CREATING A 100A POWER SUPPLY AND HEAT SINK FOR HIGH POWER DIODE

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STATEMENT OF CANDIDATE

I, Umair Rehman, declare that this report, submitted as part of the requirement for the award of Bachelor of Engineering in the Department of Electronic Engineering, Macquarie University, is entirely my own work unless otherwise referenced or acknowledged. This document has not been submitted for qualification or assessment an any academic institution.

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ABSTRACT

The (fictitious) start-up company Bedrock Photonics will be releasing in the next year or two high power fiber lasers that involve semiconductor diode lasers as the initial source of light. The light from these sources is used to excite custom optical fiber in order to produce the laser emission. This project will involve setting up the electronics and computer interfacing of an original equipment manufacturer (OEM) high power diode laser current driver device that is capable of 100 A and 6V output. Once operating, the driver will be connected to 30 W and 80 W fiber-coupled diode laser for testing. The project will build the necessary software to run the current driver continuously. The project is the combination of Photonics and Electronics to make professional Continuous Wave Current Driver which can be used to operate any kind of diode laser. The project includes safety switches, temperature control of the current driver and diode laser and variable output power. This project will discuss all the circuits which has been designed specifically for this control system and it has the potential to improve in the future.

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Chapter 1

Introduction

DIODE laser is an essential part of photonics technology. Diode lasers and related photonics integrated circuits have been commercially used in different fields of technology and made its own importance for the new World. They have vast variety of applications ranging from daily used products to highly sensitive and complex systems related to medical and atomic physics. Multiwavelength transmitters and receivers use diode lasers for optical fiber communication systems carrying gigabits of information, travelling in seconds. Diode laser devices have become more reliable, efficient, and inexpensive. They can reach high output powers into kilowatt range [16].

Coherent high power laser diode has been used in this project. This diode laser can be used for variety of products but we will focus on medical applications. Medical specialties are benefiting from innovations and performance improvements of diode laser.

Due to the highly nonlinear voltage current characteristics of LD with low impedance, it requires a constant electric current in continuous wave form to get constant optical power. It is very important to maintain the constant current because fluctuation can cause temperature rise of the laser diode, which can destroy the laser. If the LD becomes uncontrollably hot it can affect the output of the LD, which is unacceptable for medical applications. So main purpose of the project is to make the variable 0-100A laser diode driver to run different types of diode lasers for different applications. We will use OEM Ilumina 600W power supply for the input power for the diode laser and we will make the interface system of the driver according to our requirements to control the output current and voltages. The finalised document will include all the schematics of the interface structure, input and output power. Chapter 1 will cover all the requirements and specifications of LD driver and Coherent laser. Thesis overview will be discussed as well. Chapter 2 will discuss about the background knowledge (literature review) of Laser diode and power supply, related work such as thermal control with air or water and previously used laser diode systems and different types of lasers. Chapter 3 will discuss about the operation of the whole system, specifications, diagnostics and testing of the system including power supply and laser diode. This will include all the current control, thermal control and heat management of the laser diode and power supply.

1.1 Thesis Overview

Project Objectives

- Develop and build a 0-100A current driver to provide high output power to operate high power diode lasers. This includes the control system for the output power so that the driver can also be used for different diode lasers.
- Develop and build high power diode laser system which has to be operated by the current driver and investigation of the cooling requirements of the diode laser.
- Integrate both together.

The project aim is to build a complete box as a diode driver unit in which lumina power supply and its control system included as shown in figure 1.1.

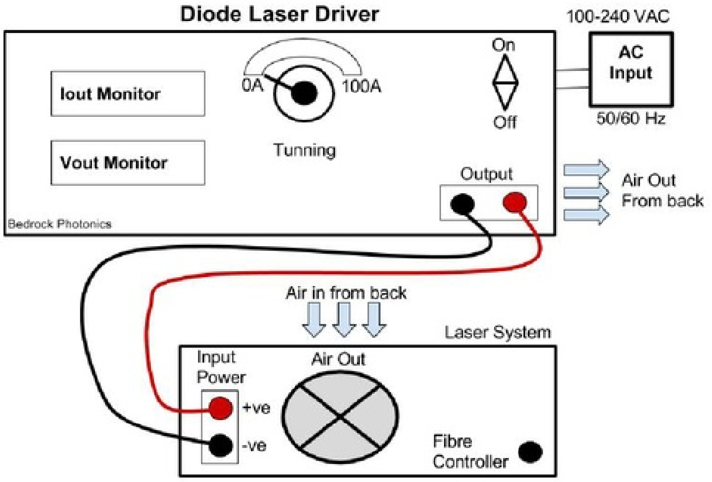


Figure 1.1: Project Overview Design

1.2 Baseline Review

This project was started on 1st of August 2016 and planned to be finished by 15th December 2016. The baseline has been generated to include all the weekdays for project activities.

1.2.1 Time Budget Review

Table 1.1 shows the project work time and total time available for the completion of the project. As shown in the table that the project is tracking well and finalised document should be released before the due date.

Table 1.1: Time budget analysis

Estimated Working Days	70 days
Realised Working Days	35 days
Percentage of Working Days passed	94%
Perceived Completion of Project	100%

1.2.2 Financial Budget Review

A budget of 300 dollars have been allocated for the project. Some small devices has been purchased but most of the electronic components were available in the lab. There will be few products needs to be purchased to finalise the project but future projections indicate that this project will not use the whole budget. Expensive stuff such as Power Supply and Diode laser has been purchased and provided already in the lab.

Table 1.2: Financial Budget

Components	Price
Arduino Uno	$14
Switches	$20
Wires	$25
Enclosed Box	$180
Sensor	$15
Total	$254

Chapter 2

Background and Literature Review

This chapter review all the functions and characteristics of the Diode laser and Continuous wave current driver.

2.1 Diode Lasers

The use of semiconductor lasers or laser diodes has been a vital part in our daily lives as it helps to provide cheap and compact size lasers. These lasers are a combination of multi-layer structures that need a nanometre scale accuracy as well as intricate design. The importance of the theoretical design is not only used from a fundamental angle, but also to generate modern and conceptual potential designs. Levels of accuracy and labour are needed for the description, and can hence create various levels of understanding. It is a common aspect of all systems that the laser is an inverted carrier density system. The electric field is driven by the results of the carrier inversion, which is known as an electromagnetic polarization. In majority scenarios, a resonator consists of an electric field. Laser performances however entail the properties found in the resonator.

Within semiconductor laser theory, the optical gain is produced in a semiconductor material. The material chosen relies on the wavelength required and the properties such as modulation speed. It is a bulk semiconductor however majorly perceived as a quantum heterostructure. There are two options for pumping, either electrically or optically. A common framework can be used to describe these structures which vary in levels of complexity and accuracy. A radiative recombination of electrons and holes are used to generate light in a semiconductor. This is done to produce more light by stimulated emission rather than lost from absorption.

2.1.1 Theory of Operation

Laser operation depend on two conditions, stimulated emission of the amplifying medium and feedback by an optical resonator. Stimulated emission is the process in which incoming photon interact with an excited electron to drop down to lower energy level. The starting point of the laser operation is attained if the gain in the resonator compensate for the overall losses e.g apparent losses due to extraction of light. Both conditions has to be satisfied in order to operate laser diode other than solid-state and gas lasers. The semiconductor structure of the resonant itself using the crystal facets as mirrors. The gain of the diode lasers is not only based on excited single atoms, ions or molecules but concerns with the whole crystal structure. Quantum wells are applied in modern semiconductor lasers to restrict the excited volume of electrons to reduce the threshold current. Quantum wells are thin layers semiconductor structure in which we can control the quantum mechanical effects [1]. The layers consist of different crystal compositions. A schematic of laser diode is shown in Figure 2.1.

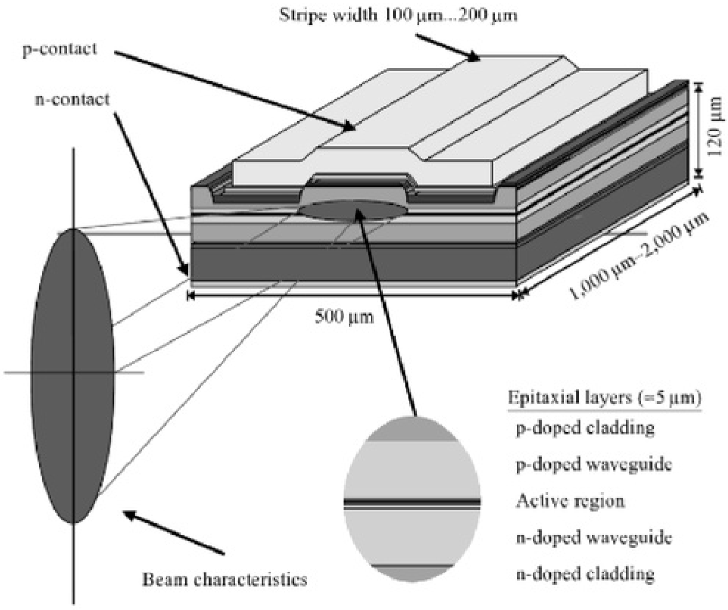


Figure 2.1: Schematic of semiconductor diode stripe laser

Figure 2.2 shows the electronic state of crystals form energy bands. In Figure 2.2 Eg is the energy difference between valence and conduction band. E_{fc} and E_{fv} is called quasi fermi level which means population of electrons in conduction band and valence band. At room temperature, band filling up to the fermi energy level according to the Paulis principle. Paulis principle states that two identical particles cannot occupy the same quantum state simultaneously. The fermi level is always between two energy, valence and conduction bands in semiconductor crystal. Between both energy bands there is a gap and that minimum gap is band gap. If the electron is shifted to the conduction band such as absorption of a photon then it will leave a hole in valence band. The optical gain is generated by radiative recombination of those electron pairs and hole pairs. The difference of the two energy levels correlate the energy produced by photons. The wavelength of the laser is determined by the size of the band gap and figure 2.3 shows the important oscillation wavelength region and laser diode material [2].

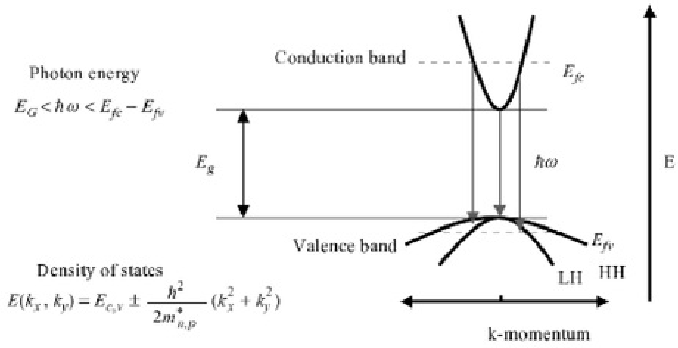


Figure 2.2: Band Structure of a direct semiconductor crystal

2.1.2 Optical Gain in Semiconductor

Electrical current can be pumped into semiconductor diode lasers. Semiconductor is doped by the atoms with higher or lower number of electrons in outermost shell, so is can create a new quantum mechanical state in the band gap. If the new state is close to the valence band then electrons take the place by leaving holes in the valence band. Positively charged carriers are created due to which it can carry current, this process is called n-doping. On the other hand thermally excited electrons to the conduction band and if potential difference is applied then electrons will carry the current which called n-doping. As we can see in figure 2.1, the diode laser is always consist of n-doped part and p-doped part. So at the pn junction optical gain will be generated because positive electric potential at n-doped region will move the holes at p-doped region and negative electric potential at p-doped region will move the electrons to the n-doped region. So at the pn-junction when electrons and holes combine together they create one photon, and photon energy then will be converted to light. The potential difference must be above the potential difference given by the band gap to produce a significant current flow.
In the first semiconductor diode lasers there were simple homojunction devices which consist of GaAs. The active region thickness was typically $2um$. Due to the improvements of epitaxial growth methods, the modern semiconductor diode lasers active region is quantum well, which consist of $10nm$ thin layer surrounded by material with a larger band gap. The injected barriers captured in those thin layers by the potential barriers. The quantum well has InGaAs. The band gap offsets should deliver high barriers almost $> 100meV$ to have negligible leakage of carriers by the heat produced. Normally at room temperature it has $24meV$.

Dependence of output characteristics on injection current

Forward biasing current is injected into p-n junction, which creates the electron energy decay into photon emission. It is quite similar to the process of the LED, where as in LED the decay occurs spontaneously to produce light and that light is out of phase. Therefore the decay in laser diodes are stimulated by other photons in the same junction which cause the total emission of laser diode in phase and polarised. The Optical resonator is formed by the active region of the junction.

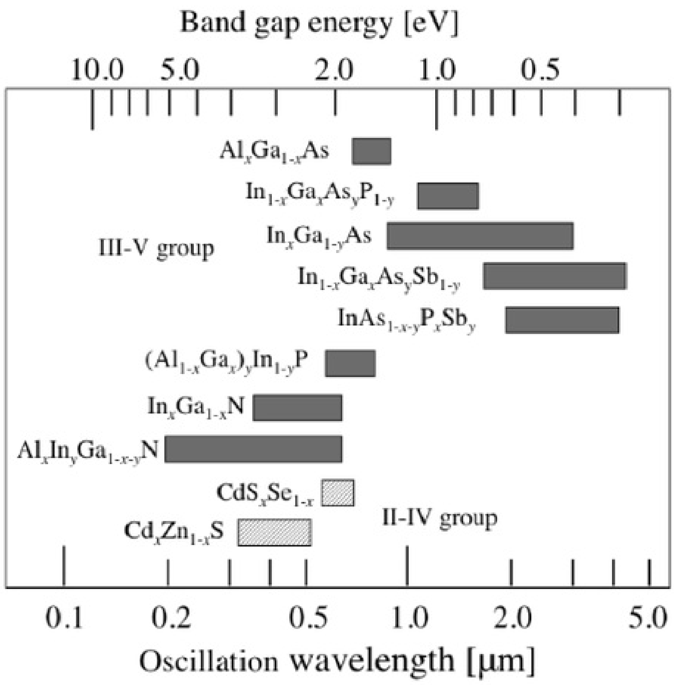


Figure 2.3: Laser diode material and oscillation wavelength region

2.1.3 Diode Current Control with Electromagnetic Interference(EMI) Protection

The output of the laser diode is highly dependant on the accuracy, stability and the quality of the drive current through the diode. Laser diodes are highly capable of small fluctuations in voltage which can produce changes in current and this process can highly shift the operating characteristics. Static charges and EMI are capable of damaging the laser diode, it might not damage the laser diode straight away but it can reduce the quality and output characteristics of laser diode. The laser diode used for this project is not cheap so protection consideration is essential.

2.2 Heat management of the laser diode

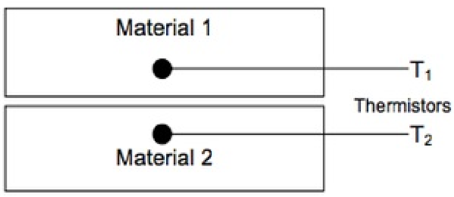
A laser is a device which has stimulated emission by emitting the amplified light as a radiation. Laser light is usually coherent, which means light is emitting in a narrow and low-divergence beam. Due to emitting of light, there is and output beam and heat generated in the diode which needs to be controlled [3]. Laser Diode performance is alot dependant on heat management due to the non-linear characteristics of semiconductor material used in Laser Diodes. The performance of the LD is also affected by packaging structure, packaging process and beam shape. Laser Diodes optical power can increase to tens and even hundreds of watts so the thermal design of the LD mount get essential. Before designing the LD mount the total heat generated by LD and thermoelectric modules should be considered. A poor design of thermal interface and packaging can lead the LD to get too hot and might damage the LD [4].

2.2.1 Thermal Resistance

When two or more materials are transferring heat such as LD mount and cold plate, thermal resistance can be measured and calculated in $^\circ C/W$. Thermal conductance is a measure of a rate of energy flowing through a surface which is determined in $W/^\circ C$. The transfer of the heat between two metal surfaces usually depends on two factors, thermal conductance and thermal resistance between two surfaces. When two surfaces joined together there can be a small (micro level) gap between the surfaces such as air, which can cause the thermal resistance. It is important to know about the conductance of the surface that how well it can conduct the heat and to remove the imperfections between the joint to minimise the thermal resistance. Equation 2.1 shows that how can we calculate the thermal resistance between two materials [5].

$$\ominus = \frac{(T_1 - T_2)}{Q} \tag{2.1}$$

T = Temperature ($^\circ C$)
Q = Heat (W)
$\ominus$ = Thermal Resistance ($^\circ C/W$)



In our case, the Coherent LD we will use has the casing of 19-element(Potassium K) which will be material 1 and for material 2 we have Aluminium plate. Both elements has high conduction characteristics.

2.2.2 Heat Sink

There are several choices for the heat sink design. We will discuss about the finned heat sinks and water cooled heat sinks and we will choose the method according to the requirements. Before choosing the method of heat sink, we need to get the total thermal load which includes the load from LD and Loads from Thermoelectric Cooler(TEC) [6].

$$P_T = P_{LD} + P_{TEC} \tag{2.2}$$

P_{LD} = Power From LD
P_{TEC} = Power from TEC
P_T = Total Thermal Load

Total thermal load is the one which need to be removed. For calculating the thermal heat from the LD we need LD current, voltage and efficiency of light Vs input power is required. Mostly the efficiency of high power laser diodes are 50%, so that it is convenient to use lower efficiency because LD efficiency decreases over the time as well.

$$P_{LD} = I * V * (1 - \eta) \tag{2.3}$$

I = LD Current
V = LD Voltage
$\eta = LD$ efficiency

Calculating TEC is difficult due to the electrically dynamic nature of the device. A way to calculate the heat removal of the heat sink by equation 2.4.

Q = Heat Removal Capacity of Heat Sink (W)
k = Thermal Resistance of Heat Sink ($°C/W$)
Δt = Ambient Temperature (T_A) Minus Temperature of Heat Sink

$$Q = \frac{\Delta t}{k} \tag{2.4}$$

Finned Heat Sink

This is one of the methods to remove the heat produced in LD. This method rely on natural convection or forced convection. The performance of the finned heat sink is dependant on the size of fins, fin height and fin density. Forced convection by putting a fan can improve the performance of the heat sink. This method is good and low in cost but usually used for low power laser diodes.

Water-Cooled Heat Sinks

At the heat output greater than 50 Watts, thermoelectric coolers can become expensive and bulky. For high power laser diodes we need to dissipate the maximum heat. The best option for high power laser diodes are water cooled heat sink. The cold plate consist of metal piping through which water is passed by water cooler chiller. Liquid takes all the excess heat and water cooler chiller cools the water and the process goes on. Water is a good conductor for dissipating the heat.

2.3 Applications of High Power Lasers

Due to the improvements of diode lasers in recent years, industries have established and innovated the applications of high power lasers specially for materials processing and medical use. We will put more focus on medical applications because the diode laser we will use in this project is more based on medical purpose.

2.3.1 Soldering

One of the earliest applications of high power laser diodes for material processing was soldering. Laser soldering main advantage over conventional soldering is that the laser beam can hit the target accurately without heating the surrounding part of the device in the process of reflow and vapor-phase soldering and it also reduces the risk of thermal damage because the power of the laser is controlled as well. Devices or connectors can be down to 200 um diameter in size, as a result it can be laser soldered efficiently. High power laser beams of 10-30W can delivered through optical fibres for surface mount soldering. Laser surface mount soldering has been achieved by many workers because such a power level can be delivered by a compact size(like a laptop computer) laser system. Diode lasers offer a great advantage over Nd:YAG or CO_2 laser due its reliability and compactness and also due to the shorter wavelength, the output of the diode laser is absorbed in a better way by soldering material. Commercial telephone companies are using the laser soldering techniques for joining the telephone connectors by using 25W diode laser, which is positively impacting the cost and production [7].

2.3.2 Transformation Hardening

Studies shows that Relatively high power diode lasers ($< 500W$) are being used by workers for hardening the stainless steel [8]. The hardening of 400 series stainless-steel tapes by diode laser using $15W$ fibre. For 0.15mm thickness tape can be hardened by using $500W$ diode laser at 30m/min. There is a good uniformity of hardened depth by using laser hardening flat-top beam. Moreover, the process is efficient for hardening the micro edges such as saw blades, cutter drums, scalpels for medical use, etc. There is one drawback of hardening method by laser is that the diode laser system is very sensitive to the backreflection which can damage the diode laser [9].

2.3.3 Medical

Diode Laser technologies are enabling the direct use of LD in a new range of medical applications. Gas and solid state lasers were the only solution previously. High power diode lasers easily can be controlled to any output power from 0-100 percent, whereas solid state lasers have the threshold based on operating conditions that permits the power between 60-100 percent [10]. One of the main advantage of high power laser diode is that it responds instantaneously to the mode power on whereas solid state lasers have fluorescence lifetime in milliseconds. There is virtually no delay between the input of operating surgeon to the emission of radiation. The availability of wide ranges of wavelength makes the diode laser a perfect tool for several medical applications. Table 2.1 shows the available diode laser wavelengths for medical applications. Medical applications mostly based on fibre coupled diode lasers due to the safety requirements of the medical development. Interlock switches and and surgical fibers which are mostly disposable plays a vital role. If the fibre over heat or burn off, then it can be replaced straight away without delaying the surgery. Diode lasers can be used in the surgeries for cutting the tissues or coagulating the blood vessels. An effective technique such as laser vaporisation can be used for removing the cancer cells. One of the most common surgeries in ophthalmology by diode laser is photocoagulation of the human retina. Hair removal treatments, dermatology safe as well as treatments of wrinkles, acne, removal of fat cells and tattoo removals.

Table 2.1: Medical applications with the range of wavelengths

Wavelength / nm	Applications
630-635, 652, 668	Medical photodynamic therapy
810 +- 10	Cosmetic, hair removal, dental, biostimulation, surgical, ophthalmology
940	Varicose vein removal
980 +- 10	Dental, prostate treatment, surgical, ophthalmology
1064	Hair removal, tattoo removal
1450 - 1470	Acne treatment, endovenous laser treatment

2.4 Power Supply

As we know now that the Diode Lasers are immensely responsive of small fluctuations in voltage, which can result into large currents hence can damage the LD. Continuous high current is required to operate the LD. The performance of the laser is highly dependant on the supply of current. In this part of the report we will discuss how does a power supply fulfills all the requirements of providing the required outcomes. As per medical safety requirements, a power supply should be safe, reliable and efficient enough to be used for medical purposes.

2.4.1 Design of the Driver

It is important to design a constant current driver to regulate the output power of the LD. LD is an light emitting device with high power density which mostly depend on the drive current and it also requires the high steadiness of the drive current. Negative feedback technology has a lot of benefits for designing a constant current circuit, such as highly stable current, resistance of non-linear distortion, wide passage frequency and high signal to noise ratio. Hence, constant current driver is a highly recommended method for operating the laser diode. Figure 2.4 shows the block diagram of the current driver.

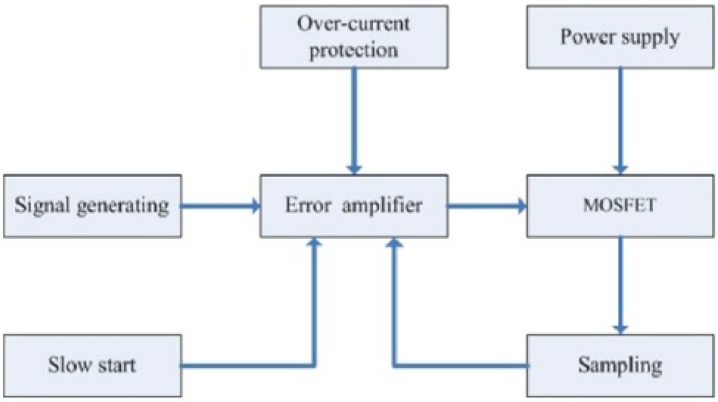


Figure 2.4: Driver - Block Diagram

The driver consists of the following circuits such as, feedback circuit, sampling circuit, modulation circuits and protection circuits. Protection circuits are important to increase the life of current drive and to avoid the damaging of the LD by unstable current. Protection circuits has two parts, over-current circuit and slow start circuit.

Considering the output current which is 100A, it consist of high power device to provide significant current. Currently devices used for high frequency switching, they have fast switching thyristor and VMOS(vertical metal oxide semiconductor) field-effect transistor resulting in improving high rising and falling edge of the output signal. VMOS field-effect transistor is usually used in circuits as a switching device and it's ideal for our case as well. MOSFET (Metal Oxide Semiconductor Field-Effect Transistor) controls the voltage and it requires low current [11] [12]. MOSFET has high input resistance by which it rapidly connect the load to DC supply by switching on and off, it also produces current pulse. It has a simple drive circuit, figure 2.5 shows the equivalent circuit of VMOS.

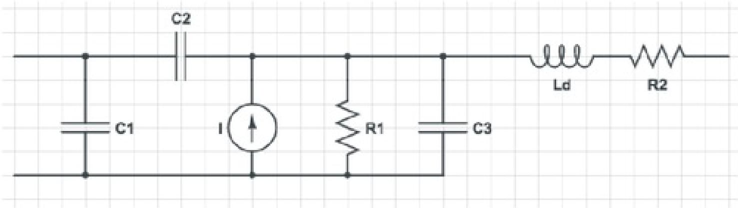


Figure 2.5: Equivalent circuit of VMOS

2.4.2 Constant Current Circuit Design

Constant current driver schematic diagram is shown in figure 2.6. So the square wave modulation signal generated by the circuit is Vr. Vr signal goes to the non-inverting port of the amplifier 1, which controls the VMOS transistor to control the conduction level of the system so the current could be gained. Sampling voltage is produced on Rs by the output current, which is then sent to the feedback system. The feedback system is essential to keep the dynamic balance of the entire system. The capacitor 1(C1) is used as an integration capacitor to prevent oscillation. R3 controls the rising speed and quality of the signal.

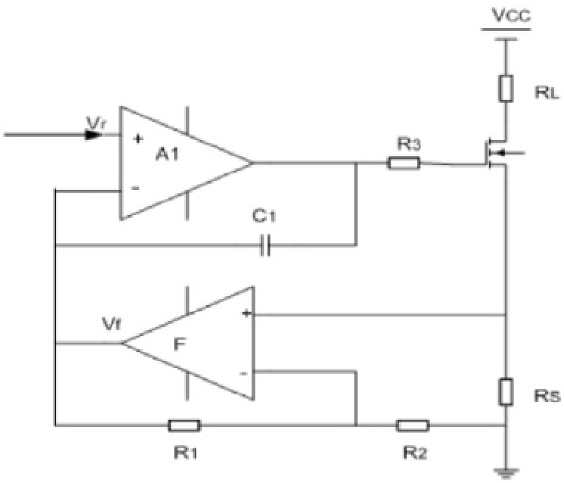


Figure 2.6: Equivalent circuit of VMOS

We will use the basic theory of amplifier in which non-inverting voltage is equal to inverting voltage.

$$V_f = V_r$$

The relationship between the input voltage and output current is

$$I_o = \frac{R_2}{(R_1 + R_2) \cdot R_s} \cdot V_r \tag{2.5}$$

In the equation R_s(sampling resistor) and V_r(reference voltage) are the main factors of the system.

2.4.3 Protection Circuit

Design of the protection circuit is divided into two parts, slow start circuit and over current protection circuit.

Slow Start Circuit

The main reason of the slow start circuit to is to secure the fundamental security of the laser and VMOS transistor. A driver can produce current inrush at the starting point due to the effect of internal capacitance device, which can easily damage the LD and VMOS transistor. As we can see in figure 2.7, signal to operational amplifier can not enter straight away, it will have a certain delay to rise from zero to required value.

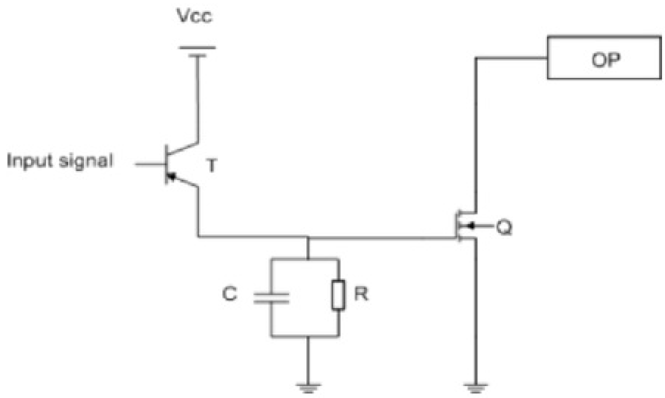


Figure 2.7: Slow Start Circuit diagram

So when there is no input signal the PNP transistor (T) will be on low, when the transistor is turned on it will charge the capacitor (C) due to which Q grid voltage gets high and

Q will turn on. If the laser is not working then Q transistor will hold the modulation signal, which will make the modulation signal low. On the other hand if the input signal turns the transistor T high, Capacitor C will discharge to make the connection of VMOS transistor.

2.5 Lumina Power Supply

As we have discussed earlier that the power supply needs to be controlled according to the requirements so LDD(Laser Diode Driver) is designed by Lumina Power, inc specifically for the OEM(Original Equipment Manufacturer) high power continuous wave laser diode systems. Continuous Wave(CW) is an operation of a diode laser in which the LD is continuously electronically pumped and it continuously emits the light(beam). OEM Lumina LDD has the following features:

- Safer laser diode operations
- 0-100A variable control of output current
- Safe rise and fall times
- Compact design (small size)
- Low conducted electromagnetic emissions
- Low leakage (for the medical applications)

For our project although all the key features mentioned above is important but the most important part is low leakage current and low conducted emissions for medical applications. Electromagnetic Interference (EMI) is an interference created by the external sources such as electromagnetic induction, it can also affect the performance of the circuit. Leakage current is to ensure that the direct contact with the medical equipment should be leveled to its minimum to avoid electric shocks.

How does this leakage current originate?

The driver contains large capacitance and leakage current is a direct function of line-to-ground capacitance value. Large capacitance means low impedance in common mode current which cause the disturbance rejection of the common mode. Therefore, leakage current can also be a cause of filter performance. However, to limit the magnitude of ground return currents, the maximum value is required. The grounded capacitance provides the path to Common Mode current flow in the chassis. The equipment is required to be grounded properly to avoid hazards. However, if the equipment is not grounded properly, the human body will become the path for the ground which can cause an electric shock. If the faulty grounded situation occurs, the maximum leakage current specification, (which is pretty low in our case) limits the ground return current to its safest range [13].

2.5.1 AC Input Power Circuitry

The conducted EMI(Electromagnetic Interference) is reduced by putting the AC input power through a line filter. Line filter consists of minimum resistance to ground to lower the leakage currents.

The power supply has a NTC(Negative Temperature Coefficient) resistor in the input circuit to limit the inrush current. When the system is switched on straight away after switching it off, it creates high inrush current due to low impedance of the resistor. So the inrush current is limited by the internal resistance of the power supply. The power supply needs atleast 5 minutes to remain off at the temperature of <25°C to cool down. The cold start up can make the inrush current from 20A to 50A according to the configuration. The inrush current pulse shape is shown in figure 2.9. Channel 2 is 10A/division and I_{peak} is less the 50A.

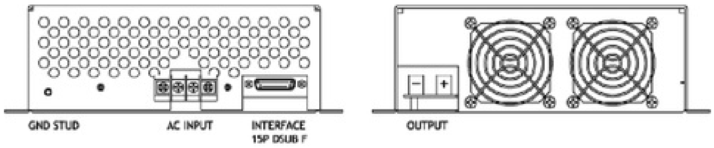


Figure 2.8: Dimensions, Input and output ports of the Power Supply

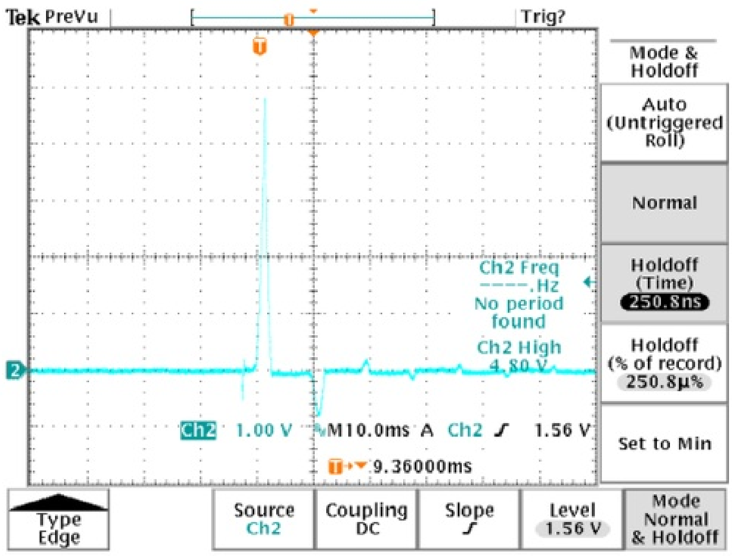


Figure 2.9: Inrush current pulse shape

When the power supply turns on it produces the inrush current as shown in figure 2.9. The power supply consist of capacitors across the input line, to get to the steady state voltage, the capacitors need current to charge which produce inrush current. High spikes can create electromagnetic interference in the circuitry, which can lead to the breaking of the circuit. Inrush current is always higher than the normal output current and it can range from 5-100 times greater than the operating current. In figure 2.9 the first peak is inrush current due to the charging of EMI filter capacitors and the second peak is when the inverter turns on to get to the steady state [14].

2.5.2 Power Factor Correction Boost Inverter

AC input current to the power supply can cause high amplitude, high harmonic content and narrow spikes. Therefore, there is a power factor boost inverter shown in figure 2.10 which boosts the input voltage to 400VDC so that the input AC current is tuned to keep the phase with input AC voltage. However, non-50/60 Hz harmonics are decreased to almost zero so that the power is delivered by fundamental frequency only, which increases the efficiency of the power supply. Lumina also used soft switching boost inverter to reduce the switching noise due to which smaller heat sink is required.

2.5.3 Zero Voltage Switching Inverter

Zero Voltage Switching (ZVS) in an electronic circuit is switched when the output load voltage is zero. ZVS inverter has been used instead of PWM(Pulse width modulated) to step down the 400VDC to appropriate output value as shown in figure 2.9. ZVS is the latest technology used in most of the electronics today. It uses the most modern high frequency/low loss/low noise topology. Effectively there is no switching loss in the inverter because of suitable capacitance across each switching device and appropriate output inductor. The only loss is I^2R with the drain resistance of the MOSFETS. Therefore, ZVS adds up with other features to reduce noise, EMI and overall heat sink requirement [15].

2.5.4 Output and Control Circuit

To keep the output noise and ripple very low, two stage RC filter has been designed and installed in the power supply. Control circuit controls all the safe operation of the laser diode, rise and fall times along with current regulation.

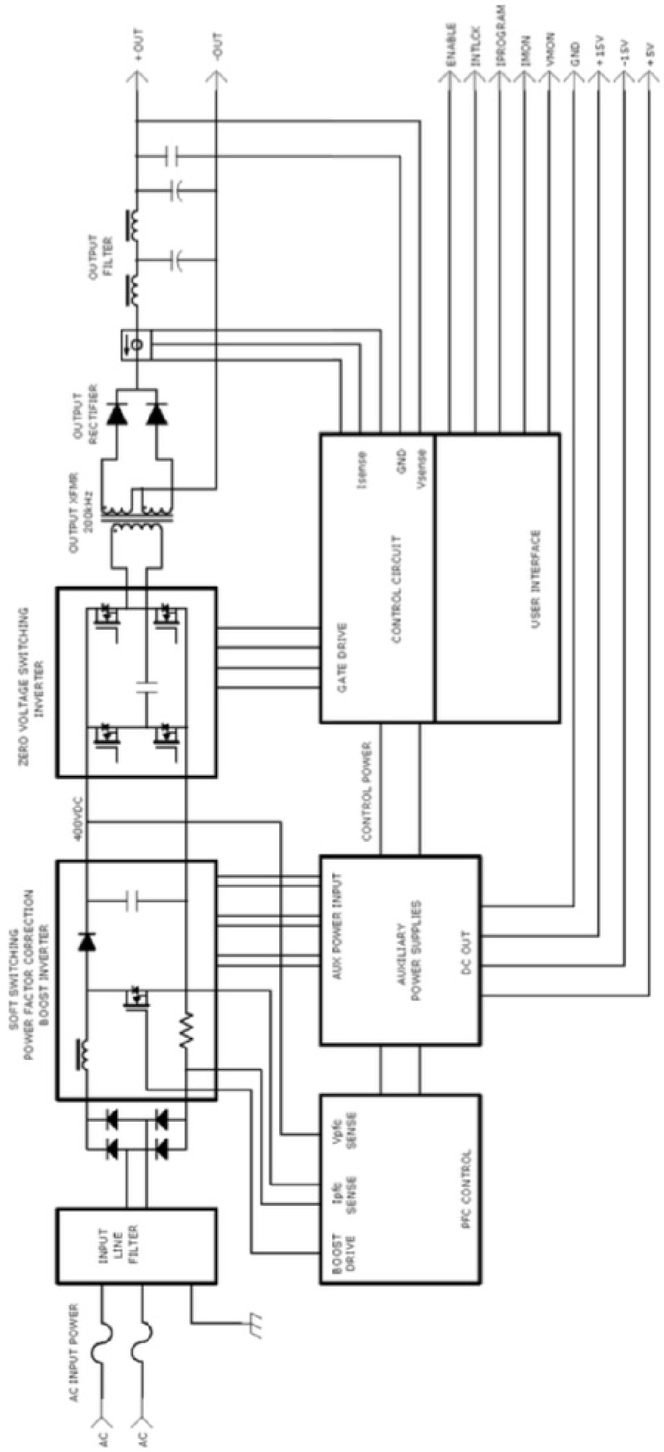


Figure 2.10: LDD Block Diagram

Chapter 3

Design and Performance Testing

In this chapter we will design the power supply interface to operate the power supply. After designing the interface we will test and diagnose the power supply output power with the dummy load. Matching of the output results with the datasheet of the power supply.

Coherent Diode laser provided for this project will also be tested with the power supply. The output of the diode laser optical gain will be compared with the data sheet of the diode laser. The design of the temperature control system and heat management.

3.0.1 Interface of the power supply

Interface in power supply can be controlled with 15 pin D sub shown in figure 2.8 to control all the functions of the power supply such as output current, monitoring output current and voltage and interlock switching. There are 15 pins with different functions and user interface is designed by us according to our requirements. Table ?? shows all the functions of Pins by numbers.

3.0.2 LDD Interface

Interface is provided in LDD with 15 pin D sub shown in figure 2.8 to control all the functions of the power supply such as output current, monitoring current and voltage. There are 15 pins with different functions and user interface is designed by us according to our requirements. Figure 3.1 shows all the functions of Pins by numbers.

Pin #	Pin Name	Functional Voltage Level	Description
1	**Enable** (input)	High = RUN = +5V to +15V Low = OFF = 0V	The **Enable** function turns the output section of the power supply ON and OFF. When the power supply is enabled, current is delivered to load as programmed via **Iprogram(+)**, Pin 7. Rise times resulting from **Enable** are approximately 25msec.
2	N/C		
3	**Interlock** (input)	Open = OFF Connect to GND = RUN	The **Interlock** function can be connected to external interlock switches such as door or overtemp switches.
4	GND		Referred to (-) output of power supply.
5	**Vout Monitor**: (output)	$0 - 10V = 0 - Vout_{max}$*	The output voltage of the supply can be monitored by **Vout Monitor**.
6	**Iout Monitor** (output)	$0 - 10V = 0 - Iout_{max}$	The output current of the supply can be monitored by **Iout Monitor**.
7	**Iprogram(+)**: (input)	$0 - 10V = 0 - Iout_{max}$	The power supply output current is set by applying a 0-10V analog signal to **Iprogram(+)**.
8	N/C		
9	GND		Referred to (-) output of the power supply.
10,11	**+5V @ 0.5A** (output)		Auxiliary +5V power supply for user. Up to 0.5A output current capability.
12	**-15V @0.5A** (output)		Auxiliary -15V power supply for user. Up to 0.5A output current available.
13,14	**+15V @0.5A** (output)		Auxiliary +15V power supply for user. Up to 0.5A output current available.
15	Gnd		Referred to (-) output of the power supply.

Figure 3.1: LDD-600 Interface Functionality

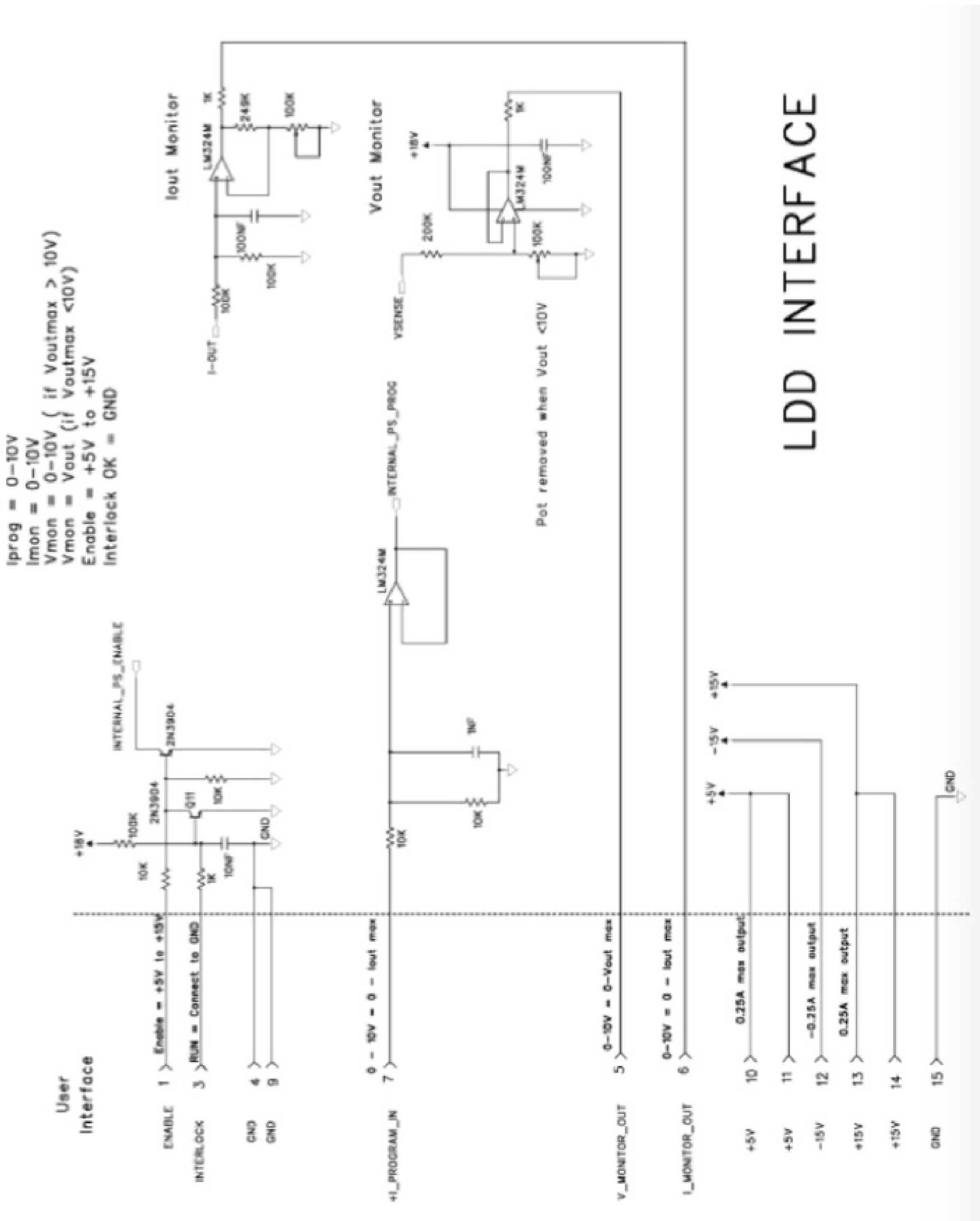


Figure 3.2: LDD-600 Interface Schematic

In figure 3.2 we can see the internal circuitry of the interface. Our job is to design the interface with the help of table in figure 3.1 to control the power supply. Before applying any AC Power we need to provide variable 0-10V to Pin-7 ($I_{program}$) to control the output current. Pin 3 interlock should be connected to the ground otherwise the power supply will not turn on. Pin 1, Enable includes the function of soft start, rise time is approximately 15 to 20msec. In Figure 3.3 we can see the response of I_{out} to Enable signal with CH1 I_{out} 20A/div and CH2 Enable. Ch1 rise time is 17.37ms.

Interface also includes the output monitoring of the power supply with current and voltage monitor, so we can monitor the output current and set the output current accordingly. Devices Used for Interface so far Interface has one switch for enabling the power supply. Voltage and Current digital monitor. 0-10V variable voltage regulator to control the analogue signal for $I_{program}$ function to control the output current of the power supply.

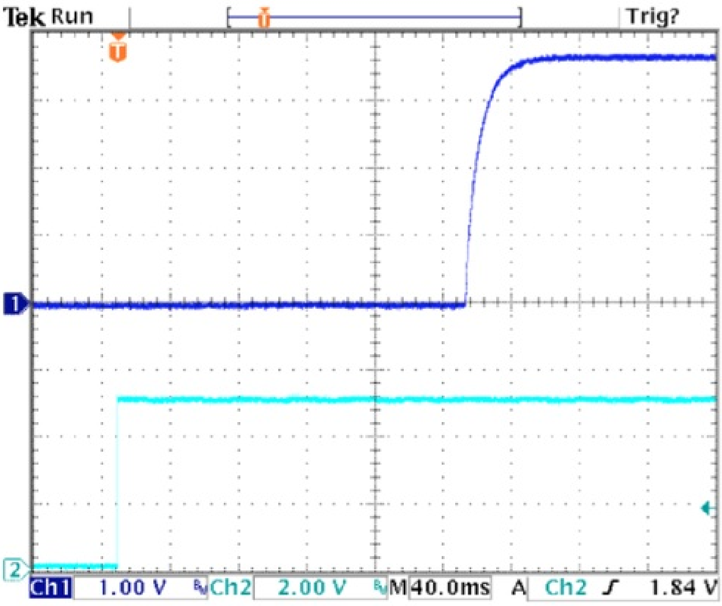


Figure 3.3: Response of Iout to Enable Signal

Programmable Current Limit DIP Switches

Dual Inline Package (DIP) is a pair of manual switches to control the configurations of the device. Internal DIP has been provided in the driver to limit the current. This option is useful for the OEM user to customise the system output for the variety of systems. This option can protect the laser by setting the maximum output so the driver never exceeds the maximum set output. Table 3.1 shows the DIP switch settings to control the current output.

Table 3.1: DIP switches function

S1	S2	S3	S4	I_{max} / Output
OFF	OFF	OFF	OFF	110%
OFF	OFF	OFF	ON	103%
OFF	OFF	ON	OFF	98%
OFF	OFF	ON	ON	92%
OFF	ON	OFF	OFF	88%
OFF	ON	OFF	ON	84%
OFF	ON	ON	OFF	80%
OFF	ON	ON	ON	77%
ON	OFF	OFF	OFF	74%
ON	OFF	OFF	ON	70%
ON	OFF	ON	OFF	68%
ON	OFF	ON	ON	65%
ON	ON	OFF	OFF	63%
ON	ON	OFF	ON	60%
ON	ON	ON	OFF	58%
ON	ON	ON	ON	56%

If we set the switches to 68%, it means 60A maximum output. The device is programmed by analogue system of $I_{program}$ with 0 - 10V. With these switch settings, when the analogue value reaches 6.8V it will give the maximum output even if you change the analogue value to 10V. So with these switches we can limit the output current.

Output current testing of the power supply

Due to the maximum output load of 600 watts, it was important to test the power supply with a dummy load of 600 watts or more before connecting the diode laser. It was hard to find a load that big to test the driver output current so we have limited the output current to 56% to test and diagnose the driver. 300W dummy load was available in the lab and the output current was tested as shown in table 3.2.

Table 3.2: Driver Output Current Results

$I_{program}$ / V	Output Current / A	Power / W	Output Voltage / V
0	0	0	0
0.23	2.606	0.5	0.207
0.31	3.51	0.8	0.281
0.42	4.43	1.3	0.355
0.53	5.80	2.3	0.464
0.75	7.63	4	0.614
0.93	9.47	6.1	0.767
1.0	10.39	7.4	0.843
1.22	12.66	11	1.035
1.4	14.49	14.5	1.192
1.62	16.79	19.5	1.390
1.81	18.64	24.2	1.552
2.03	20.51	29.4	1.718
2.25	22.84	36.8	1.927
2.43	24.75	43.6	2.10
2.61	26.71	51.5	2.31
2.83	29.12	62.2	2.55

As we can see in table 3.2. $I_{program}$ value is an analogue signal in voltage to control the output current and voltage. The driver is functioning perfectly fine and it is ready to connect to the diode laser.

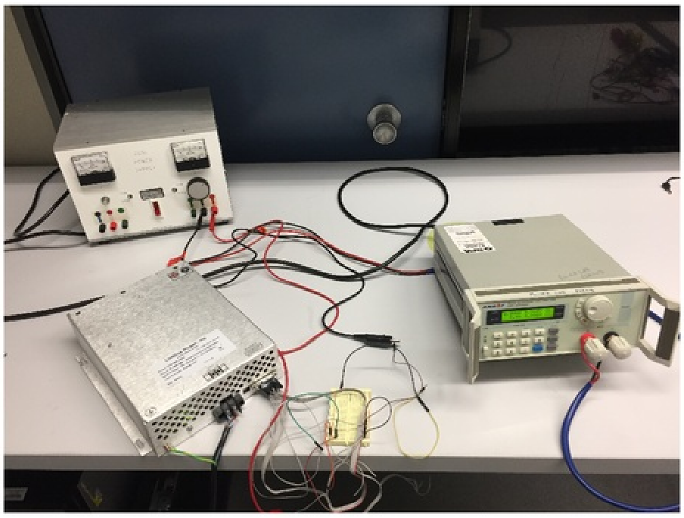


Figure 3.4: Driver System Testing

3.1 Diode Laser

We will use Coherent Fap 800-30W-805.Oto laser diode. Coherent is the highest quality fiber-coupled diode lasers in the market. They offer the simplest way of delivering the output power to the application. Coherent lasers have following features:

- High reliability
- High Efficiency
- High Brightness
- Rugged Construction

The lasers have following applications:

- Solid-State Laser Pumping
- Soldering
- Heating
- Plastic Welding
- Medical

3.1.1 Optical Specifications

CW(Continuous Wave) output power	30W
Center wavelength	808nm
Center Wavelength Tolerance	+- 3.0
Spectral Width	<3.5 nm
Wavelength Temperature Coefficient	0.28 nm/C
Beam Divergence	<0.14 NA
Beam Diameter	810 um

3.1.2 Electrical Characteristics

Slope Efficiency	>0.8 W/A
Conversion Efficiency	>35%
Threshold Current	8 to 10 (A)
Operating Current	<46A
Operating Voltage	<2.1V
Recommended Hookup Wire (gauge)	8 or heavier

3.1.3 Thermal Specifications

Thermal Resistance (typical)	0.7 C/W
Case Operating Temperature	(-20 to 30) C
Case Storage Temperature	(-20 to 30) C

Recommended Heat Sink

Capacity	100W
Thermal Resistance	<0.1C/W

Coherent laser and water cooling system has been provided in the lab as shown in figure 3.5. Diode laser temperature is controlled by water chiller available in the lab.

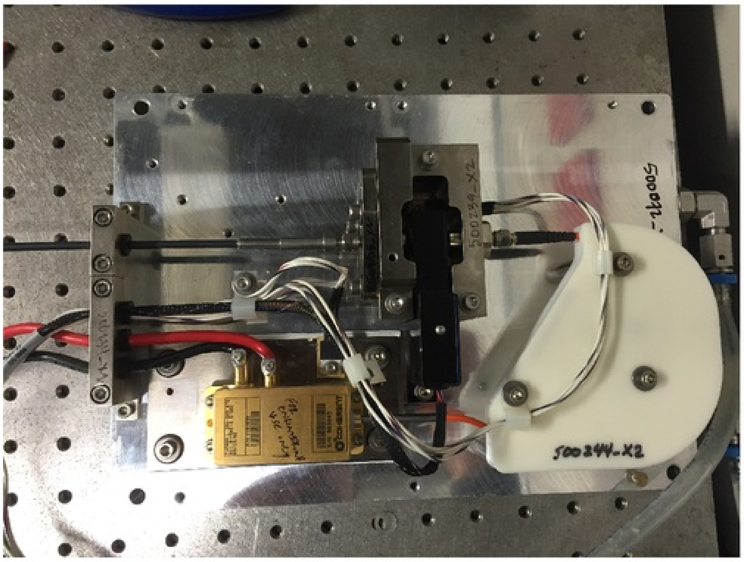


Figure 3.5: Coherent Laser installed with water cooling system.

All the high power advanced devices dissipate thermal energy and cooling systems are necessary to control the output and the durability of the device. Heat management is required due to the heat produced by input power.

Due to semiconducting materials in laser diodes, it produces very high heat loads. The optical efficiencies of the laser diode are highly dependant on temperature, thats why we need precise temperature control. In figure 3.6, water chiller is shown which we will use for the cooling the diode laser.

Figure 3.6: Water Cooling Chiller

3.1.4 Testing of the diode laser

After testing the power supply, we will connect the LD with the power supply to diagnose the practical characteristics of the LD. While connecting the power supply output wires to the LD we must make sure that there should be no direct contact of human body with the open end of the LD wires. Because LD is capable of shocks even when it is off or not connected to any power supply. Figure 3.7 shows the whole system.

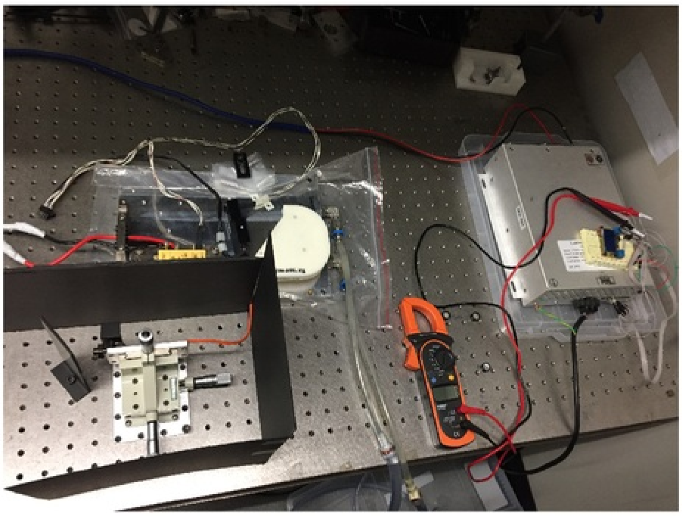


Figure 3.7: Laser Diode system

Table 3.3: Output Power of Diode Laser

$I_{program}/V$	**Power Output / W**	**Voltage Output / V**
0.76	1.581	1.86
0.87	2.617	1.89
0.91	3.14	1.91
1.02	4.16	1.94
1.09	5.19	1.97
1.2	6.20	2.0
1.28	7.21	2.03
1.31	7.71	2.04
1.42	8.71	2.07
1.46	9.20	2.09
1.5	9.71	2.1

Table 3.3 shows the output results of the LD. The threshold current of the LD is matching with the datasheet but the potential difference is quite high due to which maximum output power of the LD can not be retrieved. The reason of the high potential difference is the wire from power supply to LD, the wire is not heavy so I have ordered the new wire(8AWG).

Chapter 4

Design of the System

In this chapter we will discuss about the whole design of the system including power supply interface design, temperature sensor design and how to integrate and run as a whole system. There is also a brief introduction of two new devices added in the project to make the system, Temperature Sensor LM35DT and Arduino Uno Chip.

4.1 Design of the Circuit for Temperature Control

As we have discussed about the thermal management control in previous chapters, so we know to control the temperature is important to obtain constant optical gain of the laser as well as safety of the diode laser. We will use Temperature Sensor LM35dt for the system to measure the temperature and display the temperature on LCD display to monitor the temperature of the base of Diode Laser. We will also use this temperature sensor for setting a maximum operating temperature ($< 30°C$ according to the data sheet) so if in some situations cooler does not cool enough and the temperature rises from $30°C$ so the system will cut the output power from the power supply to prevent the diode laser from damaging.

4.1.1 Temperature Sensor LM35dt

We will use LM35dt temperature sensor for our system. The LM35 series are the precise integrated-circuit temperature sensor, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature [Data sheet LM35]. The advantage of using LM35 series is that it calibrates in Kelvin, so the user does not have to subtract a large constant voltage from the output to obtain convenient centigrade scaling. Over a full temperature range from $-55°C$ to $+150°C$, we don't have to provide usual accuracies of $\pm 3/4°C$ and $\pm 1/4°C$ for room temperature. Its easier to make a interface of temperature sensor with LM35 series due to its low output impedance, linear output and precise inherent calibration. It can be used with both $-ve$ or $+ve$ power supply. The sensor draws only $< 60\mu A$ from it supply and it also very low self heating $< 0.1°C$. Figure 4.1 shows the structure and pins of the temperature sensor (LM35dt).

Features

- Calibrated directly in Celsius
- Linear +10 $mV/°C$ scale factor
- $0.5°C$ accuracy at room temperature
- Suitable for remote applications
- Low cost
- Operates from 4 to 30 Volts
- $< 60\mu A$ current drain
- Low self heating
- Non-linearity only $\pm 1/4°C$ typical
- Low Impedance (0.1Ω for $1mA$ load)

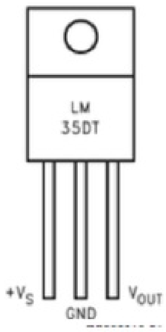


Figure 4.1: LM35DT Temperature Sensor

The sensor can be glued or cemented to the base plate of diode laser. The temperature will be within about $0.01°C$ of the base. You can also solder lightweight heat fins to the sensor to decrease the thermal time constant and the response gets more accurate. In our case, we dont need heat fins because the operating temperature is lower than room temperature.

4.1.2 Arduino

Arduino is an open source electronics platform based on hardware and software. The user friendly features of arduino make it very useful tool for professionals as well as students, programmers, etc. It can be programed with required set of instructions to the microcontroller. Arduino has the ability to make thousands of different applications with different projects. It is inexpensive compared to other microcontroller platforms. Arduino has different boards, Arduino Uno is one of them which is microcontroller board based on ATmega328p. It has 14 digital input and output pins, 6 analog inputs, 16 MHz quartz crystal, USB connection, power jack and a reset button shown in figure 4.2. It contains everything needed to support the microcontroller. It can be simply connected via usb cable to a computer to program the chip using Arduino software which is an open source software. There are some technical specifications of Arduino Uno we should know before using.

- Operating Voltage	5V
- Input Voltage(recommended)	$7 - 12V$
- Input Voltage (limits)	$6 - 20V$
- Digital I/O Pins	14
- Analog Pins	6
- DC Current per I/O Pin	40mA
- DC Current for 3.3V Pin	50mA

The power can be provided from USB or Power Source of 5V. We will used Lumina Power Supply Interface Auxiliary 5V output voltage for Operating the Arduino.

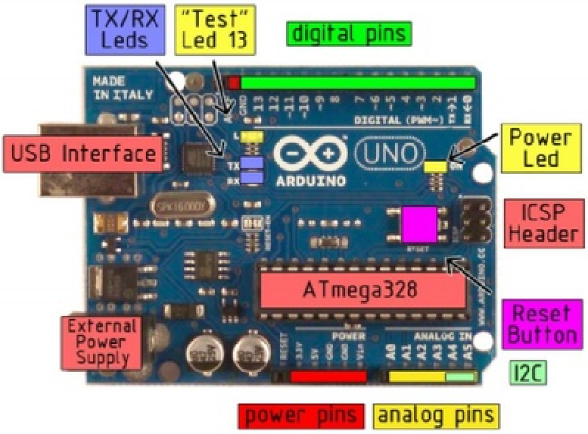


Figure 4.2: Arduino Uno

4.1.3 Temperature Sensor Circuit

We will make a temperature sensor circuit with LM35DT sensor. Temperature sensor circuit will read the temperature of the operating diode laser and will display the temperature on LCD display in $°C$. We will integrate the sensor LM35DT with Arduino Chip. Arduino can read the output value of the sensor and then convert that measured value into $°C$ and can display the output on LCD display.
Components required for the circuit:
- Arduino Uno Board
- LM35DT Temperature Sensor
- 16x2 LCD Module JHD 162A
- 10K Potentiometer
- Wires
- Resistors
- LED

As we have discussed about the Lumina Power Supply interface output and inputs pins in chapter 3. We will use Pin 10 of the Lumina Power Supply interface, which gives 5V output shown in Figure 3.1. Figure 4.3 shows the first step of the circuit with LM35 sensor connected to 18K resistor to give the temperature range of $-55°C$ to $+150°C$.

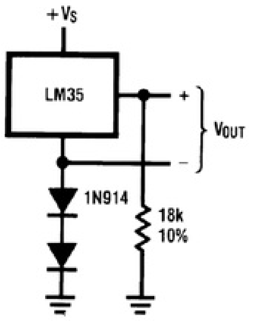


Figure 4.3: Temperature Sensor Single Supply

Figure 4.4 shows the connection diagram of the temperature sensor circuit. In input voltage of +5V to LM35, Arduino and LCD Module is coming from Lumina Power Supply interface. We use the same ground as Lumina Power Supply interface. The Programming is required for the for the Arduino Uno Board to perform the operation. The Arduino Board is not only used for temperature sensing, there are some other operations will be performed by Arduino Board such as, cutting off the output Current to the diode laser if temperature rises from the operating temperature limit and the LCD displays the Operating temperature as well as output Current. Arduino Board is acting like a brain in our system.

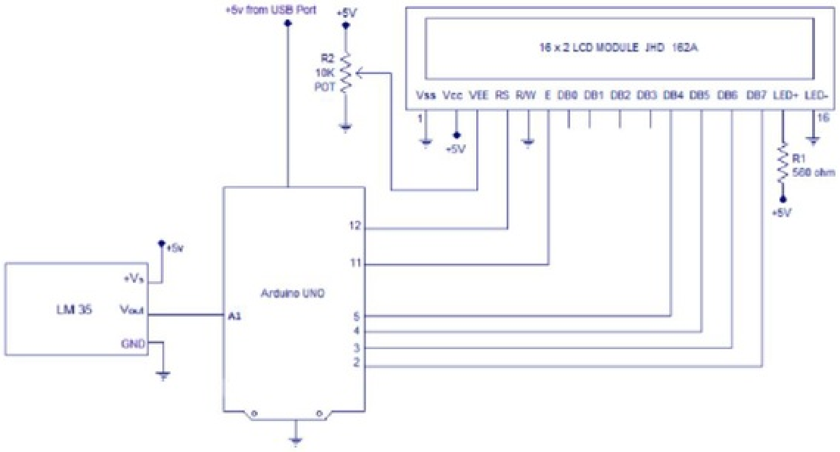


Figure 4.4: Connection Diagram of the Circuit

Code for Arduino Uno Board

```
#include<LiquidCrystal.h>
LiquidCrystal lcd(12, 11, 5, 4, 3, 2);
const int sensor=A1; // Assigning analog pin A1 to variable 'sensor'
const int sensorValue = A3; //check
float tempcen; //variable to store temperature in degree Celsius
float tempfah; //variable to store temperature in Fahreinheit
float vout; //temporary variable to hold sensor reading
float voltage; //check
float cur;
void setup()
{
  pinMode(sensor,INPUT); // Configuring pin A1 as input
  pinMode(sensorValue,INPUT);
  Serial.begin(9600);
  lcd.begin(16,2);
  lcd.print("BedRock Photonics");
  delay(3000);
}
void loop()
{
  vout=analogRead(sensor);
  vout=(vout*5000)/1024;
```

```
  tempcen=vout/10; // Storing value in Degree Celsius
  voltage=analogRead(sensorValue);
  voltage=((voltage*50)/1023)-4;
  cur=voltage;
  //tempf=(vout*1.8)+32; //For Converting to Fahrenheit
    lcd.setCursor(0,0);
    lcd.print("in DegreeC= ");
    lcd.print(tempcen);
    lcd.setCursor(0,1);
    lcd.print("Current/A="); ///lcd.print("in Fahrenheit=");
    lcd.print(cur);

  if (vout >60) {
        digitalWrite(7,HIGH);
                } else {
                        pinMode(7, OUTPUT);
                        digitalWrite(7,LOW);
                        }
  if (vout >60) {
        digitalWrite(8,HIGH);
                } else {
                        digitalWrite(8,LOW);
                        }
delay(1000); //Delay of 1 second for viewing in serial monitor
}
```

After doing all the Connections, first we test the Temperature sensor if its working properly or not, and then after we are sure that all the connections are correct we can solder all the connections to a board. In our case it looks something like in figure 4.5. The figure looks a little messy with wires but we can see that the LCDs are soldered separately with the Arduino Board because LCD suppose to be fitted in the Final box of the project. One more reason for Arduino Board to be separate so in future if Arduino crashes, we just have to put new board with a same code mentioned above.

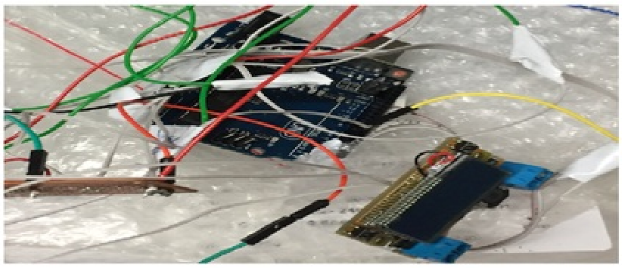


Figure 4.5: Arduino Connections

Integrate Lumina Power Supply interface with Arduino Temperature Sensor

In this step we will discuss some of the Lumina Power Supply Interface Pins and how we can integrate them with Arduino. As we know from chapter 3 that Lumina Power Supply has 3 auxiliary outputs +5v, -15v and +15v and we know that we need to provide 0 - 10V Analog voltage to Pin 7(Iprogram) for controlling the output current to the laser diode. So we need a 0 - 10V voltage regulator, figure 4.6 shows the circuit for making a 0 - 10V voltage regulator from -15V and +15V DC supply from the interface of power supply.

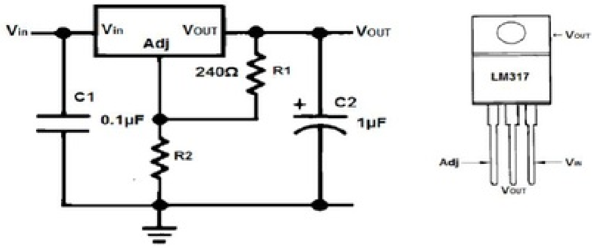


Figure 4.6: Circuit of Voltage Regulator

Figure 4.6 shows the circuit of the Voltage Regulator and front view of LM317 device. If we replace R2 with 10K Potentiometer, it becomes variable Voltage Regulator. We will connect +15V DC from power supply to Vin in figure —reffig416. We have to add two capacitors and 240Ω resistor. And the output (Vout) goes to Pin 7($I_{program}$) to run the power supply. The two resistors connected to Adjustable pin (Adj) which determine the voltage needs to be adjusted for the output. Adjustable voltage regulator is determined by the equations 4.1.3.

$$V_{out} = 1.25V(1 + \frac{R2}{R1})$$

(4.1)

If the we follow the equation, we can see that the bigger value of R2 will increase the value of Vout. So after adding the 10K potentiometer, the output results are shown in a graph in Figure 4.7. The voltage regulator is working fine and ready to be installed in the process. So as we turn the Knob of Voltage Regulator, the output current changes as shown in chapter 3 table 3.2.

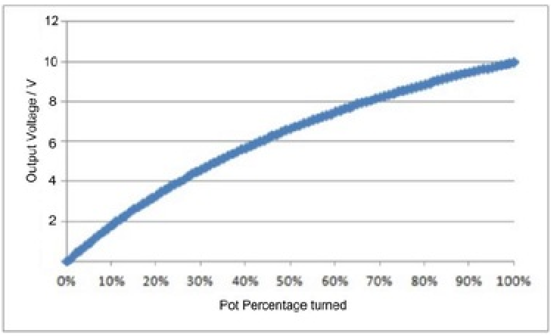


Figure 4.7: Voltage Regulator Output vs Pot percentage

4.1.4 Design of the Whole System

So far we have made Temperature Sensor Circuit and Voltage Regulator Circuit and we have Arduino board and Power Supply interface. In this section we will provide the complete connections of all the different circuits we have made and setup of the project.

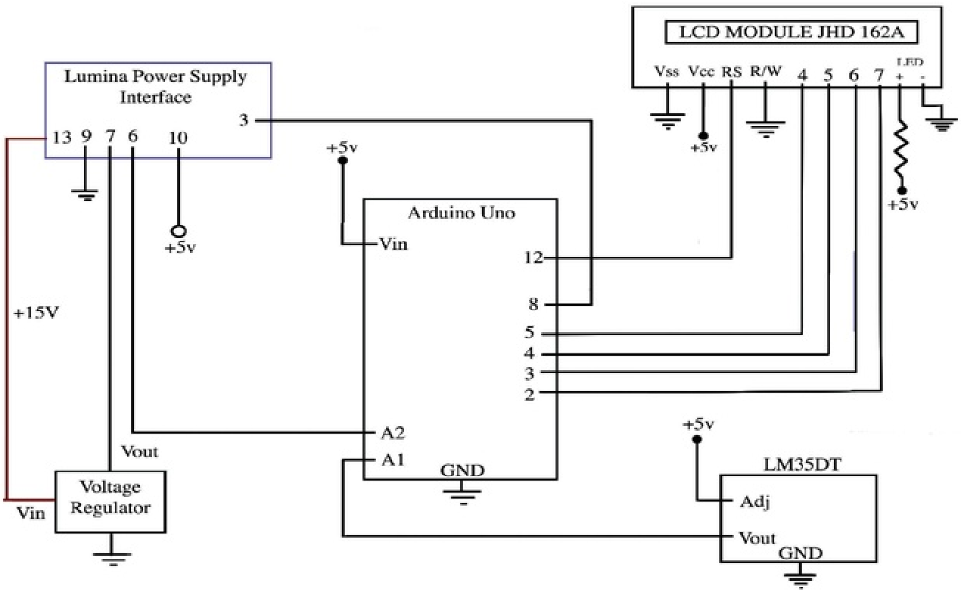


Figure 4.8: Whole System Connection

In this step, the Laser Diode system is ready to go. All the wires and devices are connected and we just need AC power to turn on the system as test as a whole system.

4.2 Final Testing of the whole System

Over the past two decades the reliability of the laser diode has been developed by the latest testing techniques and equipments. The requirements to measure the optical and electrical parameters accurately is complicated if we compare to any other electronic device. There are different package styles and different power levels of available laser diodes. Laser diode life testing happens in production line by applying high temperature under controlled conditions.

Before we turn on the system, we have to make sure that we have proper eye protection because we will be dealing with high power lasers. Turn on the water chiller before turning on the system so the temperature gets stable and make sure that the chiller is working. In this section we will demonstrate the laser system and we will identify the following features of Diode Laser:

- Optical Power Output
- Wavelength of the diode laser
- Spectral Width
- Output Laser Power in different temperature conditions

4.2.1 Output Optical Power

In this section we will use Optical Power Meter to measure the output power of the laser with different input current. Table 4.1 shows the basic operating characteristics, which includes the measurement of laser output current(A), voltage(V) and Optical Power(W). Low and spontaneous emission has been observed at low forward current gain in the active region of the diode. As we increase the current, after the threshold current which is 8 - 11 Ampere, gain increases the cavity losses and light begins to come out which we can see from the infrared camera (available in the lab). The emitted light begins to increase rapidly as we go beyond the threshold current as shown in figure 4.9. Figure 4.9 also shows that information from the data sheet of the laser diode is quite close to the practical readings such as in the data sheet, slope efficiency is ¿0.8 W/A, which is pretty close and the power increases by the factor of 0.8W and 0.9W as we increase the current.

Table 4.1: Diode Laser output measurements

Iprog (Input) / V	Output Current / A	Output Voltage / V	Optical Power / W
0.76	5.90	1.71	1.62
1.06	8.90	1.76	4.60
1.50	14.33	1.83	9.82
2.15	22.15	1.93	16.72
2.70	28.50	2.01	22.50
2.92	31.68	2.04	24.47
3.33	36.37	2.11	28.52
3.44	37.06	2.12	29.44

These readings are different than the first readings mentioned in chapter 3, because that time the wire resistance was more due to its less thickness, the wire was the reason for the high potential difference with less current. New and thick (8 AWG) wire has been installed and now as you can see in the table 4.1 that 30W of optical power was gained at 2.1v(which is the maximum operating voltage for the diode laser).

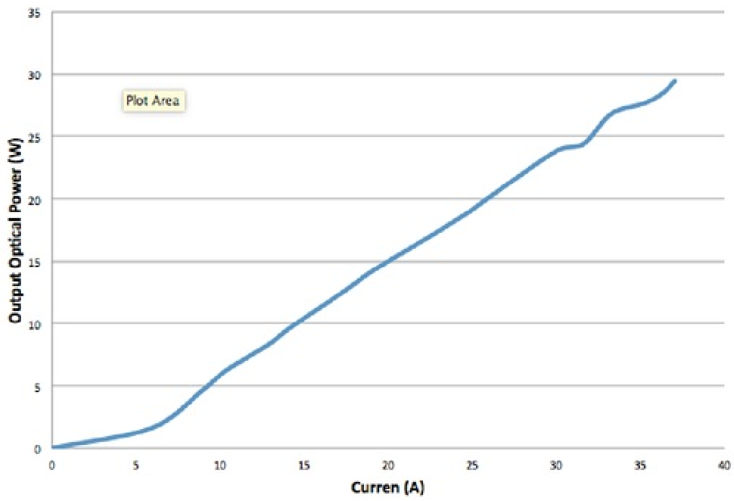


Figure 4.9: Laser Diode LIV Characteristics

Thermal management of the laser diode is very important because laser diode operating characteristics are very sensitive to the diode junction temperature, as the temperature increases the threshold current increases as well and the efficiency of the laser diode decreases as shown in Figure 4.10.

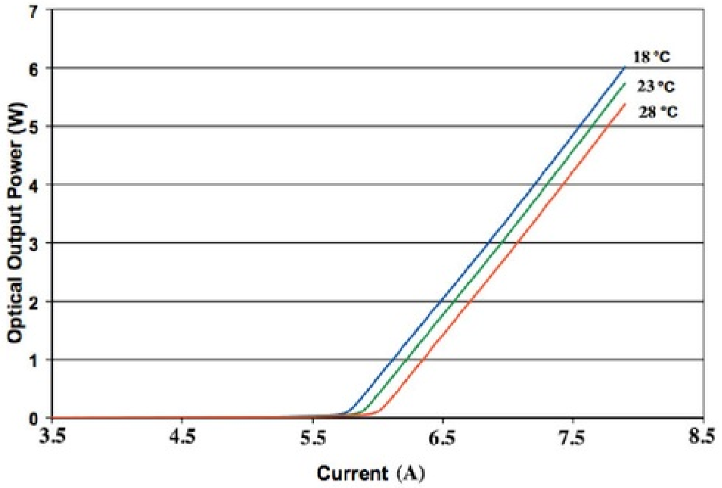


Figure 4.10: Light vs Current (Temperature Dependance)

During the experiment we tried to check the maximum optical gain, whether the laser is able to give the maximum optical power or not. The maximum power 29.84 Watts was gain at 37 Ampere with 2.12 voltage. Figure 4.11 shows the Optical Power Meter showing the maximum power measured.

Figure 4.11: Optical Power Meter

4.2.2 Wavelength of the Laser Diode

We know that the wavelength of the laser diode is 808nm from the data sheet. It is required to test the wavelength practically with Optical Spectrum Analyzer. So for determining a wavelength we need to align the fibre coming from the laser diode to fibre from Optical Spectrum Analyzer. Optical Spectrum Analyzer Fibre radius is bigger than usual fibre radius so even if the beam is not accurately aligned straight to the Analyzer fibre we will still get the wavelength. Figure 4.12 shows the wavelength measured by Optical Spectrum Analyzer.

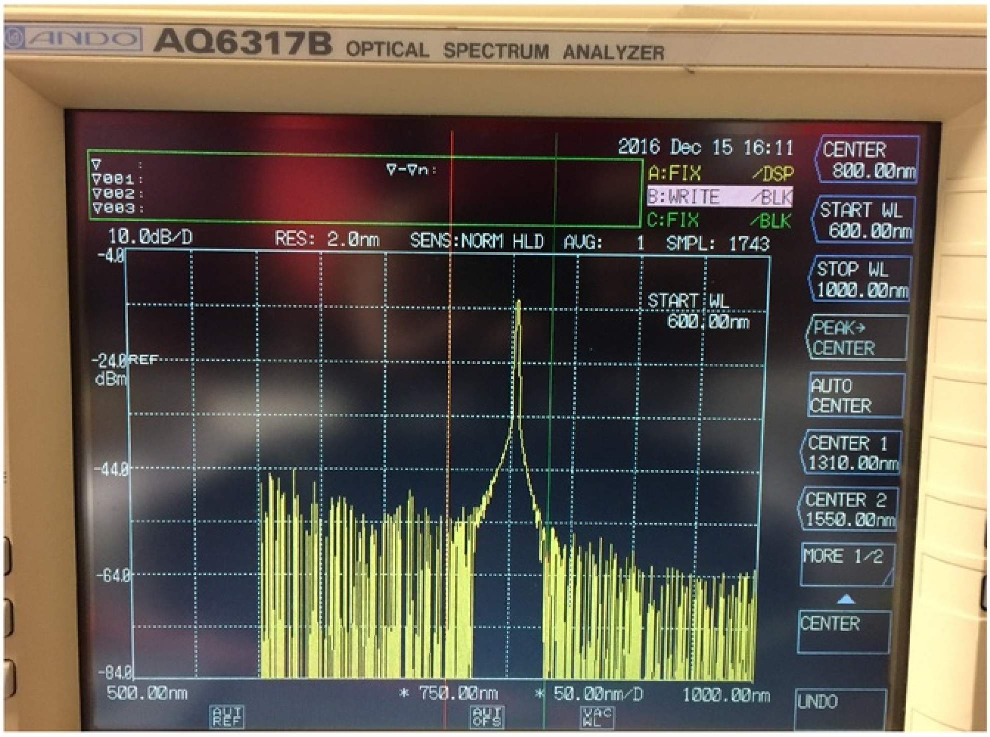


Figure 4.12: Wavelength of the Laser

Overview

Till this stage the whole system is working absolutely fine. We have fulfilled all the requirements. The system is ready to be used for professional purposes. The CW Current Driver can be used for any high current electronic device. The name we have given to the device is BedRock Photonics 100A current driver. The final integrated structure in a box is shown in figure 4.13.

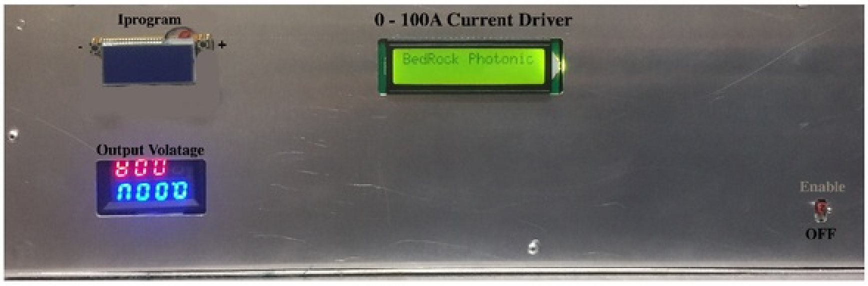


Figure 4.13: BedRock Photonics 100A Current Driver

4.3 Set Up

- Connect AC power
- Make sure the enable switch is down
- Turn ON the AC power
- The system will turn on, you can hear the fans on high speed.
- By this time you can see the the Iprogram input voltage on the LCD, if the input voltage is high such as 5v, the output after enabling straight away will give 50A of current. So keep the Iprogram low before enabling the driver.
- Enable switch turn Up to enable the system, the fans sound will increase.
- Keep changing the Iprogram input upto the requirements.

4.4 Troubleshooting

If sometimes driver is not working properly, reset the AC power and keep all the switches down. If in some situations, driver needs to work without temperature assessing so there is an option to run the driver without operating temperature sensor for the diode laser. There is a switch stating with and without temperature sensor.

Chapter 5

Conclusions and Future Work

5.1 Conclusions

The main goal of this project was to make 0 - 100A current driver system and integrating the high power laser diode with a driver. Also to make thermal management system for current driver and diode laser. Current Driver was made perfectly fine according to the requirements, current driver has a smart heat management system which allows it to give constant output power for long periods. On the other hand heat management of diode laser was tried to be controlled by forced air but that was not successful because high power diode laser dissipated high amount of heat and which needs to be control otherwise we can damage the diode laser. So water cooling method was applied for the diode laser and which works perfectly fine and the optical output power is pretty constant which is required for medical applications.

We have an enclosed system of current driver displaying the required outputs on LCDs during the operation of the system. Diode laser which we are using for this project went to its maximum power with constant output power for long time which means the current driver and diode laser is ready to be used for medical applications. There is a lot of potential for this project in future to make different applications as the technology keeps on improving.

5.2 Future Improvements

This project has the potential to be technologically more advance in the future. The LCD screens on the front side of the enclosed box could be mounted properly for the better finish. The box can be more presentable by decreasing the size and by using less LCD screens. We can make a proper menu with a buttons and one screen which can control and display the output. The Current Driver has the potential to be used for various electronic devices.

Chapter 6

Abbreviations

CW	Continuous Wave
LD	Laser Diode
OEM	Original Equipment Manufacturer
LDD	CLaser Diode Driver
EMI	Electromagnetic Interference
NTC	Negative Temperature Coefficient
ZVS	Zero Voltage Switching
PWM	Pulse Width MOdulated
TECS	Thermoelectric Coolers

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Appendix A

Data Sheets

This section contains all the important datasheets of electronic devices used for this project.

A.1 FAP800-30W-805.0to 811.0-F<3.5-25C

The is the datasheet for Diode Laser we are using for this project.

COHERENT.

FAP 800 Series

High-Brightness Fiber-Coupled Bars

Fiber Array Packages (FAP) from Coherent are the highest quality fiber-coupled diode lasers in the industry, offering you the simplest way of delivering the output from a diode laser bar to your application.

The FAP 800 series consists of a 19-element conduction-cooled diode laser bar, lensed and coupled to an 800 µm, multimode fiber bundle array.

FAP 800 Series Features:

- High reliability
- High efficiency
- High brightness
- Rugged construction

FAP 800 Series Applications:

- Solid-state Laser Pumping
- Plastic Welding
- Soldering
- Heating

Superior Reliability & Performance

www.Coherent.com/FAP800Series

FAP 800 Series

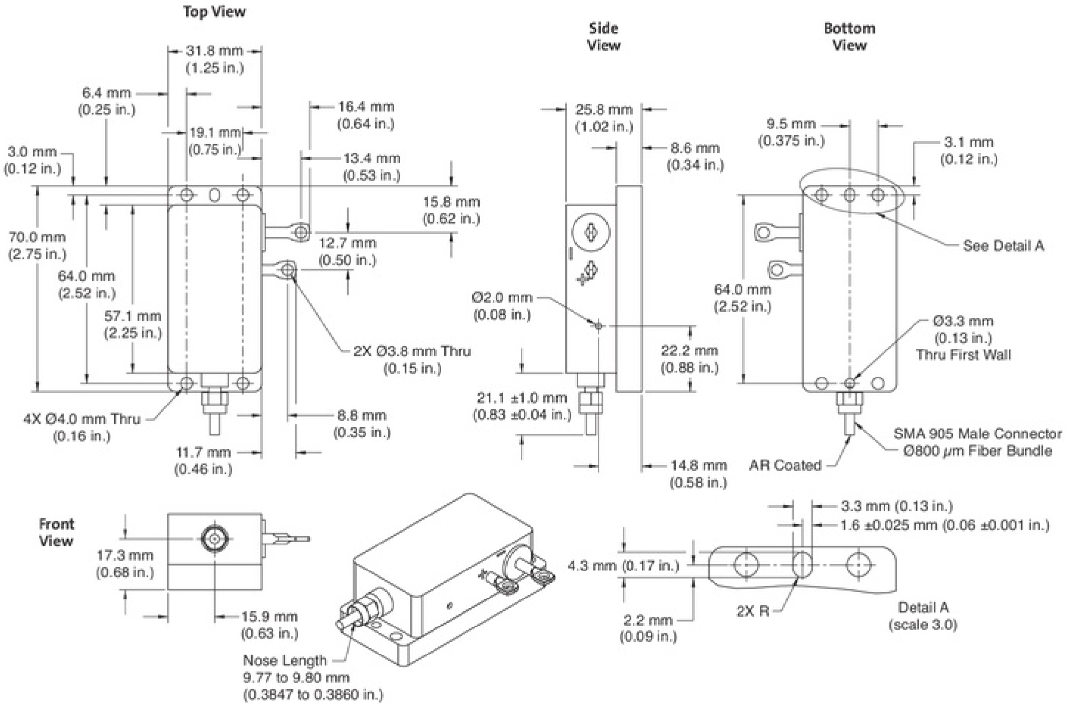
High-Brightness Fiber-Coupled Bars

Device Specifications	FAP800-16W-804.0to 810.0-F<3.0-25C-STD	FAP800-16W-805.0to 811.0-F<3.5-25C	FAP800-30W-792.0to 798.0-F<3.5-25C-STD	FAP800-30W-805.0to 811.0-F<3.5-25C
Part Number	1080859	1057746	1049769	1059281
Optical Specifications[1]				
CW Output Power (W)	16	16	30	30
Center Wavelength[2] (nm)	807	808	795	808
Center Wavelength Tolerance (nm)	±3.0	±3.0	±3.0	±3.0
Spectral Width[2] (nm)	<3.0	<3.5	<3.5	<3.5
Wavelength Temperature Coefficient (nm/°C)	0.28	0.28	0.28	0.28
Beam Divergence[3] (NA)	<0.16	<0.14	<0.16	<0.14
Beam Diameter (µm)	810	810	810	810
Electrical Characteristics (typical)				
Slope Efficiency (W/A)	>0.8	>0.8	>0.8	>0.8
Conversion Efficiency (%)	>35	>35	>35	>35
Threshold Current (A)	8 to 11	8 to 11	8 to 11	8 to 11
Operating Current (A)	<28	<32	<46	<46
Operating Voltage (V)	<2.0	<2.0	<2.1	<2.1
Recommended Hookup Wire (gauge)	8 or heavier	8 or heavier	8 or heavier	8 or heavier
Thermal Specifications				
Thermal Resistance (typical)(°C/W)	0.7	0.7	0.7	0.7
Case Operating Temperature (°C)	-20 to 30	-20 to 30	-20 to 30	-20 to 30
Case Storage Temperature (°C)	-20 to 60	-20 to 60	-20 to 60	-20 to 60
Recommended Heat Sink				
Capacity (W)	100	100	100	100
Thermal Resistance (°C/W)	<0.1	<0.1	<0.1	<0.1
Mechanical Specifications				
Weight	300 g (10.3 oz.)	300 g (10.3 oz.)	300 g (10.3 oz.)	300 g (10.3 oz.)
Fiber Connector	SMA 905	SMA 905	SMA 905	SMA 905

1 All values measured at case temperature (T_C) = 25°C.
2 Custom center wavelengths and custom spectral widths are available, some from stock. Consult your Coherent representative.
3 The numerical aperture of the output beam is defined as the sine of the half-angle of the divergence cone that encircles 90% of the energy.

COHERENT.

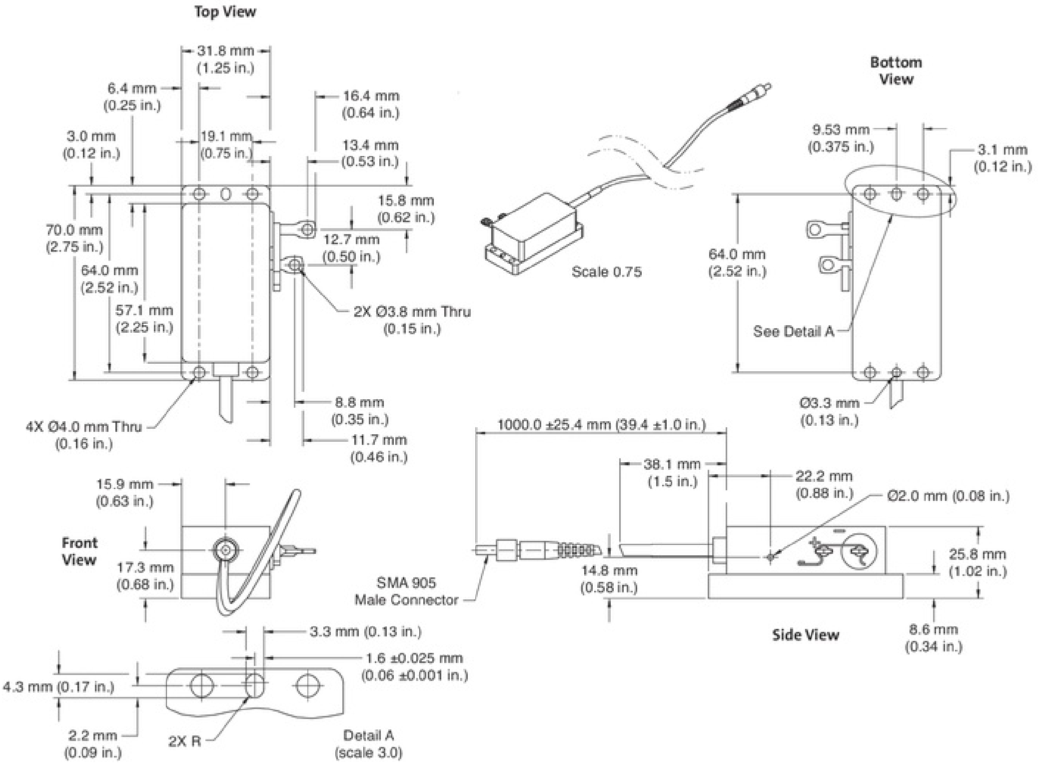
Mechanical Specifications



FAP 800 Series

High-Brightness Fiber-Coupled Bars

Mechanical Specifications



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UK/Ireland	+44 (1353) 658 833

Printed in the U.S.A. MC-156-04-0M0615Rev.D

A.2 LDD-600-100-6

The is the datasheet for Continuous Wave Current Driver we are using for this project.

LDD High Power CW Laser Diode Drivers

The LDD series is a new family of OEM laser diode drivers designed for the emerging high power laser diode industry. The LDD series is ideal for high power applications where economy is important and performance cannot be compromised. Compact size is possible due to the low-loss Zero Voltage Switching inverter and incorporation of planar magnetics. The LDD is virtually wire free.

Power factor is greater than 0.99 and conducted emissions meet stringent European regulations. No additional line filters required to meet EN 55011 emission requirements.

The LDD family has been designed with the knowledge that a high power laser diode is an expensive device. Rise and fall times are strictly controlled to reduce high voltage transients which could damage the laser diode.

Lumina Power, INC.

26 Ward Hill Avenue, Bradford, MA 01835
Ph: 978-241-8260 / Fx: 978-241-8262
www.luminapower.com / sales@luminapower.com

ADVANTAGES

- Ideal for OEM applications
- Safe turn-on/turn-off
- Compact design
- Power factor correction
- Auxiliary +15V/-15V/+5V
- Low conducted emissions, low leakage
- ROHS Compliant

Configurations:

- Output current up to 300A
- Maximum output voltage to 200V
- Analog or RS232 interface
- Universal input for all world voltages
- CE and safety agency approved
- Available handheld controller

LDD High Power CW Laser Diode Drivers

Model	Poutmax	Ioutmax	Input Voltage	Size (L x W x H)
LDD-50-XX-YY	50 Watts	15 amps	100-240VAC ± 10%	6.75" x 3.63" x 3.25" 17.1 x 9.2 x 8.26 cm
LDD-100-XX-YY	100 Watts	50 amps		7.5" x 5.8" x 2.6" 19 x 14.7 x 6.6 cm
LDD-150-XX-YY	150 Watts	60 amps		
LDD-250-XX-YY	250 Watts	80 amps		
LDD-600-XX-YY	600 Watts	100 amps		9.9" x 7.3"x 2,6" 25.1 x 18.5 x 6.6 cm
LDD-1000-XX-YY	1000 Watts			
LDD-1500-XX-YY	1500 Watts		200-240VAC ± 10%	
LDD-2500-XX-YY	2500 Watts	150 amps		13" x 8.5" x 3.4" 33.2 x 21.6 x 8.6 cm
LDD-3000-XX-YY	3000 Watts	200 amps		17" x 16.6" x 3.4" 43.2 x 42.2 x 8.6 cm
LDD-6000-XX-YY	6000 Watts	250 amps	200-440VAC ± 10% 3Ø	17.3" x 16.6" x 4.25" 43.9 x 42.2 x 10.8 cm

XX = maximum required output current, YY= maximum required compliance voltage
Maximum compliance voltage for LDD-2500 = 50V.

Specifications

INPUT
Voltage: See table above
Power Factor: >.98 (LDD-6000:~t80%)

INTERFACE
Connector: 15 Pin "D" Sub Female
Current Program: 0-10V for 0-Max Current
Current Monitor: 0-10V for 0-Max Current
Voltage Monitor: 0-10V for 0-Max Voltage
(Optional RS232 interface available)

PERFORMANCE
Rise/Fall Time: >10msec standard (faster rise times available)
Current Regulation: <0.5% of Maximum output current
Current Ripple: <0.5% of maximum output current
Current Overshoot: <1% of maximum output current
Power Limit: Limited to maximum power with power fold-back circuit

ENVIRONMENT
Operating Temp: 0 to 40°C
Storage: -20 to 85°C
Humidity: 0 to 90% non-condensing
Cooling: Forced air

REGULATORY
Safety: LDD-150/250: UL60950
LDD-600/1000/1500/2500/3000: UL60950 (Industrial), UL60601-1 (medical) Emissions/Immunity: FCC 47 CFR Class A Emissions, EN55011:1998 Group 1 Class A Emissions, EN61000-3-2, EN61000-3-3, EN60601-1-2:2001

AUXILIARY OUTPUTS
+5V @ 200mA
+15V @ 200mA
-15V @ 200mA

Note: No auxiliary outputs on LDD-50, No +5V output on LDD-100/150. Performance cannot be guaranteed below 25% of rated output

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LDD-Interface

Connector Type: 15 Pin D-Sub Female

Pin #	Pin Name	Functional Voltage Level	Description
1	Enable (input) (note1)	High = RUN = +5V to +15V Low = OFF = 0V	The Enable function turns the output section of the power supply ON and OFF. When the power supply is enabled, current is delivered to load as programmed via Iprogram(+), Pin 7. Rise times resulting from Enable are approximately 25msec.
3	Interlock (Input)	Open = OFF Connect to GND = RUN	The Interlock function can be connected to external interlock switches such as door or overtempswitches.
4,9, 15	GND		Interface Return
5	Vout Monitor (output)	0-10V = 0-Voutmax (note:2)	The output voltage of the supply can be monitored by Vout Monitor. See note below
6	Iout Monitor (output)	0-10V = 0-Ioutmax	The output current of the supply can be monitored by Iout Monitor.
7	Iprogram (input)	0-10V = 0-Ioutmax	The power supply output current is set by applying a 0-10V analog signal to Iprogram(+).
8	Pulse Control (input) (pulsed fuction is also avaiable on LDY series drivers)	TTL High = On TTL Low = Off Default = On (LDD-2500/3000/6000 only)	The output of the LDD-2500/3000/6000 may be pulsed by applying a TTL signal to Pulse Control, pin 8. The amplitude of the output current pulse is determined by the current level programmed via Pin 7, Iprogram(+). Rise fall times of <1msec are typical. Contact Lumina Power for faster rise and fall times.
10,11	+5V (output)		Auxiliary 200mA Not available on LDD-50/100/150
12	-15V (output)		Auxiliary 200mA Not available on LDD-50/100/150
13,14	+15V (output)		Auxiliary 200mA Not available on LDD-50

1. Always disable power supply (pin 1 low) prior to appying the mains voltage.

2. Pin 5 If maximum compliance voltage is less than 10V, Vout Monitor will read output voltage directly. If maximum compliance voltage is greater than 10V, then Vout Monitor will be scaled such that 0-10V = 0-Voutmax. Applying a program voltage greater than 10.5 volts will latch power supply. Output current will not exceed 105% of rating.

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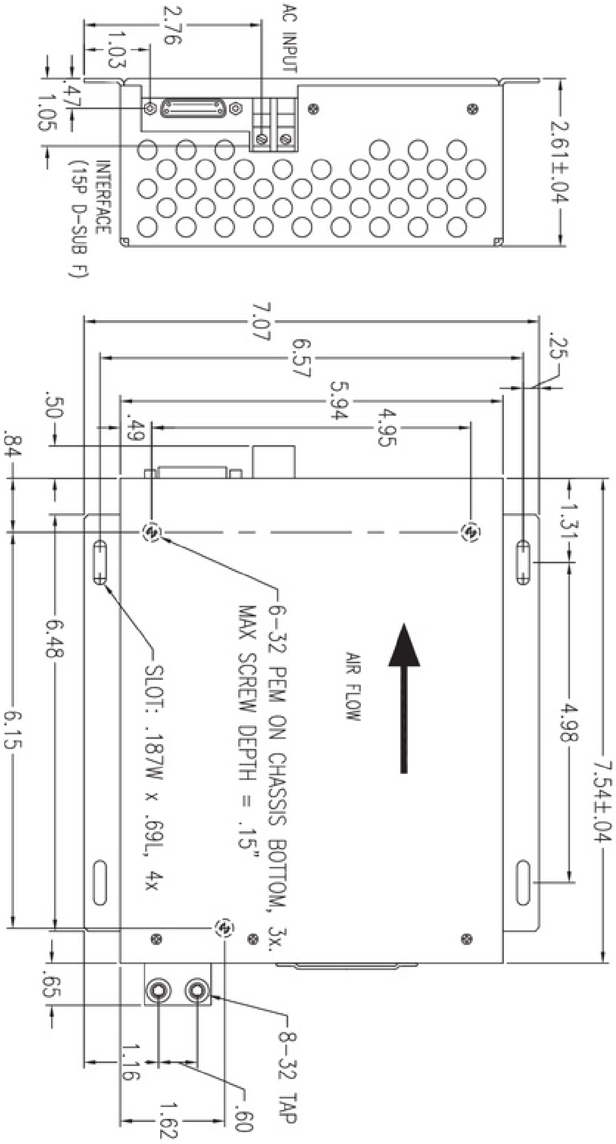
LDD High Power CW Laser Diode Drivers

Outline Drawings

LDD-100/150/250



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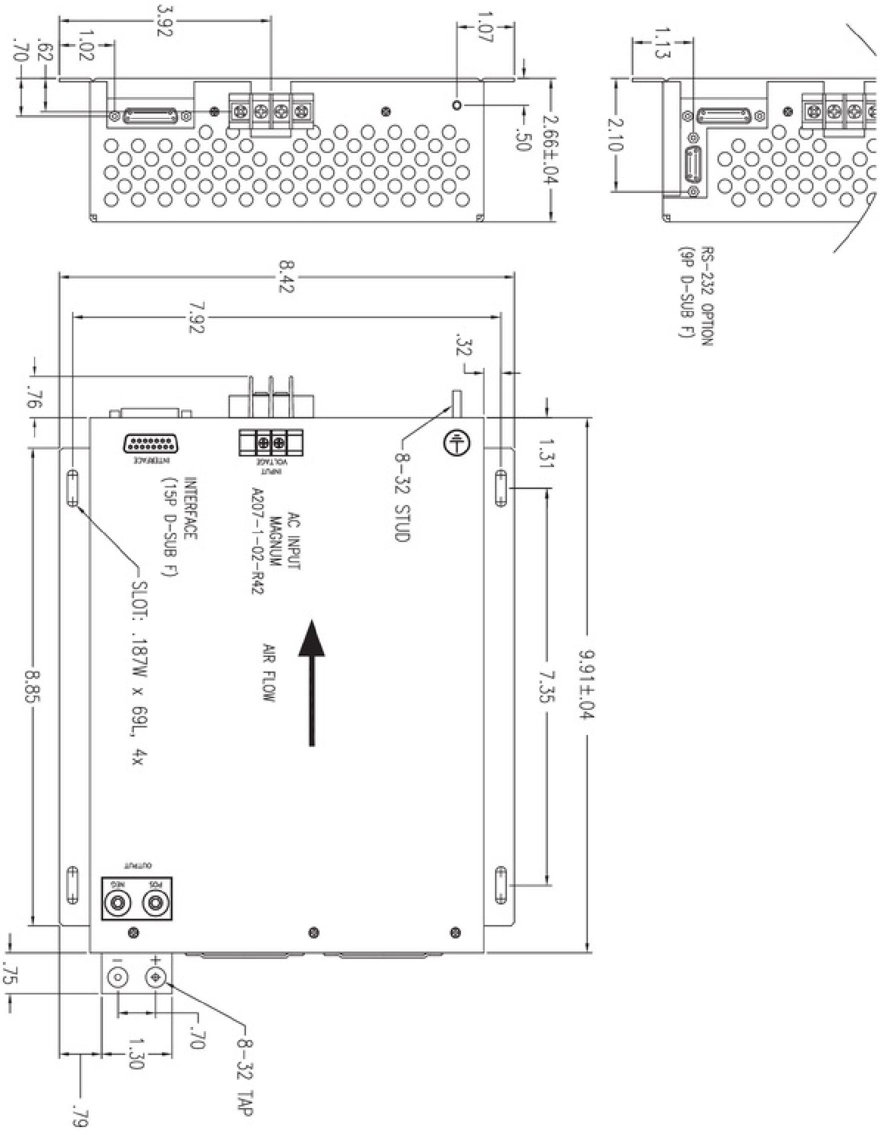
LDD High Power CW Laser Diode Drivers

LDD-600/1000/1500



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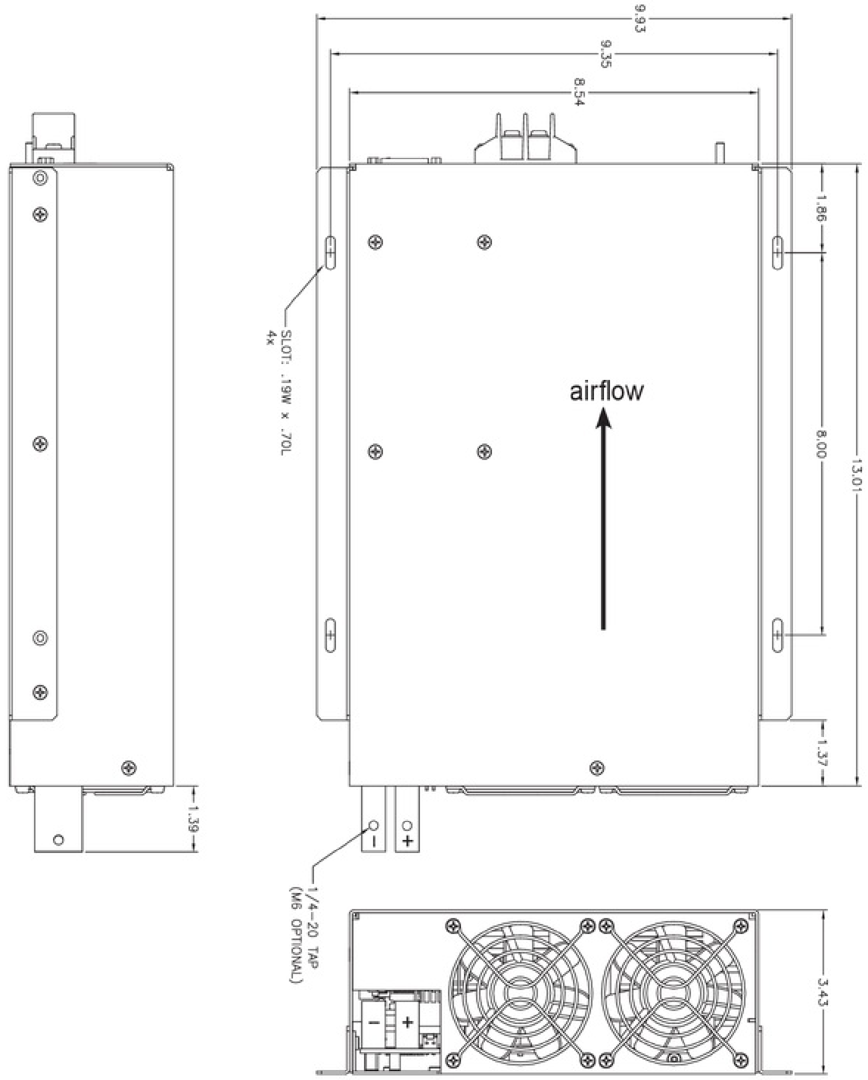
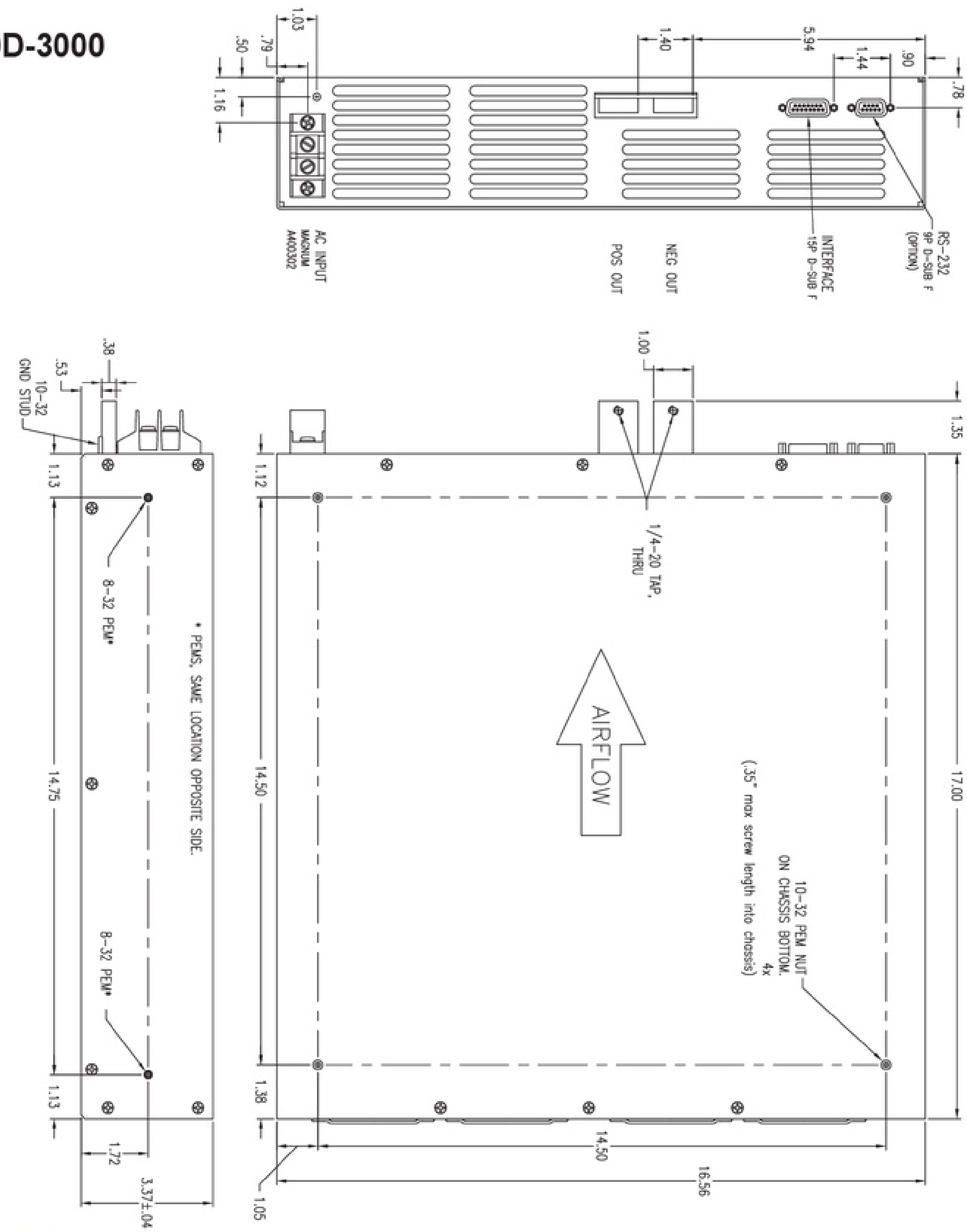
LDD High Power CW Laser Diode Drivers

LDD-2500



LDD High Power CW Laser Diode Drivers

LDD-3000



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LDD High Power CW Laser Diode Drivers

LDD-6000