vibration tested. A pigtailed diode has a back reflection level of 40 dB and a coupling efficiency of 45%.

The laser diode is pigtailed to a 3 m long PM single mode fiber. The fiber is covered with a 3 mm (outer diameter) loose tube kevlar jacket and has core/cladding diameter of 4 μm/125 μm. The PM fiber is used to preserve the polarization of the output from the diode. The polarization of light changes whenever an ordinary single mode fiber is induced to stress (bend or twist), position change, and/or temperature change. This change in polarization occurs even in short fiber and is undesirable in the case of the LIM, which requires a constant polarization output. PM fibers use the difference in propagation constant of light for two perpendicular polarization directions to prevent the polarization of the light from changing. This phenomenon, known as birefringence, creates two principal transmission axes within the fiber. When the input light into the PM fiber is linearly polarized and is oriented along one of these two axes, the output light from the fiber is linearly polarized and is aligned with the principal axis even under conditions of extreme stress.

OZ Optics Ltd. uses the tilt adjustment technique to couple light from the diode to the fiber. This is done in two stages. The first step involves the use of a collimating lens and a collimator wrench (to adjust the distance between the diode and the collimating lens) to obtain a collimated output beam from the diode. This collimated output is then coupled to the fiber using a second lens by OZ Optics' patented tilt adjustment technique. The focal lengths of the collimating and coupling lens are selected so as to transform the optical properties of the laser diode output to match the mode field pattern of the fiber as closely as possible.

4.3 Driver Circuit

Laser diodes have long operating lifetimes, on the order of tens of thousands of hours, provided they are handled with care and operated with proper driver circuits. A number of reasons including current surge, electro static discharge, and temperature surge contribute to the reduction of a laser diode's lifetime or to its complete failure.

4.3.1 Current Surge

There is a maximum value of current that can be used to drive a laser diode. This maximum value varies from diode to diode. When the current driving a laser diode is greater than the allowable limit, even for a fraction of a second, the diode will be damaged and the extent of damage depends on the sensitivity of the particular diode. The sensitivity of the laser diode to overcurrent is due to the fast response of the laser output to the driver current variation and the large amount of positive feedback present during the lasing action.

The fast response time is an inherent characteristic of the diode. The relation of the laser diode output to the driver current is shown in Figure 4.3. The plot indicates a rapid increase in the slope of the output above the threshold current. Above the threshold current, a small increase in the drive current results in a steep increase in the optical output. The high optical output leads to overheating of the end facets (mirrors) of the laser diode structure. Depending on the power intensity, the overheating causes deformation or destruction of the facets, and renders the laser diode useless. The current surge occurs due to various reasons including:

- Power line transients that occur briefly and cause spikes on the drive current,
- Transients that occur during the startup, which result in the driving current to exceed the maximum operating point, and
- Increase of the drive current by the user.

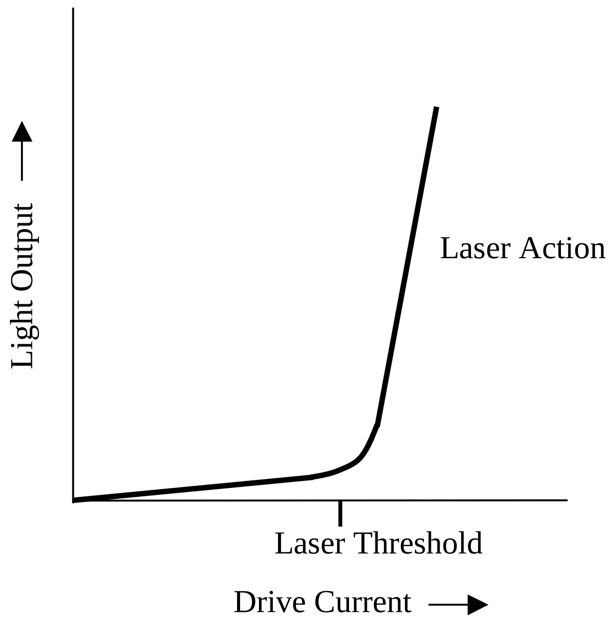


Figure 4.3 Laser Diode Output Versus Drive Current

Thus it is necessary to design a driver to ensure that the current input to the laser diode never exceeds the allowable limit. The driver should have provision to filter out transients. It also needs a slow start circuit to increase the current level smoothly to its operating point and a current limit circuit that prevents the drive current from increasing above the allowable limit even if the user attempts to increase the current through a current control resistor.

4.3.2 Electro Static Discharge (ESD)

Among the various causes for the failure of the laser diode, the most common reason is ESD. ESD takes place when the laser diode comes in contact with a human who has not taken any ESD precautions or in contact with an ungrounded instrument. ESD causes a sudden spike in the current through the laser diode. If the drive circuit is operational, the current surge results in a sudden increase in the optical output and damages the mirror facets. Even when the drive circuit is off, the current surge due to ESD is often strong enough to destroy the narrow active p-n junction of the laser diode.

Taking precautions when handling the diode and when using it in the circuit can prevent failure due to ESD. Use of anti-static wrist straps, anti-static mats, equipment with proper grounding, and shortening of leads of the diode when not in use prevents damage to the diode. When the diode is used in the circuit, it should be completely isolated from any ohmic contact with the external factors like humans and outside equipment.

4.3.3 Temperature Surge

Increase in the temperature of the laser diode is one of the causes for its failure. Small increase in temperature lowers the frequency stability of the laser output and a large increase damages the diode. The bandgap of the diode varies with temperature, and as mentioned earlier, the output wavelength of the diode is proportional to its bandgap. Thus a variation in temperature affects the stability of the output wavelength. When the temperature increases, the absorption of the output by the facets increases. The photodiode that is present to stabilize the output detects a drop in the output and increases the drive current. Higher drive current increases the optical output and hence the temperature. This vicious cycle continues causing damage to the facets. To combat this problem, a heat sink is used to dissipate excess heat and a thermoelectric cooler (TEC) is used to maintain a constant temperature.

The laser diode is mounted on a heat sink to remove the heat generated during photon emission. The heat sink plate should have enough area to conduct the heat from the diode and dissipate it. It should also be free of any ohmic contact with external instruments and humans, which might result in ESD.

A TEC is used, when the frequency stability and the operating temperature range are important criteria. A TEC is made of two dissimilar materials like two dissimilar conductors or a combination of n-type and p-type semiconductors. One of the materials acts as a hot plate and the other functions as a cold plate. Depending on the direction of current flow through the plates, heat transfer takes place and the TEC is either heated or cooled. Thus by connecting the cold plate to the laser diode and the hot plate to the heat sink, the temperature of the laser diode is stabilized. When the temperature increases, the cold plate absorbs the additional heat and transfers it to the heat sink through the hot plate. A drop in temperature is compensated by the flow of heat from the hot plate to diode through the cold plate.

4.4 Laser Driver

As mentioned in the earlier section, there are several reasons to use a driver, and not just a regular power supply, to operate the laser diode. Three options are available for the design of the driver:

1. The first option is to use a commercially available laser diode driver. Several manufacturers including ILX Lightwave and Melles Griot make universal drivers that can be used to operate a wide range of laser diodes. However, the size and cost restrictions prevent the use of the above drivers in the LIM.
2. The second approach is to design a transistor and chip level driver circuit and implement it. This approach is quite inexpensive but requires considerable amount of time. Furthermore, the use of several individual components increases the probability of failure of the driver.
3. If methods 1 and 2 are considered to be at the two extremes of the driver design spectrum, the third method can be considered to be in the middle. In this method, the driver is constructed using commercially available circuit blocks to perform functions like current and

temperature control. The cost, time required, and the probability of failure for this method is midway between the methods 1 and 2.

Considering the project requirements the third method is chosen to drive the laser diode.

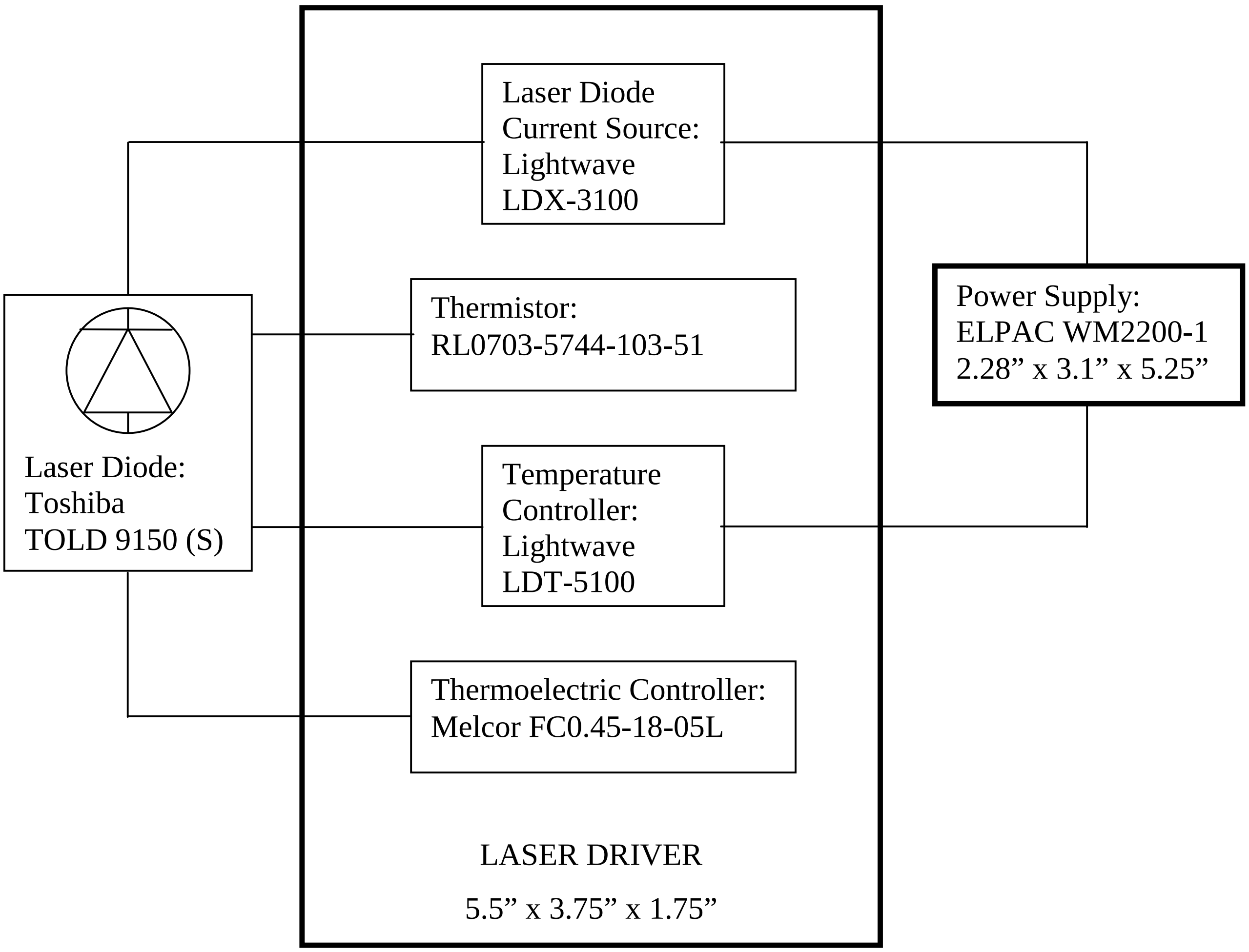


Figure 4.4 Block Diagram Of Laser Source

The laser driver performs two main functions: current control and temperature control. The block diagram of the driver designed to operate the Toshiba laser diode is shown in Figure 4.4. The current source ensures the driver current input to the laser diode never exceeds the allowable limit. The combination of the thermistor, TEC, and temperature controller functions to maintain the temperature of the laser diode in the acceptable range.

4.4.1 Current Source

The purpose of the current source is to avoid current surge due to power line transients, start up transients, and increase of current by user. The current sources manufactured by ILX Lightwave and Thorlabs were studied. The selection of the current source is based on the following criteria:

Output current range: The current source must be able to supply the current necessary to drive the laser diode (95mA to 125mA for Toshiba laser).

Monitor photodiode current range: It should be able to take the range of monitor current from the laser (0.04mA to 0.25mA for Toshiba laser) as input.

Availability of a slow start circuit: The presence of a slow start circuit filters the startup current surges.

Provision to check the exact value of the output current and photodiode current: This enables the user to know whether the maximum allowable limit of the driver current has been reached.

Ability to provide current / power control: It is possible to ensure safe operation of the laser diode by controlling either its input driver current or its optical output power. Since both the drive current and the optical output are interelated, it is possible to control one factor by fixing the other to be a constant. Commercially available current sources might provide control of either current or power or both.

Provision to indicate error in operation: This helps the user to identify the reason for abnormal operation during the initial implementation of the driver design and also during repair.

On analyzing different commercial current sources based on the above factors, LDX-3100, manufactured by ILX Lightwave is chosen for the design. The block diagram showing the I/O, measurement/control and power input connector is included in the APPENDIX.

LDX-3100 has two modes of laser current control. One is the constant current mode, where the supply current to the laser is maintained at a constant value. The other is the constant power mode, where the output optical power is maintained at a constant value using the photocurrent from the laser’s rear-facet mirror as feedback. The desired mode is selected by placing the

"MODE SELECT" jumper (J3) in the suitable position. The selection of the mode is done when the current output to the laser is disabled.

LDX-3100 has two trimpots to control the output drive current and a jumper to control the input photodiode current. The maximum current output from LDX-3100 is specified by the "CURRENT LIMIT" trimpot (R50). The maximum operating current of the laser diode is used to set this trimpot. The trimpot can be set to output a current in the range of 0 to 270 mA. The output current does not exceed the upper limit set by R50, irrespective of whether the constant current or the constant power mode has been chosen. The laser diode has a photodiode that is used to stabilize the output power as mentioned earlier. The "PHOTODIODE RANGE" jumper is used to fix the maximum photodiode current that is input to LDX-3100. The value of current output from the LDX-3100 is controlled by the "I/P SET" trimpot (R57). It is used to vary the driver current from 0 mA to the upper limit set using the "CURRENT LIMIT" trimpot.

LDX-3100 has two control inputs, namely, OUTPUT ON (pin1 of connector J1) and "ISO CONTROL" (J7). OUTPUT ON is the master switch that turns LDX-3100 “on” and “off”. The LDX-3100 is “off”, when OUTPUT ON is grounded, and is “on” when OUTPUT ON is open or when it is pulled high using a +5 V supply. The output from OUTPUT ON drives a green LED, which turns on and off along with LDX-3100 output. The "ISO CONTROL" takes a TTL signal as input from an outside or an isolated source to enable and disable the output from LDX-3100. A logic low input to the control turns “off” the output from LDX-3100, and a logic high or no connection turns LDX-3100 “on”.

The measurement/control connector (J1) is used monitor the operation of the LDX-3100. The connector has three output monitor pins and three status monitor pins. The ACTUAL LASER CURRENT (pin 10), LIMIT CURRENT (pin 8), and PHOTODIODE CURRENT (pin 6) are the output monitor pins which provide output proportional to the output laser current, limit current set using R50, and the input photodiode current, respectively. The three status monitor pins are the OUTPUT STATUS (pin 2), LIMIT INDICATOR (pin 7), and OPEN CIRCUIT ERROR (pin 4). A logic low output on either the OUTPUT STATUS or OPEN CIRCUIT ERROR indicates that the output from the LDX-3100 is “off”, and a high impedance or a logic high indicates normal operation of the circuit. The OPEN CIRCUIT ERROR is turned "on" when there is an open circuit in the connection or when there is a high impedance load. This output switches to logic high once the output is enabled. A logic high on LIMIT INDICATOR indicates that laser current is within allowable limit and it switches to logic low when the limit is reached.

4.4.2 Temperature control

The temperature of the laser diode is maintained within acceptable range using the temperature control circuit from ILX Lightwave, the thermistor, and the TEC.

4.4.2.1 Temperature Controller

Temperature control is implemented using LDT-5100 from ILX Lightwave, in two steps:

1. A thermistor is used to measure the temperature dependent resistance.
2. This resistance is used by LDT-5100 to vary the driving current to a thermoelectric cooler (TEC), thus completing a closed loop.

The driving current output from LDT-5100 is positive when cooling is needed and is negative when heating is required. LDT-5100 is capable of providing highly stable temperature with fast settling times. The thermistor resistance and consequently the desired temperature can be set by using an on-board trimpot or an external resistor. The "RESISTOR SELECT" jumper (J6) is used to make the selection. In the internal mode an onboard 50 Kohm onboard trim pot "R SET" (R52) provides the control resistance while in the external mode the resistor connected between the pins 5 and 6 of the "TEC I/O" connector (J1) is used as the reference point. The external resistor can be either a fixed value or a variable one.

The maximum value of current output from the LDT-5100 to the thermistor and the thermoelectric cooler are set using the "THERMISTOR CURRENT" jumper (J5) and "CURRENT LIMIT" connector (J4), respectively. Depending on the thermistor sensor chosen, "THERMISTOR CURRENT" is set to either 100 μA (Default value) or 10 μA. The "CURRENT LIMIT" connector has five values ranging from 250mA to 2A and they correspond to both the positive and negative load currents.

The settling time required to stabilize the temperature depends on the gain of the closed loop in the LDT-5100. This gain can be varied between 1 and 50 using the "TEC GAIN" trim pot (R44).

Similar to LDX-3100, LDT-5100 has a measurement / control connector (J2) to monitor its operation. The measurement / control connector has an output control pin, two pins for output monitoring and three status monitoring pins. The function of the OUTPUT OFF (pin 1) control is similar to the OUTPUT ON control of LDX-3100. When this pin is grounded, output to the Thermoelectric module is turned "off" and the output is turned "on" when no connection is made. The "ACTUAL RESISTANCE MONITOR" (pin 10) and "TE DRIVE CURRENT MONITOR" (pin 8) provide output proportional to thermistor resistance value and the current that drives the TEC, respectively. Connector J2 has three pins to function as "THERMISTOR OPEN" (pin 6), "TEC OPEN" (pin 4) and "OUTPUT ON / OFF" (pin 2) outputs. Under normal operation THERMISTOR OPEN and TEC OPEN are in logic high level while a logic low indicates high impedance across the thermistor and the TEC, respectively. The OUTPUT ON / OFF line is grounded when the output is turned on and is high when there is no output.

4.4.2.2 Thermoelectric cooler

The TEC manufactured by Material Electronic Products Corporation (MELCOR) was used in the driver to provide a stable operation temperature. The selection of a TEC depends on three parameters:

1. The highest temperature of operation (T_h),
2. The lowest temperature of operation (T_c), and
3. The total heat that has to be pumped by the TEC (Q_c), which is equal to the power generated across the device (Current * Voltage).

When the above three quantities are known, the TEC required for a system can be selected from the universal performance graphs (included in the APPENDIX) using the following steps provided by MELCOR.

1. Calculate $\Delta T = T_h - T_c$. For TOLD9150, $T_h = 50°$ C and $T_c = -10°$ C.

   Hence $\Delta T = (50 - (-10)) = 60°$ C.

2. Choose the operating current of the TEC. The universal performance graphs provide an operating current ranging from 10 G to 50 G, where G is the thermoelement geometry factor. The thermoelement geometry factor is characteristic of a TEC. A typical value of 35 G corresponding to 70% of the maximum current is suggested by MELCOR as a desirable operating current.
3. For a ΔT of 60° C, an operating current of 35 G, and a T_h of 50° C obtain the value of (Qc/G*N) from the universal performance graph. N corresponds to the number of thermoelectric couples present in a TEC. The value of Qc/G*N was found to be 0.75.
4. The maximum operating current for TOLD9150 is 79.9 mA and the operating voltage corresponding to this current is 2.5 V (obtained from the specification graphs that are included in the APPENDIX). The power output from TOLD9150 is 79.9 mA * 2.5 V, which is 0.2 Watts. Thus Qc is 0.2 Watts. Substituting the value for Qc in the expression Qc/G*N = 0.75 yields a value of 0.26 for G*N.

Hence a TEC with a factor of G*N greater than 0.26 has to be chosen for the laser system. FC 0.45-18-05L with a G*N factor of 0.29 is selected for the system. The specifications for the TEC are included in the APPENDIX.

4.4.2.3 Thermistor

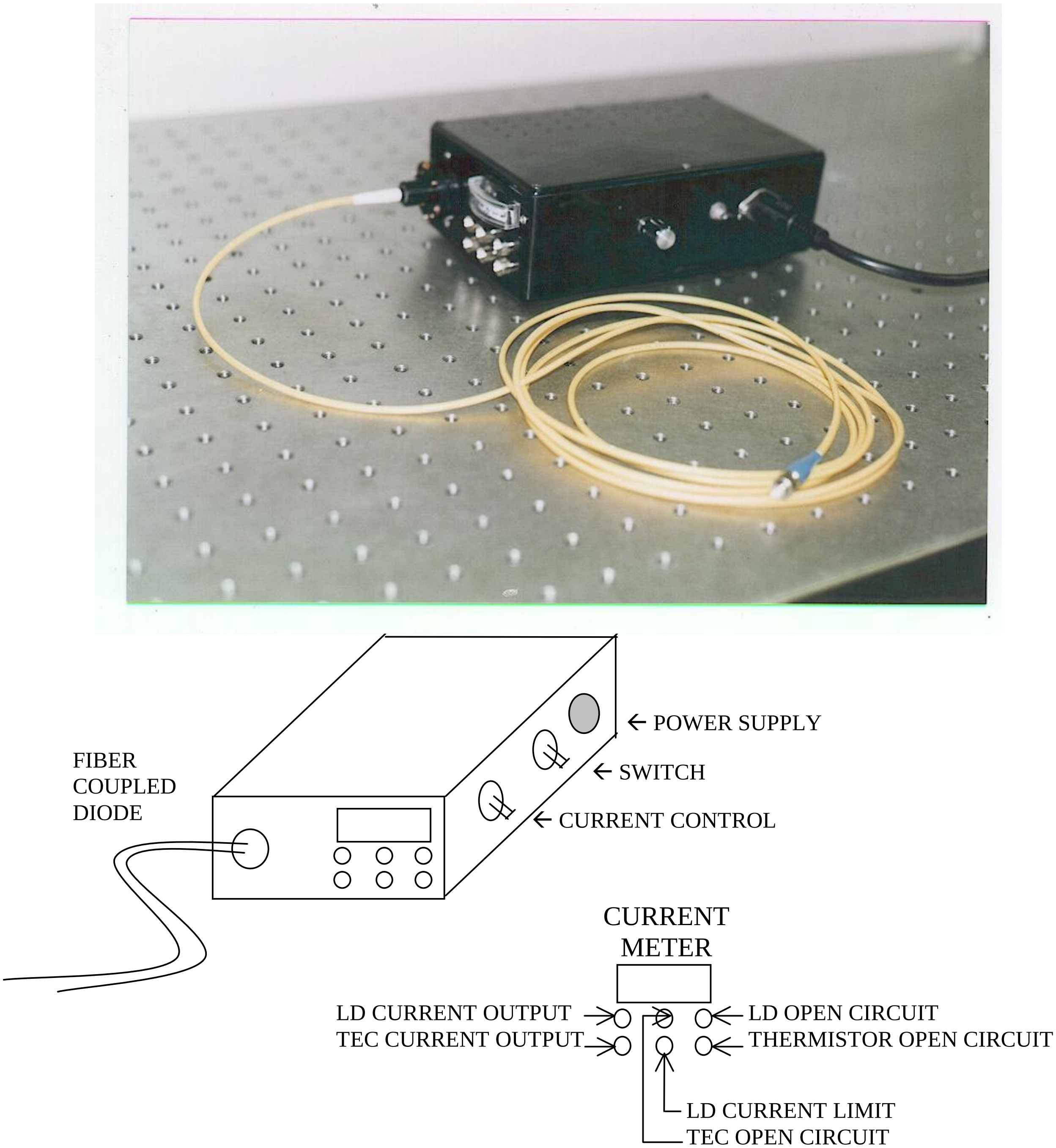
A thermistor is a two-port device, which exhibits a non-linear relation between its resistance and its temperature. Most of the commercial thermistors have Negative Temperature Coeffcients (NTC), with its resistance decreasing with increasing temperature. The thermistor is used in combination with a TEC and a temperature controller circuit to provide a stable temperature for operation of the laser diode. Through proper choice of the above three components it is possible to achieve a temperature stability of up to 0.001° C. Though most of the thermistors cost less than a dollar, their highly non-linear characteristics pose a major problem in selecting the appropriate one. The data sheets for the Toshiba laser indicate the temperature range for the diode case to be -10° C to 50° C. Usually 10 KΩ thermistors are considered a good choice for most laser diode cooling applications where high stability is required near room temperature [16]. The thermistor used in the module is Keystone Thermometrics' RL1008-5820-97-SP. This is a precision thermistor with a resistance of 10 KΩ at 25° C. This highly stable thermistor has a working temperature range of -40° C to 100° C with a tolerance of +/-0.2° C from 0° C to 75° C. The physical dimensions are indicated in the data sheets included in the APPENDIX. Its small size allows placing it in close proximity to the laser diode for accurate measurements. It ensures a fast change in temperature with its time constant of 10 sec. Thus the high sensitivity, small size, fast response times, and low cost ($11.50) make Keystone's thermistor a good choice to be used in the driver module.

4.4.3 Power Supply

The power supply used in the module is ELPAC WM220-1. Lightwave recommends this power supply for use with their LDT and LDX series. The packaged unit with its triple independent outputs can be used to control the Lightwave circuits. The size (2.6" x 3.8" x 6.4") and cost ($100) are less than the other recommended power supplies. The specifications are included in the APPENDIX.

4.5 Construction of the laser driver

The fabricated laser driver with its controls and display panel is shown in Figure 4.5 and the wiring diagram of the driver is shown in Figure 4.6. The controls include the power on switch, the current control knob, and the connector to the power supply. The display panel contains LEDs to indicate the normal operation of the laser source as well as any error condition. The LD CURRENT OUTPUT LED and TEC CURRENT OUTPUT LED indicates normal operation of the constant current circuit and temperature control circuit, respectively. The TEC OPEN CIRCUIT LED goes on when the TEC is damaged. The laser diode will be damaged if operated without the TEC. However, the size of the heat sink allows the laser diode to be operated for several minutes without TEC. Hence, the TEC open circuit condition does not automatically disable the laser diode output. When the maximum value for drive current is reached, the LD CURRENT LIMIT LED goes “on”. Once this LED goes “on”, any attempt to increase the drive current through the current control knob is neglected by the driver circuit. The THERMISTOR OPEN CIRCUIT LED indicates that the thermistor is damaged. When no current flows through the laser diode, the LD OPEN CIRCUIT LED goes “on”. This condition might be due to damage to the laser diode or to the constant current circuit. The display panel also has an analog display to indicate the value of the drive current.



PANELS AND CONTROLS

Figure 4.5 Laser Source

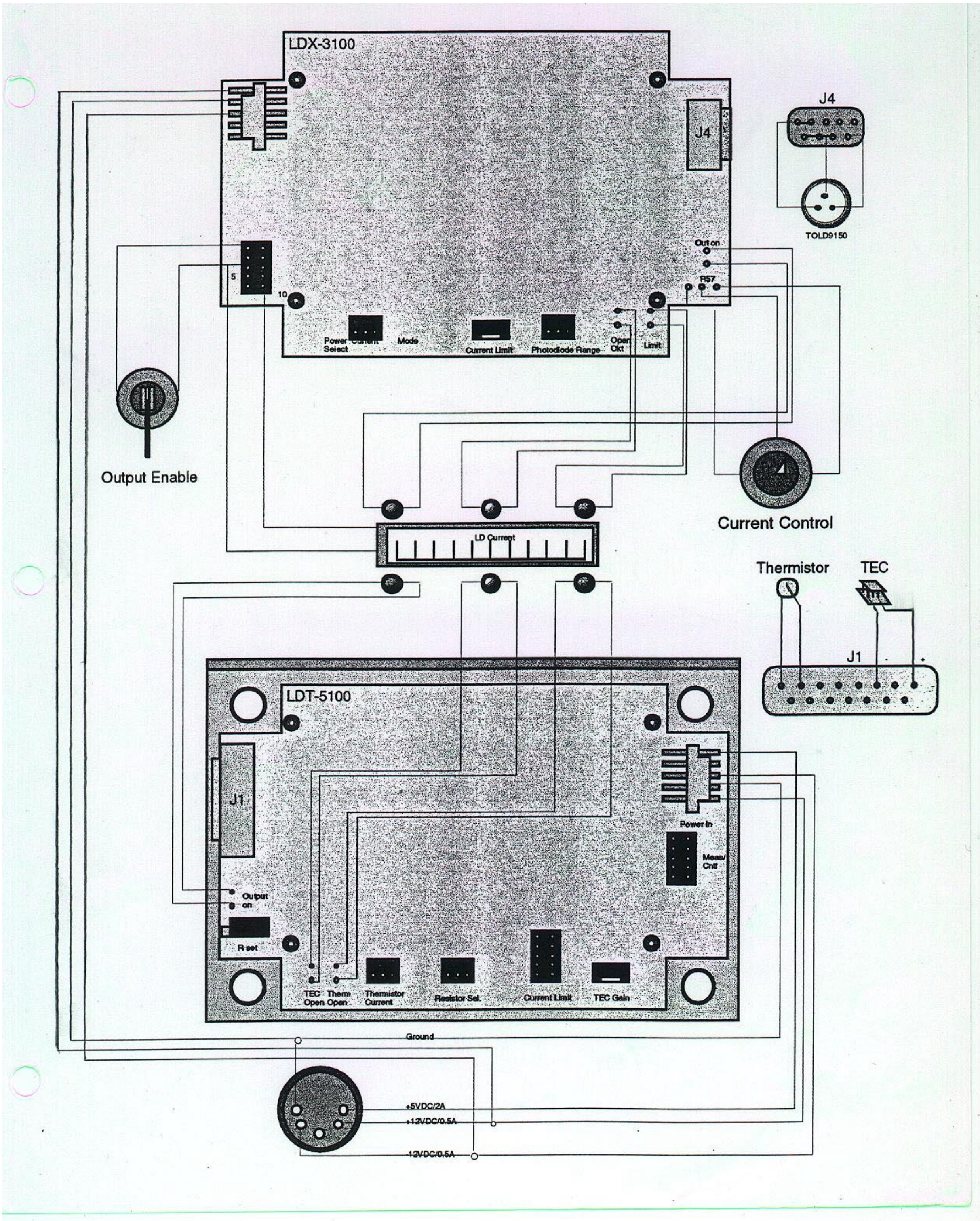


Figure 4.6 Wiring Diagram Of Driver

The laser diode with its fiber pigtail and the heat sink is mounted on the wall containing the display panel. The construction of the heat sink is shown in Figure 4.7. The LDX-3100 and LDT-5100 are anchored to each other and to the wall of the box opposite to the controls. The laser diode, the constant current circuit, and the temperature control circuits are controlled by the power “on” switch. This ensures that the current control and cooling circuits are turned “on” at the same instant as the laser diode. When the system is turned “on”, the output current from the constant current circuit is enabled after a 3 sec delay. The current is then ramped to the value set by the current control knob, located beside the power switch. The delay prevents damage to the laser diode due to spikes and overshoot of the desired driving current.

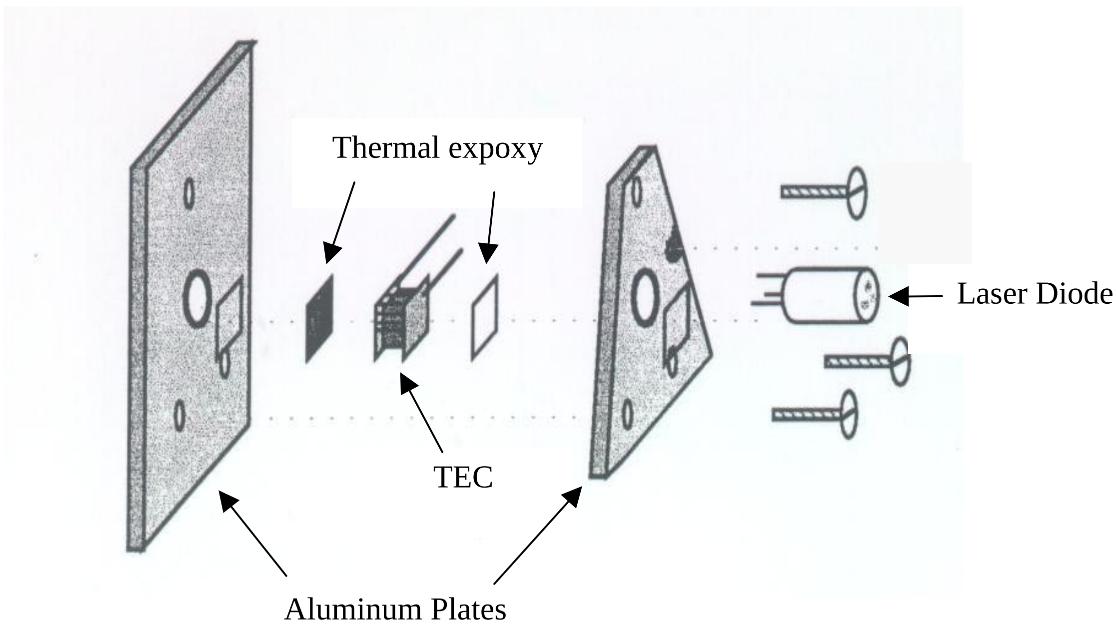


Figure 4.7 Construction Of Heat Sink

4.5.1 LDX-3100 settings

1. The current control knob is a potentiometer that replaces R57 shown on the LDX-3100 specification sheets in Appendix. The current control knob can be turned even after the current limit has been reached. This does not increase the current (and consequently does not harm the laser diode), since the current limit circuit effectively stops any increase in current beyond the value set by potentiometer R50 on the LDX-3100. Potentiometer R50 is shown on the specification sheets of the LDX-3100. The potentiometer is set at a maximum current

of 79.9 mA, which is the operation current of the TOLD9150 laser diode. To prevent damage to the laser diode, external access to R50 is not provided.

2. Jumper block J3 in LDX-3100 is paced in the CURRENT mode to facilitate control over the laser diode output power, by varying the input drive current.
3. The photodiode present in TOLD9150 can accept a maximum current of 0.1 mA. The jumper block J6 in LDX-3100 indicates the maximum photodiode current that is output from the laser diode. The jumper is placed in the 1 mA position since the laser diode has a maximum current output of 0.1 mA.

4.5.2 LDT-5100 settings

1. The MELCOR FC 0.45-18-05 TEC module has a maximum current rating of 800 mA. As mentioned earlier, the desired operating current of the TEC is 70% of its maximum current. Hence the desirable operating current is 560 mA. The jumper J4 in LDT-5100 is used to select the driving current of the TEC. The value in J4 that is nearest to 560 mA was 500 mA and hence it is selected as the driving current of the TEC module.
2. The gain of the TEC circuit, which is set using the trimpot R44, determines how quickly the current supplied to the TEC can change, hence how quickly the TEC can transfer heat. If the gain is set too low, the TEC will not effectively remove heat from the hot plate. If it is too high, the TEC will have a long settling time to the desired temperature, and oscillate around the quiescent point. Hence, the trimpot is set at the center value.
3. The thermistor current source jumper J5 is set to the default value of 100 μA.

4.6 System Testing

4.6.1 Output power testing

The optical power of the laser output was measured using the Newport optical power meter. The meter is capable of measuring high power in the visible range of the optical wavelengths. Using the meter, the optical power output from the pitgailed PM single mode fiber was found to be 15.435 mW, when the laser was driven with a current of 79.9 mA.

4.6.2 Coherence length testing

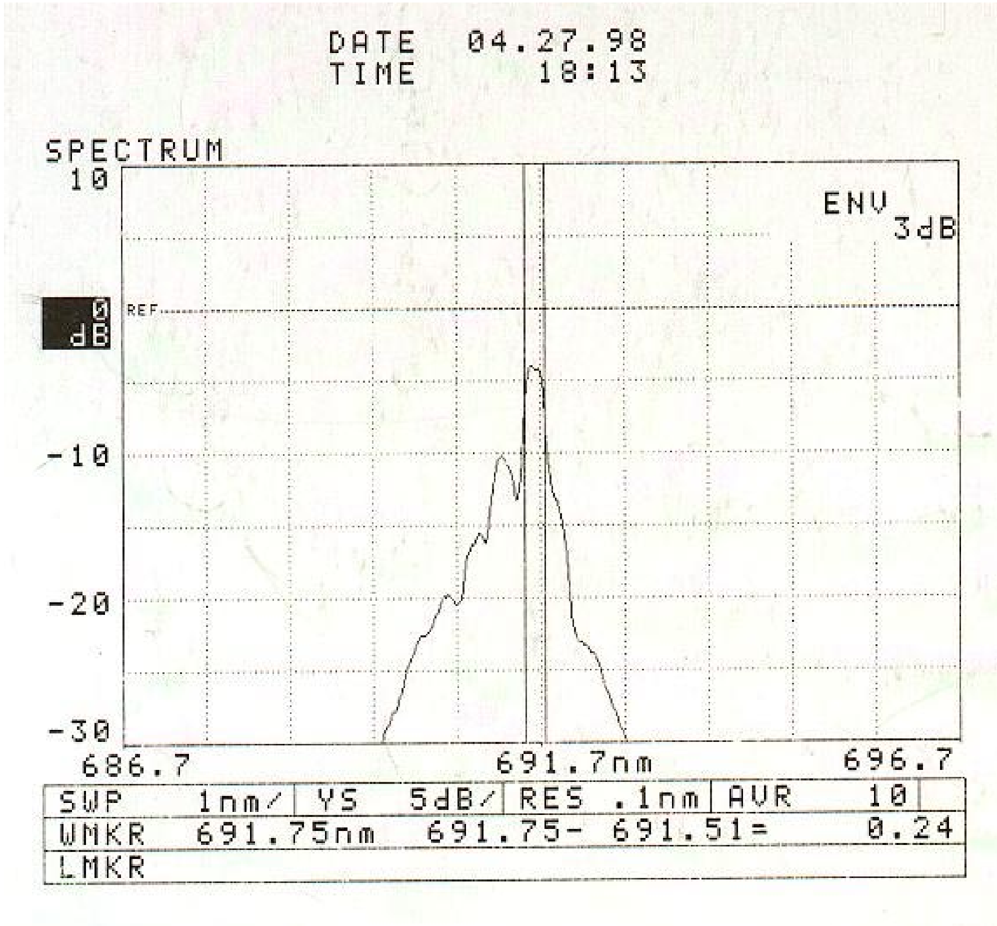


Figure 4.8 OSA Plot (Resolution Of 0.1 nm) For The Laser Output

The most important property of laser light is its coherence [14]. However, the output from a laser source is not perfectly coherent. One way of measuring the coherence of a laser source is to measure its coherence length, which is the distance over which light remains coherent after it leaves the light source [14]. The coherence length ΔL, of the laser output is given by

$$\Delta L = \lambda_o^2/\Delta\lambda,$$

where ΔL is the coherence length,

λ_o is the peak wavelenth, and

$\Delta\lambda = \lambda_2 - \lambda_1$, λ_2 and λ_1 are the half power wavelengths.

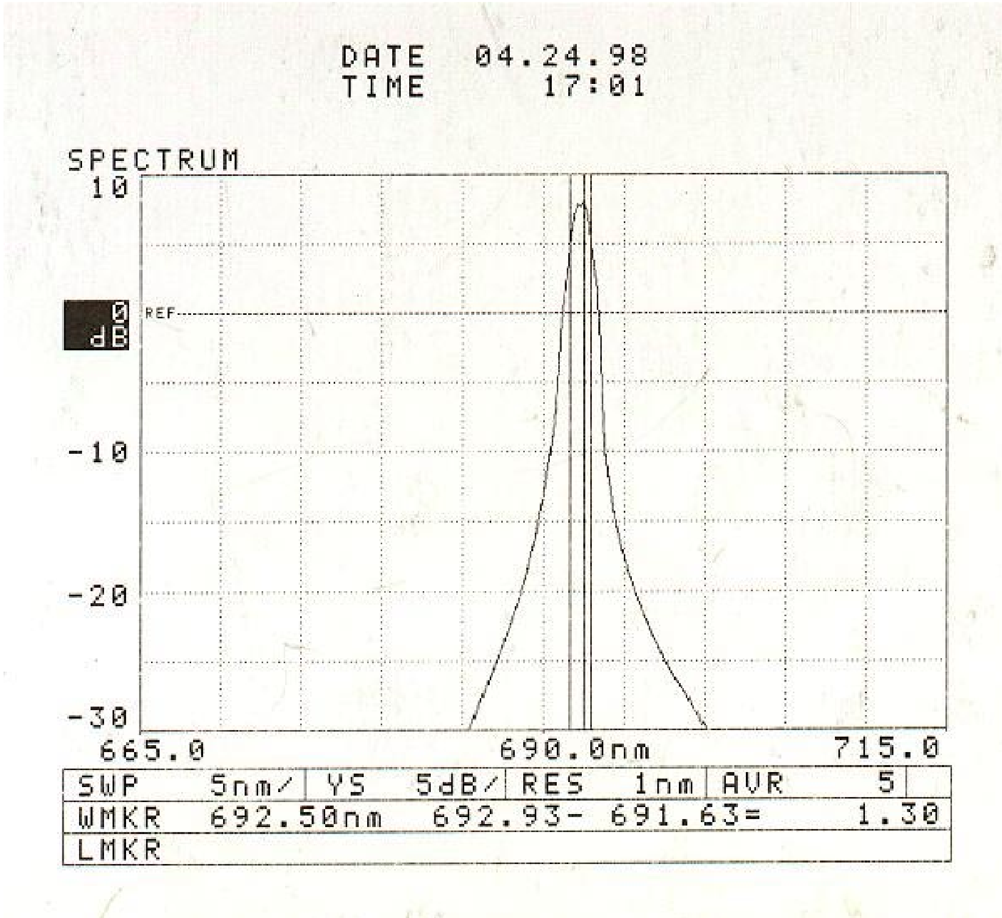


Figure 4.9 OSA Plot (Resolution Of 1 nm) For The Laser Output

The peak wavelength and the half power wavelengths were measured using an Optical Spectrum Analyzer (OSA) in the FEORC. The frequency response of the output from laser source is plotted using the OSA. The frequency response plots are shown in Figures 4.8 and 4.9. Using the above mentioned formula and the frequency plots from the OSA the coherence length is found out to be 2 mm when the resolution of the OSA is set to 0.1nm and 0.37 mm when the resolution is set to 1 nm. Thus, when the resolution is improved from 1 nm to 0.1 nm there is an order of magnitude increase in the coherence length. This indicates that the value of coherence length calculated is not the actual value. The difference in the value of coherence length obtained using the two different resolution of the OSA is due to the temporal change of the wavelength of the laser output. With higher resolution (0.1 nm), the ability of the OSA to track the change in the output wavelength is higher when compared to the lower resolution (1 nm).

Thus, in order to obtain a better estimate of the coherence length of the laser output the resolution of the OSA has to be improved. Since 0.1 nm is the minimum resolution that can be achieved using the OSA, the actual coherence length of the laser output is measured through another experiment.

A Michelson interferometer as shown in Figure 4.10 is used for coherence length testing. Michelson interferometer is theoretically the most accurate way of determining the coherence length of any temporally coherent source. The experimental setup that was used in an earlier project to measure the coherence length of a laser source is used.

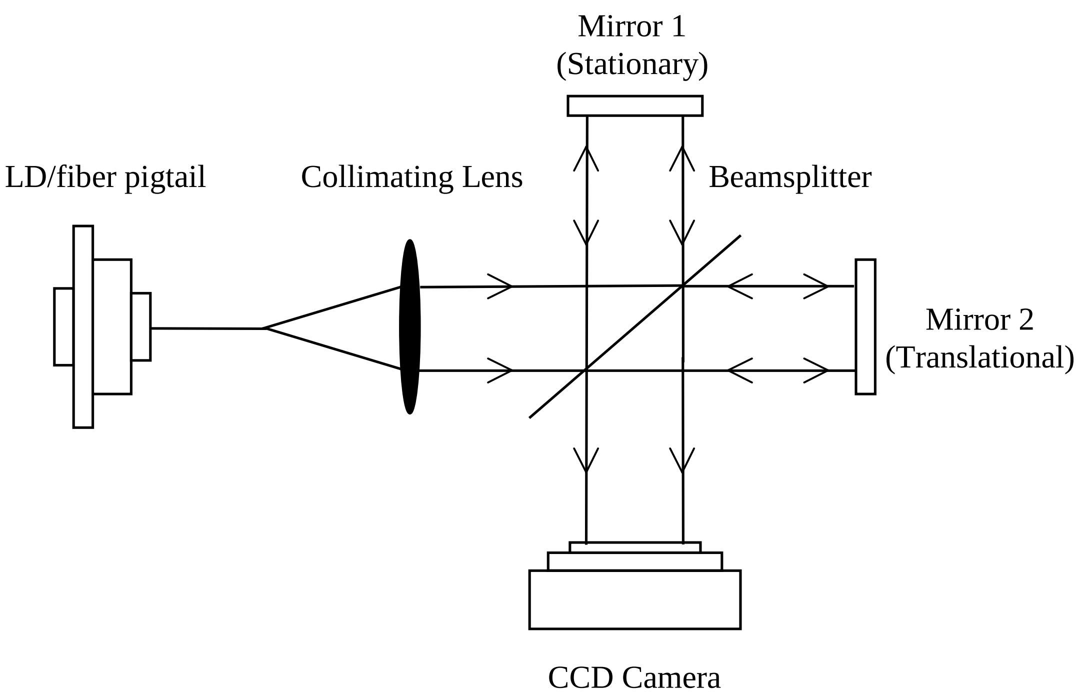


Figure 4.10 Michelson Interferometer Configuration

Experimental setup

The light beam to be tested is first collimated with a lens. It is then split into two perpendicular beams of same intensity using a beamsplitter. Both these beams are reflected normally by two mirrors, one of which can be translated along the beam path while the other mirror is stationary. The two reflected beams from the mirrors again pass through the beamsplitter generating interference fringes. A CCD camera connected to a computer detects the fringe pattern output from the beamsplitter. As the movable mirror is displaced, the fringe visibility will decrease in intensity. When the fringe visibility reaches a value of e^{-1} the displacement of the mirror is recorded. This displacement is equal to the coherence length of the source.

Experimental procedure

1. Set the beamsplitter to be equidistant from each mirror. This generates fringes with the maximum contrast. Record the intensity incident on the CCD camera.
2. Move translational mirror away from the beamsplitter until the fringe contrast is reduced to its minimum. Mark this position.
3. Move the mirror to the position of maximum contrast.
4. Move the mirror towards the beamsplitter until the fringe contrast is reduced to its minimum. Mark this position.
5. Half of the distance between the positions of minimum contrast is the coherence length of the diode.

Results

The coherence length of the laser diode is found to be about 8 mm.