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Research Article

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Design and Implementation Driving Circuit of High Power 980 nm Laser Diode

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Abstract: Laser diode with 980 nm has many attractive applications in telecommunication and photonic systems especially when it used for pumping the Erbium–Doped Fiber Amplifiers (EDFAs) which is an essential c- band amplifier that used in many applications for enhancing the nonlinear system conversion efficiency. In this work pulsed laser diode was manufactured after electronically implement the divider circuit with thermal stability of 14 pin 980 nm butterfly laser diode (AGREE SL 90S31A) that has maximum power of 160 mW. This driver circuit was based on the LM317 adjustable current regulator. The electronically chopped 980 nm laser diode achieved stable modulation in the frequency range from 1 Hz to 1 kHz. The proposed driver circuit is simple, low-cost, and successfully provides the required optical modulation for tapered fiber interferometer applications, making it a practical alternative to expensive electro-optic modulation systems such as commercial Lithium Niobate electro-optic modulators which are costly and also require expensive drivers to operate.

Keywords: 980nm Butterfly laser diode driver; pulse modulation; LM317 current regulator; low-cost optical modulator; photonic applications.

1. Introduction

Pulsed fiber-coupled laser diodes are desired sources in optical communication systems with highly sensitivities temporal response unlike continuous wave laser diode that deliver stable optical output. Short bursts of optical energy with excellent timing, fast switching [1]. High speed modulation systems needs pulsed laser to drive the system with advanced optical modulation formats with speed stating from 20 kHz to 21GHz and data rate with 25 Gbps [2]. The pulsed 980 nm laser diode imperative source in optical sensing network that need to use fine allocated narrow-band laser source which essential for high data rete system and long-haul systems [3- 5]. This vital chopped source used for pumping erbium doped fiber which is nonlinear fiber and mandatory optical element in the cavity of fiber laser system that used in many attractive photonic application such as generation of laser with special optical characteristics like multiwavelength, supercontinuum generation in C and L band Rapid time response and narrowing optical pulse can be obtained when the optical interferometric has wavelength division multiplexer operates with 980 nm laser diodes reached to Q- switched optical pulse and also mode locked toward femtosecond laser diodes pulse [3-11].

Laser diode with 980 nm has many features that make it very captivating in biomedical application either operates in continuous or pulsed mode operation with low and high level. In dental application the exposed area of the dental tubules was decreased using continuous 980 nm laser diode and this decreasing was caused by reducing thermal effects and less absorption of heat by water molecules in tissues[11] while for pulsed mode operation this type of laser was used for acceleration the movement of the orthodontic tooth with low peak power that cause less pain and swelling and faster wound healing when compared with 635 laser diode without temporomandibular disorders [12,13].

In medical imagine and optical coherence tomography (OCT), 980 laser diode was used because of its low photothermal damage, leading of reducing microleakage [14]. Main features of 980 nm laser diode that it has higher absorption cross-section and adjustable pulse width and fast rise and falling time make it crucial in optical communication system that needs excellent timing and synchronization [15]. Electronically chopped 980 laser diode has high electrical to optical conversion efficiency which makes it very necessary for designing and construction optical modulator and also optical switcher in all fiber optical communication system with ultra-high modulation speeds that make it a cornerstone in sensing, optical fiber communication system platforms also in application that deals with high modulation bandwidth with high resolution in temporal and spatial domains [16].

2. Experimental Setup and Work's Methodology

There are three circuits that are designed for obtaining stable 980 laser diodes, one for continues mode of operation, second electronically chopped this laser and the third circuit was for investigation stable laser diode with pulse modulation circuit all of these three circuits were explained in the next subsection.

a. Driver Circuit of Continuous Butterfly the 980 nm Laser Diode

The experimental setup**,** as shown in Figure 1, consists of three main components: a regulated DC power supply, an ammeter for current monitoring, and a custom laser diode driver circuit. The butterfly laser diode was mounted on an aluminum heat sink to maintain thermal stability during operation because any overheating leads to performance degradation at the output. The laser diode driver is based on the LM317 integrated circuit (IC). This IC is a multipurpose three-terminal adjustable voltage regulator that is widely used in power supply and current regulation applications. It was designed to provide a stable adjustable voltage output in the range of 1.25 V to 37 V with 1.5 A current.

One of the useful properties of the LM317 is that it can be operated as a constant current source. Such property makes it highly suitable for safely driving sensitive components such as the laser diode used in this work. The LM317 also maintains a fixed voltage drop of approximately 1.25 V between its output and adjustment terminals. By placing a resistor (R) between these terminals, the output current will be regulated according to Ohm's law:

$$\mathrm{Iout} = \frac{\mathrm{V\,ref}}{\mathrm{R}} \qquad (1)$$

Where Vref is the internal reference voltage of the IC, which is equal to 1.25Vin in this work, and R is the value of the resistor that is used to set the target current. This configuration is particularly useful for laser diodes that are highly sensitive to overcurrent conditions. Even small variations in input voltage can cause large changes in output power if not properly regulated. The LM317 effectively prevents such fluctuations by maintaining a stable output current regardless of supply voltage changes.

A schematic diagram of the circuit is shown in Figure 2. The input of the LM317 is a 12V DC supply that is filtered by a 10 μF capacitor to reduce input noise. A 5 Ω resistor of power rating 2W was used to achieve an output current of approximately 250 mA, which is sufficient to operate the 980 nm butterfly-packaged laser diode across a wide range of optical power. Another advantage of the LM317 provides built-in protection, including thermal overload protection, current limiting, and safe area compensation by protecting both the IC itself and the laser diode from excessive power dissipation or short circuits. The output stage includes a protection diode (SD05) connected in parallel with the laser diode to protect against voltage spikes and accidental reverse polarity. Finally, a DC ammeter and a voltmeter were placed across the laser diode to continuously measure the supplied current and voltage.

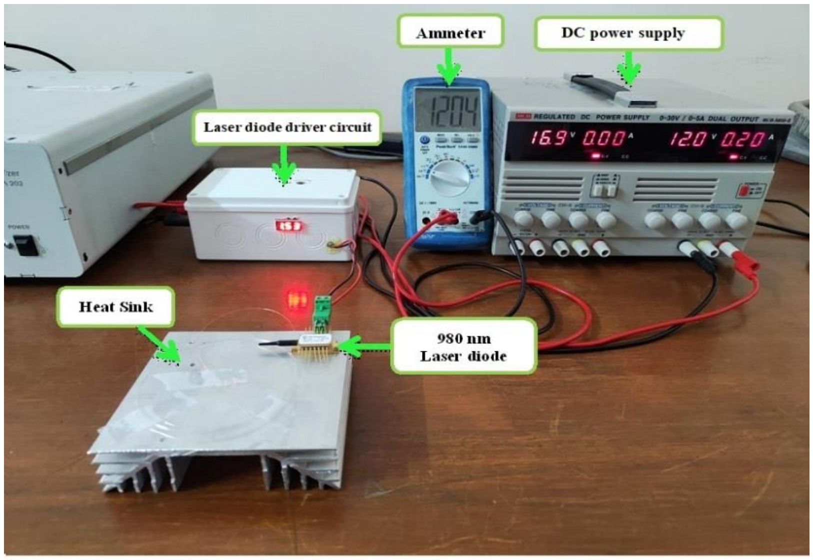


Figure 1: Experimental setup for operating the 980 nm laser diode with current and voltage monitoring.

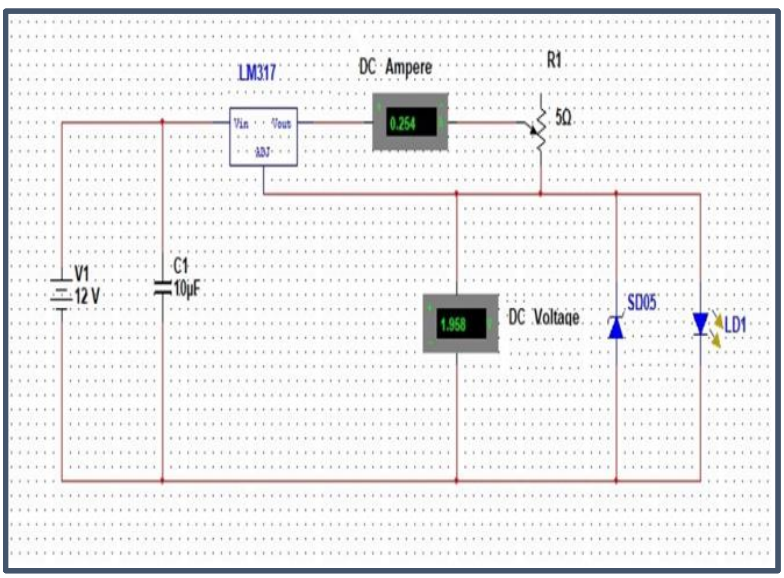


Figure 2: Schematic diagram of the LM317-based constant current laser diode driver circuit.

b. Design and Implementation of Electronically Chopped 980 Laser Diode

In the previous section, the Laser diode is operated and its performance was analyzed in continuous wave mode. In this section, the same laser is operated in pulsed and its performance is also analyzed and various current conditions. A frequency-modulated driver circuit was designed to put the continuous-wave (CW) butterfly laser diode at 980nm into pulse mode operation. The modulation is implemented using an optically

isolated control circuit consisting of a PC817 photocoupler and an IRLZ44 N-channel logic-level MOSFET driver. This configuration enables external digital signals from a function generator or microcontroller to control the laser output while maintaining electrical isolation and protecting the control circuit.
The schematic diagram for the circuit is shown in Figure 3. The design utilizes a photocoupler (PC817) and a logic-level N-channel MOSFET (IRLZ44) to safely drive a laser diode using a pulse signal.

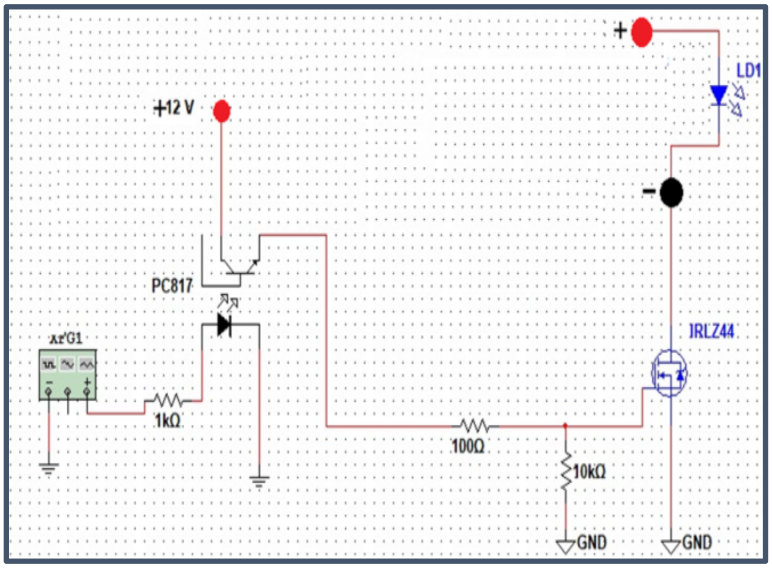


Figure (3): Frequency-modulated driver circuit.

The PC817 is a widely used low-cost photocoupler that provides high isolation voltage between the modulation input and the power stage of the laser driver of a circuit. It contains an internal infrared LED and a phototransistor in a single package. When a control pulse signal from function generator (BK Precision 4075)is applied to the input LED (pins 1 and 2), the emitted light activates the internal Phototransistor and switched it from cutoff to conduction mode, allowing current to pass through the output side across pins 3 and 4. This makes the pulse signal to indirectly control the switching device across the gate of the switching (MOSFET) without direct electrical connection which protects the low-voltage controller from transients and noise.

According to the manufacturer's datasheet, the PC817 exhibits a rise time of 4–10 µs and a fall time of 3–18 µs. These values represent intrinsic device specifications rather than the measured response of the complete system. Therefore, while the PC817 introduces a speed limitation, it ensures circuit protection, and its maximum recommended modulation frequency is typically in the range of 3–10 kHz [17].

The IRLZ44 is a high-speed logic-level N-channel MOSFET which acts as an efficient electronic switch capable of handling high current levels. It can be operated effectively with low gate voltage from 4V to 5V making it compatible with direct driving from logic-level outputs. So, the MOSFET can be activated by the photo coupler allowing the current to flow from the drain to the source to switch the large currents (up to 50 A) through the laser diode.

Based on datasheet specifications, the IRLZ44 exhibits a turn-on delay time of 17 ns, a turn-off delay time of 42 ns, a rise time of 230 ns, and a fall time of 110 ns. These parameters describe the inherent switching capabilities of the MOSFET itself, not the overall driver circuit, and they indicate that the device can theoretically operate at frequencies exceeding 100 kHz, making it suitable for pulse modulation applications [18]. The final circuit is shown in Figure 4. It combines a constant current source based on the LM317 with an optoisolated pulse-controlled MOSFET switch to enable a butterfly-packaged 980 nm laser diode to operate in pulse mode.

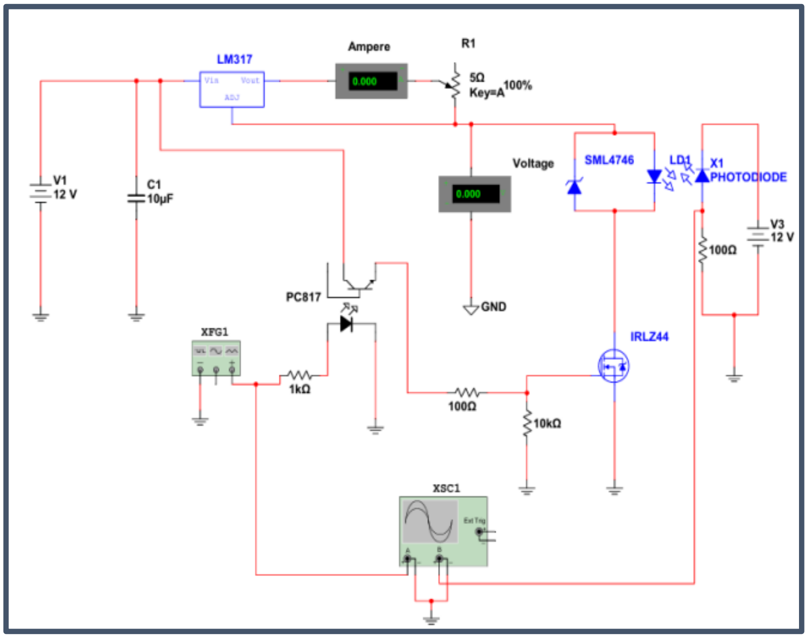


Figure 4: Final driver circuit enabling pulse modulation of a 980 nm butterfly laser diode

3. Result

To characterize the operating performance of the pump laser diode, a series of measurements were carried out to establish the relationship between the applied voltage, the corresponding current, and the resulting optical output power of laser diode. The electrical current was recorded using a digital multimeter (Peak Tech 3340 DMM) while the optical power was measured using an optical power meter (SAT-4E) coupled to the laser diode output through an FC fiber optic connector. The experimental data, summarized in Table 1, show a consistent increase in laser output power with the applied current. It is observed that as the supply voltage is increased from 1.22 V to 2.35 V, the drive current rises from 7.5 mA to 315.8 mA, and the laser output power correspondingly increases from 640 nW to 163.3 mW. This behavior demonstrates the effectiveness of the designed power supply in controlling the laser diode emission across a wide power range, enabling its use in various experimental setups requiring precise optical power control.

The results summarized in Table 1 reveal a direct dependence of the optical output power on the driving current. This relationship is further visualized in Figure 5, showing a nearly linear increase in laser power with increasing current. After stabilizing the output power of the laser diode by properly adjusting the driving current, the device was then operated in pulsed mode at a fixed optical power level without inducing any electrical damage. The response of the laser diode to external modulation was evaluated by applying pulsed signals of varied frequencies through the photocoupler gate. The waveforms were measured using a digital oscilloscope (DS110E). The red traces were taken directly from the function generator output before the input to the photocoupler, while the blue traces were obtained from the photodetector (Thorlabs DET08CFC) connected to the laser diode output that represents the modulated optical signal.

As shown in Figure 6, the blue traces correspond to the pulsed input signals generated by the function generator, while the yellow traces represent the resulting modulated optical output of the laser diode. The observed waveforms at 100 Hz, 500 Hz, and 1 kHz confirm that the circuit successfully reproduces the input modulation pattern with minimal delay and distortion, indicating its suitability for pulse-driven laser applications.

Table 1. Measured voltage, current, and optical power for the 980 nm laser diode.

	Volt (V)	Amp (mA)	Laser power
1	1.22	7.5	640 nW
2	1.27	15.54	3.5 µW
3	1.32	28.77	44.6 µW
4	1.46	47.4	7.47 mW
5	1.56	48	8.1 mW
6	1.65	70	20.78 mW
7	1.8	91.5	36.8 mW
8	1.89	129.3	55.82 mW
9	1.99	171.1	78.5 mW
10	2.06	187	89.43 mW
11	2.11	216.6	106.7 mW
12	2.25	259	130.1 mW
13	2.3	270	137.6 mW
14	2.34	285	146.7 mW
15	2.35	315.8	163.3 mW

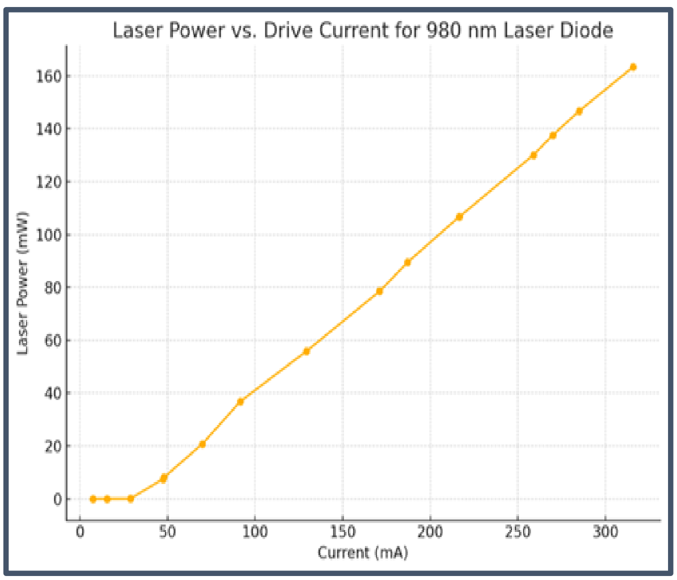
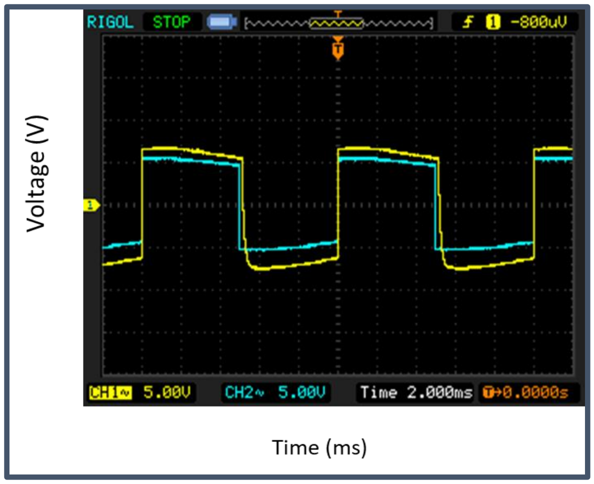


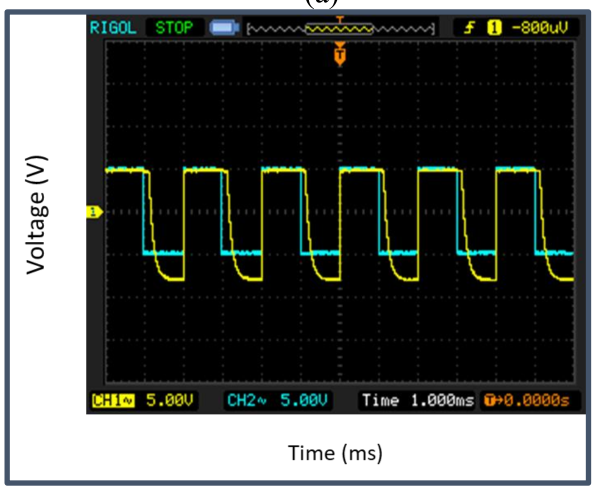
Figure 5: Relationship between drive current and optical output power of the 980 nm laser diode.

4. Conclusion

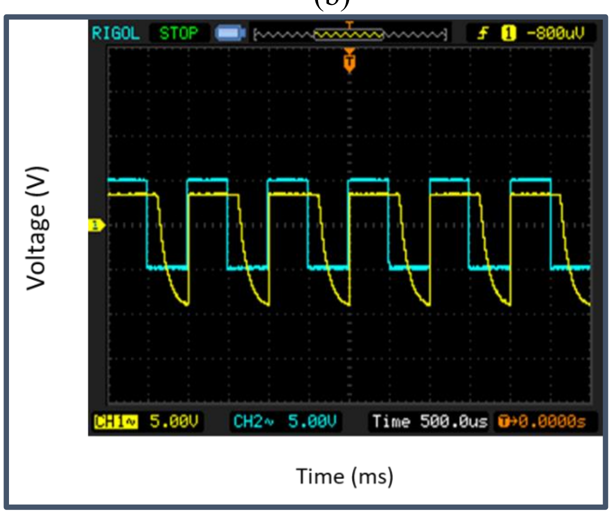
A highly stable electronically chopped 980 nm laser diode driver was implemented in this work, providing adjustable and reliable temporal characteristics suitable for optical modulation up to 1 kHz. The circuit, based on an LM317 current regulator integrated with pulse modulation, demonstrated simplicity, low cost, and effective performance. This developed pulsed laser source offers strong potential for advanced photonic and sensing applications, particularly in tapered fiber interferometer systems. It also presents a practical alternative to electro-optic modulation systems, such as commercial $LiNbO_3$ electro-optic modulators, which are very expensive. The proposed design represents a cost-effective approach for enhancing nonlinear optical modulation, with promising implications in telecommunication and photonic device integration.



(a)



(b)



(c)

Figure 6: Frequency response of the 980 nm laser diode showing input pulses (blue) and optical output (yellow) at different modulation frequencies: (a) 100 Hz, (b) 500 Hz, and (c) 1 kHz that confirm stable reproduction of the modulation signals.

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تصميم وتنفيذ دائرة قيادة لدايود ليزر عالي القدرة بطول موجي 980 نانومتر

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الخلاصة: يُعد دايود الليزر بطول موجي 980 نانومتر من المصادر الواعدة في انظمة الاتصالات الضوئية وكذلك في التطبيقات الفوتونية خصوصا عندما يستخدم في ضخ المضخمات الالياف الشمبعة بالاربيوم(EDFA) والتي تعد من المضخمات المهمة والاساسية في تحسين كفاءة التحويل في الانظمة التي تستوجب كفاءة عالية في التحويلات الاخطية.
أما في التطبيقات الصناعية، فيمكن استخدام دايودات الليزر عالية القدرة ضمن هذا الطول الموجي في عمليات اللحام، والقطع، والنقش، واللحام للمواد المتشابهة أو غير المتشابهة، بشرط أن تكون قادرة على امتصاص هذا الطول الموجي.
في هذا العمل، تم تصنيع دايود ليزر بطول موجي 980 نانومتر نوع (AGREE SL 90S31A) بقدرة قصوى تصل إلى 160 mW. استندت دائرة القيادة هذه إلى منظم الجهد القابل للتعديل LM317. وقد حقق الليزر الثنائي عند 980 نانومتر المُقطع إلكترونيًا تضمينًا مستقرًا في مجال التردد من 1 هرتز إلى 1 كيلوهرتز. وتتميز دائرة القيادة المقترحة ببساطتها وانخفاض تكلفتها، كما أنها توفر بنجاح التضمين البصري المطلوب لتطبيقات تداخل الألياف المخروطة (tapered fiber interferometer)، مما يجعلها بديلًا عمليًا للأنظمة المكلفة للتضمين الكهروضوئي مثل المبدلات الكهروضوئية التجارية المصنوعة من نيوبات الليثيوم ($LiNbO_3$)، والتي تتميز بارتفاع تكلفتها وتتطلب أيضًا وحدات تشغيل باهظة الثمن.