

Design and development of a Programmable High Current Laser Diode Driver for Fiber Laser System

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Abstract- The Laser Diodes are essential part in design and development of Fiber Laser Systems. It requires fixed amount of current as an input, so that it can provide desired optical output power. The Laser Diode Driver is an electronic circuit unit which feed a controllable constant current in to the laser diode so, that it can generate a significant amount of optical power as an output. We have designed and developed a programmable high current laser diode driver that can generate constant current into laser diode. The current can be set to any value between 0.5A to 12A by means of Arduino microcontroller or by potentiometer. The current will remain constant irrespective to the variation in input voltage and resistance of laser diode. This Programmable High Current Laser Diode Driver can be used for any continuous wave (CW) fiber laser system within the permissible output power.

Keywords: Laser, Laser Diode, Laser Diode Driver, Fiber Optics, Arduino.

1. INTRODUCTION

In a system using fiber laser source, the critical part is to design a constant current source which shall be linear, noiseless and accurate to deliver fixed current into the laser diode; to generate optical output. Laser diode driver helps us to drive laser diode by providing pre-set constant current. There are two advantages of laser diode drivers over voltage sources. First one is that the current delivered by laser diode driver shall remain constant irrespective to the type of laser diode used. In other words, the resistance offered by the laser diode shall not matter in case of a constant current source. Secondly, if fiber laser system is run on a battery, then during its operation battery discharges hence input voltage decreases. But the laser diode driver will generate a constant current into the laser diode for a particular input voltage range, thereby maintaining the output optical power at the same level.

The above advantages are not present if we drive the laser diode from a voltage source. If one connects a laser diode, directly to a voltage source, there is no way to control the current flowing into the laser diode, unless one knows the resistance of laser diode. Also, the output optical power from a laser diode varies non-linearly with respect to the voltage across the laser diode. Whereas, the output optical power varies linearly with respect to input drive current of laser diode above threshold current.

Moreover, the laser diode driver feeds a controllable constant current to the laser diode. Each laser diode has its minimum and maximum current specifications. Minimum lasing current (also known as threshold current) is defined as the current below which laser diode can't generate any power and maximum permissible current is a specified amount of current above which the laser diode will go through a permanent damage.

Generally, there are few classes or "types" of laser diode drivers. These are: Continuous Wave (CW), Pulsed Mode, low power and high-power drivers. Continuous wave laser diode driver provides a continuous current to the laser diode to produce constant output level over time, in theory forever if needed. Pulsed mode laser diode drivers generate a current with certain duty cycle. The duty cycle is the "on" time of the current source (output power will be high) to the total time of the pulse (on and off time).

The low-power and high-power drivers are common in industries and they are named depending on the magnitude of the output power fed to the load.

We have designed a 12 Amps, 16 Volts to 32 Volts programmable high current laser diode drivers having two modes of operation a) Microcontroller Based and b) Potentiometer Based.

2. HARDWARE INTERFACE

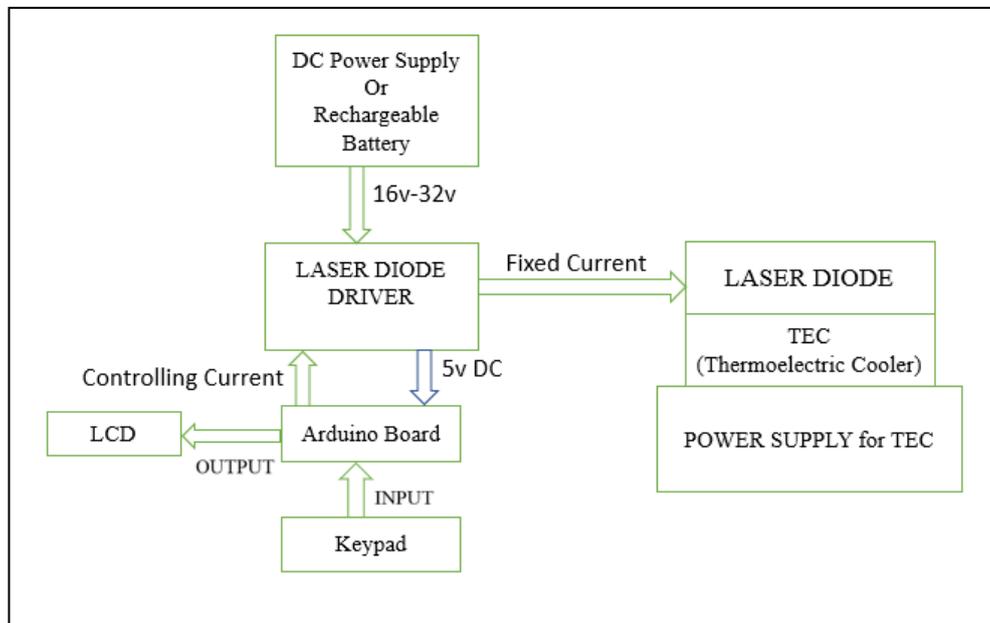


Fig 1: Block diagram of Laser diode driver experimental setup.

The overall system for driving a laser diode by a Laser Diode Driver consists of following blocks, namely:

2.1 DC Power Supply or Rechargeable Battery: A regulated DC power supply is used which acts a source to the driver circuit. We can also use a portable rechargeable battery to power the circuit.

2.2 Power supply for TEC (Thermoelectric Cooler): It is the power supply module, used to power the Thermoelectric Cooler. It also programs the set temperature of laser diode, i.e. the temperature at which the laser diode has operated.

2.3 TEC: Thermoelectric cooler operates on the Peltier effect [1]. It is constructed by two unique semiconductors, one n-type and one p-type.

It has two sides, and when a DC current flows through the device, it transfers heat from one side to another side, so that one side gets cooler while the other side become hotter. The hot side is attached to a heat sink so that it carries away heat to the ambient. The cool side may go below the room temperature and attached to laser diode. Thus, it will maintain the temperature of laser diode within the permissible range.

2.4 Laser Diode: It is a semiconductor coherent lightening device [2]; converts electrical energy into light. It is different from a LED (Light Emitting Diode) in fact that laser diode generates a highly monochromatic and coherent light. Electrically, it is equivalent to a PIN diode. It has highly doped P-type and N-type semiconductor placed on two sides of undoped intrinsic region. While Laser Diode active region resides in the 'I' (Intrinsic) region. The electrons and holes are pumped into 'I' region from N-type and P-type semiconductors that recombine with each other. As the electrons drop from higher energy level to a lower energy level it releases its energy in form of photon. Stimulated emission is produced when the light is trapped by using mirror kind of structure that makes photons to move back and forth in intrinsic region, thereby stimulating other electrons and holes to recombine. The process is continued and it generates light with the same phase and same wavelength.

We have used a fiber coupled LASER DIODE made up of AlGaAs compound having a wavelength of 976nm, output optical power is 50.3W (typically), threshold current is 0.50A, maximum operating current is 9.95A, and maximum operating voltage is 10.13V, diameter of fiber core and clad is 105 μm and 125 μm respectively (Multi Mode).

It can give 50W continuous wave optical output power.

2.5 Arduino UNO Board with LCD Display & Keypad: Arduino UNO is an open source microcontroller board based on the microchip ATmega328P microcontroller. It has 14 digital pins; 6 analog pins and it can be programmed with Arduino IDE (Integrated Development Environment) via a type B USB cable. Its operating voltage is 5V, among 14 digital pins 6 pins can generate PWM signal, DC current per I/O pin is 20 mA, DC current for 3.3V pin is 50 mA, it has SRAM of 2 KB, 1 KB of EEPROM, 32 KB of flash memory and 0.5 KB of this flash memory is used by bootloader, which helps us to upload a new code to the microcontroller without any external hardware programmer, and a clock speed of 16 MHz.

A 2X16 (2 lines and 16 characters) LCD display is interfaced with Arduino UNO by connecting 4 pins only and this can be done by using the I2C serial bus.

Connections: DATA: SDA pin – A4 pin of Arduino, CLOCK: SCL pin – A5 pin of Arduino,
POWER: PWR- +5V of Arduino, and GROUND: GND- GND of Arduino.

A 4X4 (4 rows and 4 columns) keypad is interfaced with Arduino UNO by connecting 4 row pins with 6,7,8,9 digital pins of Arduino and 4 column pins with 2,3,4,5 digital pins of Arduino.

2.6 Laser Diode Driver: It is an electronic circuit which will supply a constant current to drive a laser diode. This circuit can operate with minimum of 16V to maximum of 32V and maximum 12A current. DC-DC converters of 5V and 12V are used to provide the power supply to Arduino UNO and to the cooling fan of the external circuit respectively. A mode selection switch allows us to select the path for control voltage either from potentiometer or Arduino via low pass filter (LPF).

In potentiometer mode, a voltage divider circuit is designed to provide desired amount of control voltage, similarly in case of Arduino mode, microcontroller is being programmed to generate pulse width modulation (PWM) as per the keypad input (shown in fig. 3). The PWM signal passes through a low pass filter to produce an average value, which is then supplied to the non-inverting terminal of the Op-amp through a laser on/off switch. Transistor Q1 and Q2 act as Darlington pair to provide desired current gain [3]. A CMOS NAND buffer is connected with the laser on/off switch for controlling relay, which will bypass any surge current and protect the laser diode from permanent damage during over-current situations.

But during the over-current situation bipolar junction transistors may get damaged as current flows through transistor from relay. To protect the transistors, the over current sense circuit makes N-channel enhancement mode DMOS FET, ON thereby pulling down the control voltage to zero in over-current conditions. When the circuit is not powered or when the laser on/off switch is in off position then the normally on relay shorts the terminals of laser diode in parallel. Hence, laser diode is prevented from electrostatic discharge (ESD) events. Soft start of laser diode is achieved by a RC circuit connected before the non-inverting terminal of the Op-Amp that oppose sudden change in the input current of the laser diode and provide a smooth start depends on the RC time constant to improve the life of it. Transient spike protection is achieved by connecting a capacitor across the laser diode and the reverse polarity protection is achieved by connecting a diode in anti-parallel with laser diode.

Some features of the designed Laser Diode Driver are: Over current protection, Soft start of laser diode, transient spike protection across laser diode, reverse polarity protection across laser diode, constant current output that can be set from the keypad connected with Arduino UNO microcontroller.

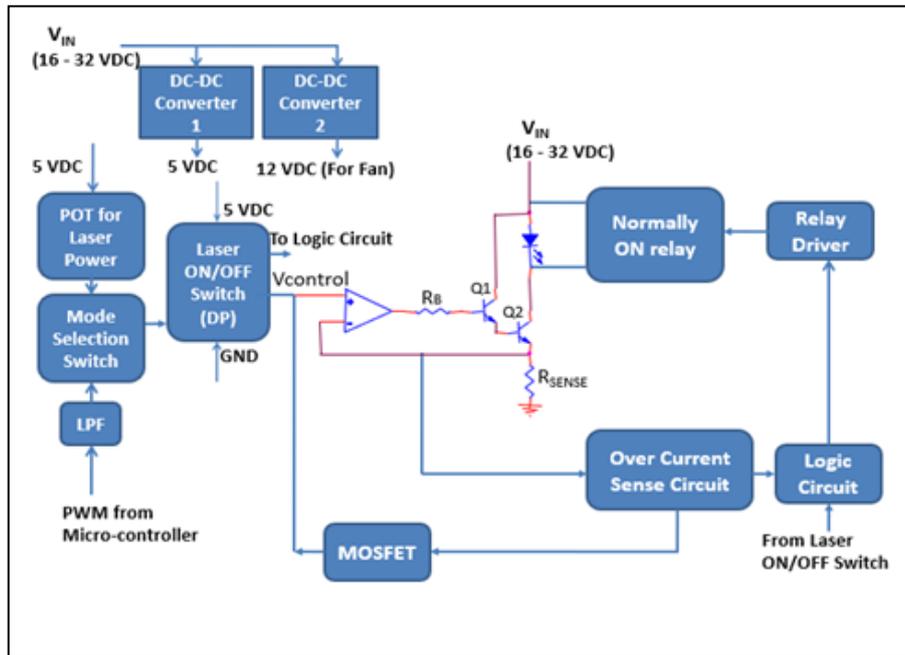


Fig 2: Block diagram of laser diode driver.

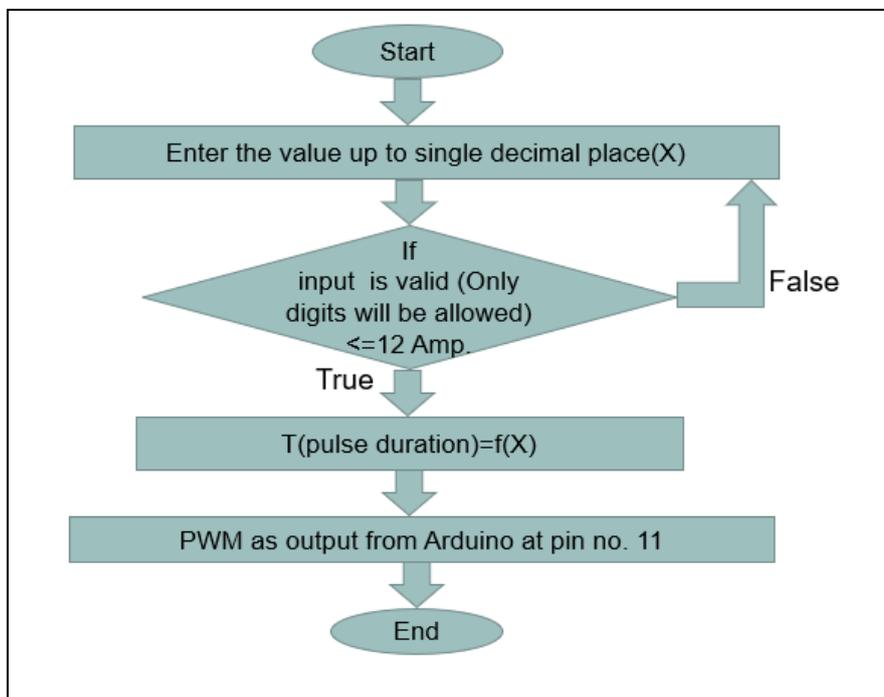


Fig 3: Flow chart of Arduino program for current controlling.

3. RESULT

Table 1: Observation table for optical output power with different input voltages and fixed current in Arduino Mode.

Arduino Mode		
Input Voltages (V)	Current (A)	Optical output Power (W)
16	6.1	32.1
18	6.1	32.3
20	6.0	32.5
22	6.2	32.6
25	6.2	32.7

Table 2: Observation table for optical output power with different input voltages and fixed current in potentiometer Mode.

Potentiometer Mode		
Input Voltage (V)	Current(A)	Optical output Power (W)
16	6.0	32.2
18	6.1	32.2
20	6.0	32.3
22	6.2	32.4
25	6.2	32.4

Arduino Mode		
current(A)	Optical output power (W) for different input voltages	
	At 16V	At 25V
0	0	0
0.5	0	0
1	4.33	4.4
2	9.7	10.3
3	14.7	16.1
4	20.5	21.6
5	25.2	26.2
6	32.1	32.7
7	37.3	37.5
8	42.9	43.2
9	48	48.8

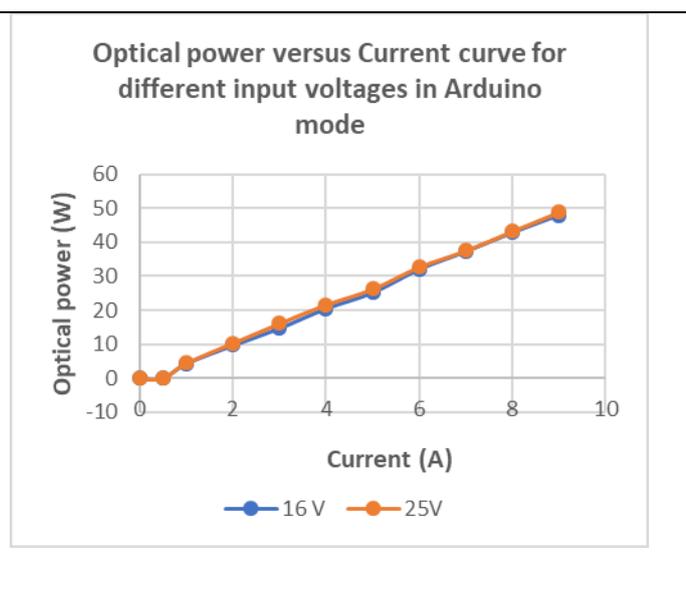


Fig 4: Optical power versus current curve in Arduino mode.

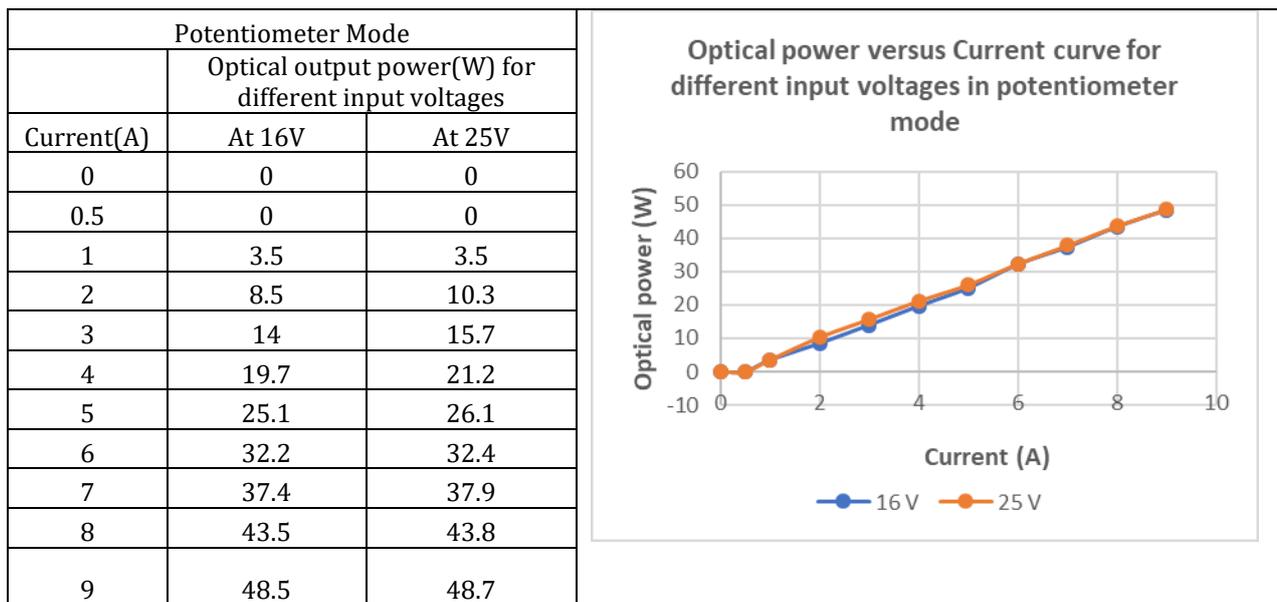


Fig 5: Optical power versus current curve in potentiometer mode.

Our driver can generate up to 12A output current for input voltage ranges from 16V to 32V. But if we use single laser diode having a lower compliance voltage (say 10V), then there will be large voltage drop across output transistor (about 21V V_{CE} for input voltage of 32VDC) which may cause thermal breakdown of transistor. Hence, the maximum input voltage should be restricted to 15V above the compliance voltage of laser diode. If we use two laser diodes connected in series each having compliance voltage of 10V, then we can easily operate our driver for input voltage of 32VDC.

4. CONCLUSIONS

This designed and developed programmable high current laser diode driver has current set accuracy of $\pm 0.8\%$ of maximum output current. Whereas, commercially available laser diode drivers in the market has current set accuracy of $\pm 0.5\%$ of maximum output current. It provides a steady current to laser diode irrespective of the change in input voltage. The output optical power levels were also stable for every value of the current fed to the laser diode.

5. Future Possibilities

In near future we can work on this developed circuit to integrate it with LabVIEW to control the circuit from remote PC and to provide a better current set accuracy.

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