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Electronically Implementation and Detection of Pulse Laser from Continuous Laser Diode

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Abstract: This research aims to design a high-speed laser diode driver and photodetector, the result is the design of the high-speed laser diode driver with a short pulse of 10 ns at 30 KHz frequency and the delivered maximum pulse voltage is 5.5 mV. Also, its optical output power of the laser diode driver is about 2.529 mW for the centroied wavelength 1546.7 nm with FWHM of 286 pm and (1270-1610) nm. The design of the circuit based on bipolar transistor where the input pulse signal is simply generated by an arduino kit with 15 kHz frequency and then compensated to trigger to small signal amplifier which was is simply NPN C3355 transistor and the output is a current driver to the laser diode. OptiSystem software and Electronic Workbench tools were used for the design of high speed laser diode diver and its simulation.

Keywords: Narrow pulse, Laser driver circuit, Pulse laser, Ultra-short pulse

Introduction

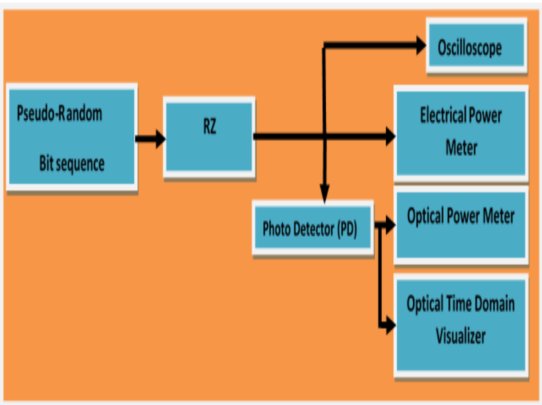
Narrow laser pulses can be used in many advances communication systems for high data rate transmission such as DWDM, Optical OFDM and super channel communication systems [1-6]. The laser diode driver presented in this paper is targeting applications in single-color or multi-color laser projectors used for multimedia, industrial and advertising purposes [7-9]. It is power-efficient, has a small size and can drive almost all commercially available semiconductor laser diodes with their recommended nominal currents by the analog modulation [10-13]. The aim of the study is to design a high-speed laser diode driver and develop specifications for the laser diode driver. After studying the papers that are shown in the references, it has been chosen the most suitable technology for the laser diode driver realization and it has been worked on design of high-speed laser diode driver circuit [14, 15]. A pulsed laser is a system which emits light in the form of optical pulses and that system has a driver circuit to deliver current pulse to laser diode to emit light. A pulsed laser periodically emits pulses of energy in ultra-short time duration [16-19].

The main purpose of this paper is to design and implement a high speed electronic switching driver for continuous laser diode and driver circuit for photodetector. After studying the operation parameters of the laser diode and the photodiode, it has been chosen the most suitable technology for them and it has been worked on design of that. Then it has been worked on improving the design performance to deliver shorter pulse width and also to meet the desired laser diode driver requirements and photodiode driver circuit. Therefore, the high-speed laser diode driver designed to drive a laser diode MLD-C55D2-1A05P2 [20] that has been used in NKT photonics and QP906 photodiode.

SIMULATION SETUPS

Simulation Setup of the Source Chopping Circuit

The electronic chopping circuit had been designed by optisystem and electronic workbench software as shown in figure 1(a&b) respectively. The pulsed laser diode driver has been designed to drive the laser diode MLD-C55D2-1A05P2. Therefore, it has to get modeling of that laser diode to use it at the design of the pulsed laser diode driver and then it can be see the characteristics of the output pulse from the laser diode. This design is done by extracting the optical and electrical characteristics of the laser diode from its datasheet shown in table 1 and then these parameters were inserted in the simulated design.



(a)

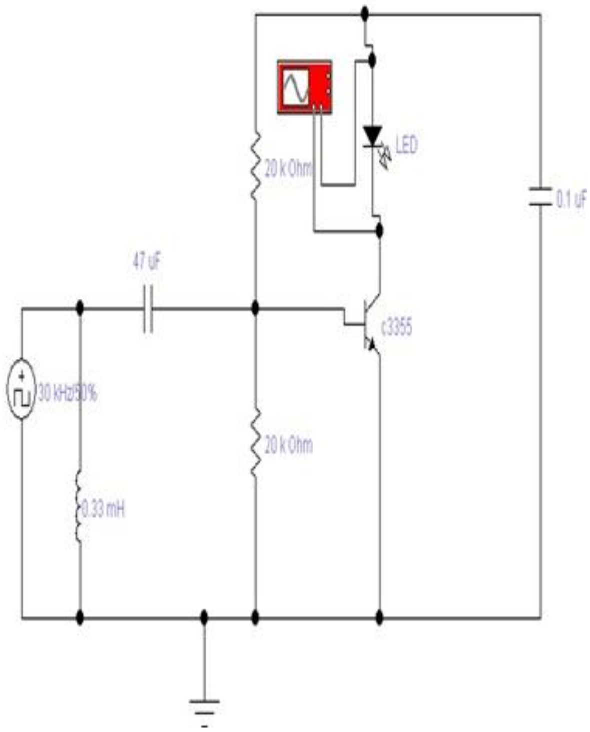


Fig.(1) :(a) Schimatic diagram of the simulation work by optisystem, (b) Simulation layout by electronic workbench.

Table (1): depicts the optical and electrical characteristics of the MLD-C55D2-1A05P2 laser diode of the chopping circuit.

Parameter	Symbol	Minimum	Typical	Maximum	Unit	Test condition
Rated Power	P_o	1	-	3	mW	Ith+20mA
Threshold Current	I_{th}	5	-	15	mA	CW
Forward Voltage Drop	V_{op}	-	1	1.2	V	-
Cent. Wavelength	λ_c	1546.7	-	-	nm	-
Cut-off Frequency	Fc	-	-	6	GHz	$If=I_{op}$

Simulation Setup of Photodetector.

The photodetector circuit was simulated by the electronic workbench software because it can gather the electronic internal components of the detector. On the contrary of optisystem software which equip compact photodetector block that can gives results directly without design. Figure 2 presents the layout of the workbench simulation design.

As seen in the figure 2, the diode is reverse biased blocking current to flow through the resistor unless there is light detected. When light is detected current flows to the resistor leaving a potential drop across both diode and resistor dividing the voltage across the branch proportional to amount of light detected.

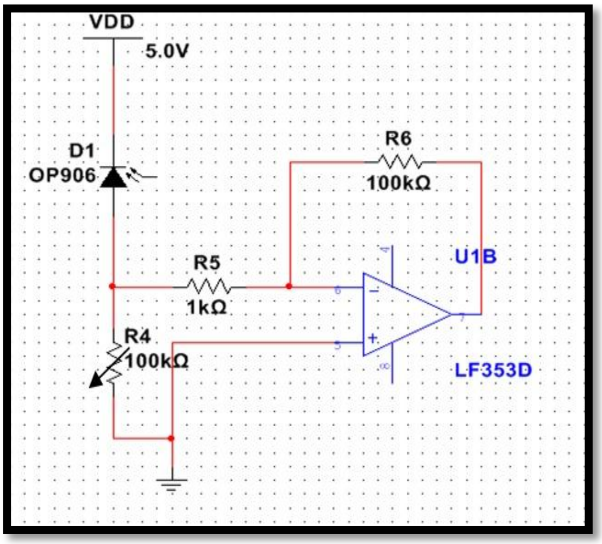
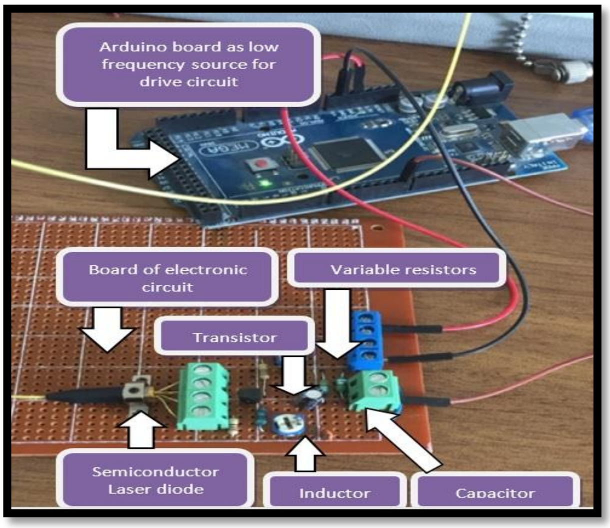


Figure 2 the photodetector simulation by electronic workbench.



(a)

(b)

Figure 3 (a-b) shows an image of the experimental setup.

EXPERIMENTAL SETUPS

Experimental Setup of the Chopping Circuit

In the practical design, a lot of parameters should be taken such as interference, especially when we handling with high radio frequency (RF) signals, each pin of welding on the board and each piece of wire can be regarded as an antenna to transmit and interfere with other signals, the probe that used in the experimental setup was designed for high frequencies, voltage source that used to feed power to the circuit should be constant to avoid fluctuation in the output optical signal, thus personal computer and arduino type mega was used as a power source to deliver constant voltage pulse signal.

Experimental Setup of the Photodetector

Every optical system should have a receiver that converts optical signals to electrical signals to restore the data sent through the system. The basic element of receivers is the optical detector. The detector is simply a photodiode operating in a specific range with a specific responsivity. The detector must be connected in reverse bias with a resistor in series; it operates in a voltage divider configuration. A differential amplifier or a comparator is connected across the photo detector or across the resistor. In both cases, the voltage is divided across the branch resistor diode ranging from no current flow, i.e., zero voltage difference across the resistor or max voltage across the diode to divide the voltage making the photodiode like a variable resistor that changes its value according to the light detected. Figure 4 shows detector circuit with metallic cover connected by faraday cage to the negative pole of the detector circuit to avoied interference from laser source circuit and other sources.

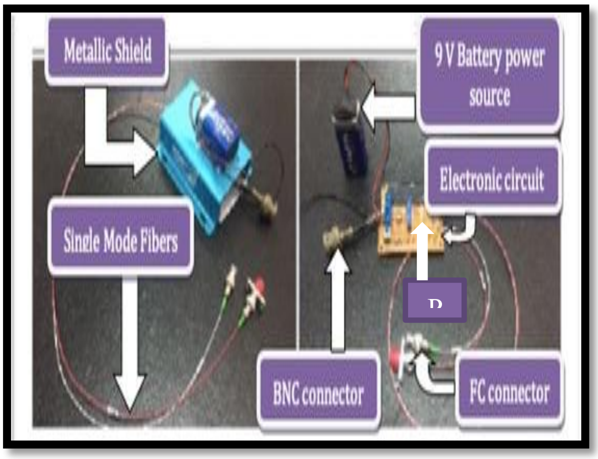


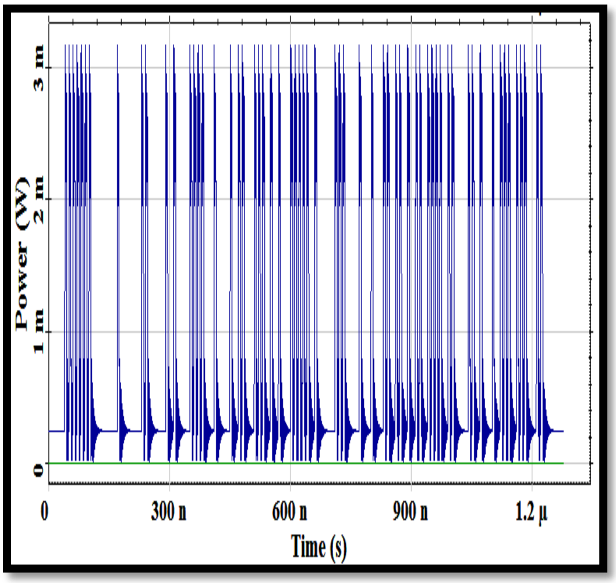
Fig. (4): Experimental setup of the photodetector circuit.

Results

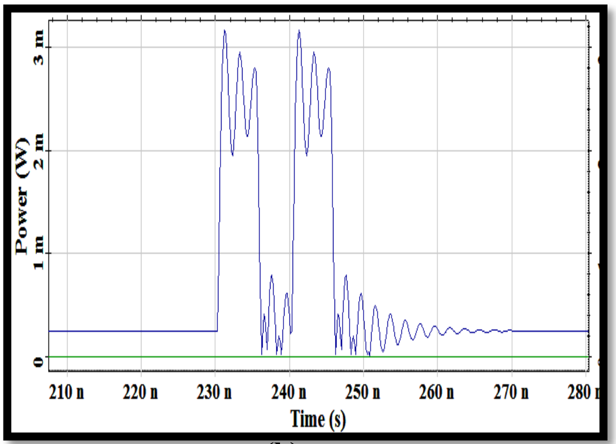
Results concerned with chopping circuit for the CW laser source.

A Simulation result of the source chopping circuit in time and frequency domains.

When the optisystem software was used to simulate the chopping circuit, the output optical signal by the CW laser diode was graphed by Optical spectrum analyzer in frequency domain as illustrated in figure 5 (a-b)



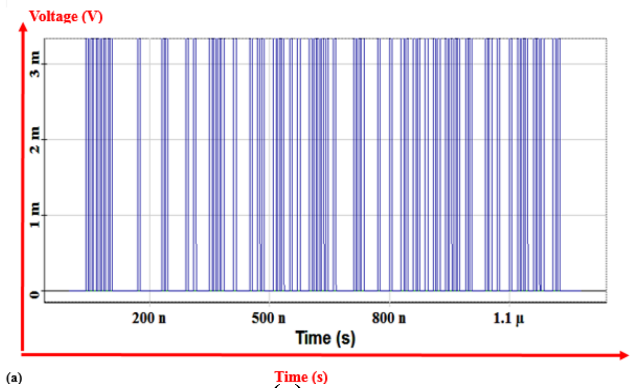
(a)



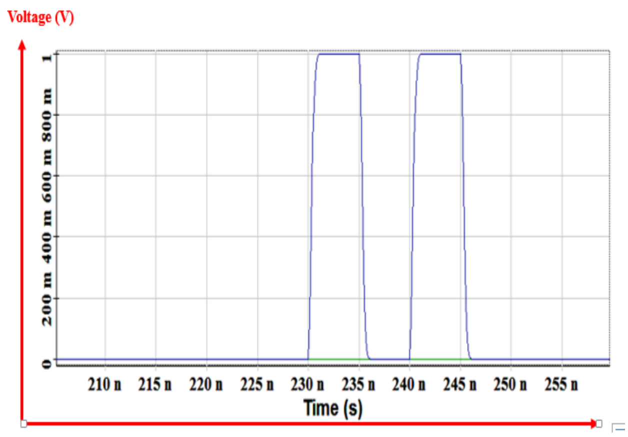
(b)

Fig. 5: (a) Result of the optisystem simulation for train of optical pulses, (b) Same signal but pulse was magnified well to emerge the pulse duration.

And when the electronic workbench software was used in simulation work, the result in time domain becomes very clear after drawn by oscilloscope trace as shown in figure 6 (a-b).



(a)

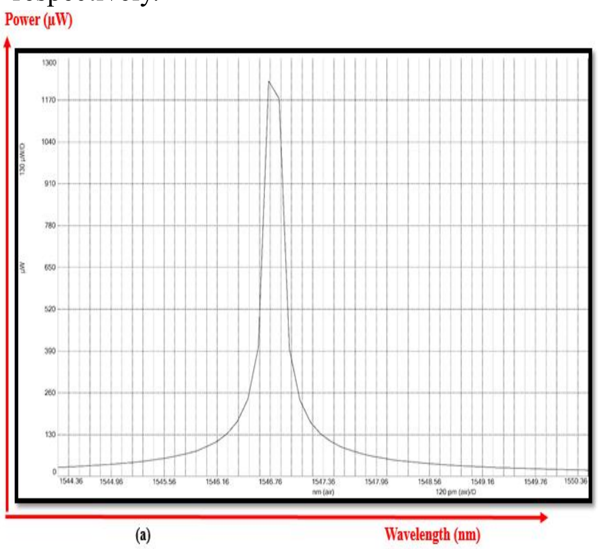


(b)

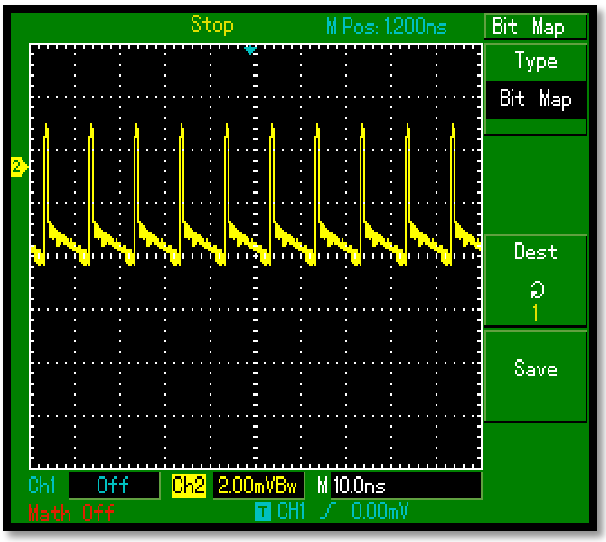
Fig. (6): (a) result of the electronic workbench simulation for train of electrical pulses, (b) same signal but magnified well to emerge its duration.

Experimental result of the source chopping circuit and designed photodetector

In this subsection of result, we used optical spectrum analyzer manufactured by Thorlab as a visualizer to display the experimental results in frequency domain and designed photodetector with digital storage oscilloscope as a visualizer in time domain as depicted in figure 7 (a-b) respectively.



(a)



(b)

Fig.(7): (a) experimental result in frequency domain by OSA visualizer, (b) experimental result in time domain by designed photodetector and digital storage oscilloscope visualizer.

From the characteristics of the laser diode, it can be seen that the laser diode turns ON when the voltage drop exceeds 1V and the forward current exceeds 15 mA. Then the laser diode start to emit optical power and increases linearly with current .
At static operating point , the NPN transistor is cut-off, and then its collector is biased to Vdc= 5 V. The transistor is cut-off as its base -emitter junction is not polarized, then its collector biased to ground to forms a buffer with a common collector amplifier configuration and it turns LD off state.
The NPN C3355 transistor work as a small signal amplifier, the pulse width of the source is compensated by the inductor L2 and forward it to the C1 and R2 cell to forms a high pass filter with a frequency cut off = 1/(2*pi*C1*R2),

The characteristics of the resultant optical signal of this work had been calculated using mathematical equations listed bellow (1 , 2 , 3); these characteristics are listed bellow in table 2.

Power = energy/ time ………………………...1

Duty Cycle = (Ton / Ton + Toff) x100% ……..…….2,
where T is the pulse duration

Pulse Repetition Rate = 1 / Pulse period ………..3

Table (2) The optical and electrical characteristics of the resultant optical signal.

Parameter	Result
Centered wavelength (λ)	1546.7 nm
P_{peak}	1250 μW at 1546.7 nm
Energy	0.0123 nJ
Duty cycle	90%
FWHM (time domain)	10 ns
FWHM (frequency domain)	286.292 pm
Pulse Repetition Rate	100 MHz

Conclusion

1- The design of electronic chopping circuit to change the output of CW laser diode to train of pulses is too important in many applications concerned in laser matter interaction specially biological one, and this design prove that this circuit can be implemented in real time by simply, cheap and available electronic components such as NPN C3355 transistor that acts as a small signal amplifier.

2- The value of the coil inductance used in circuit 0.33) mH is very important to be fixed, because after try and error several experiments it's found that this value affect the electrical pulse duration that interred to the C3355 transistor and leads to broadening in optical pulse duration, when coil inductance decrease the frequency of the electrical signal will increase and visa-versa but not less than 0.33mH because C3355 transistor is limited by charge storage time.

3- The (20) k Ohms resistor in the chopping cct. Are used for transistor voltage biasing, and they control the amplitude of the electrical output signal, which means they control operation of the laser diode, because when LD supplied by a voltage below the designed threshold voltage (1) v, then the lasing process will be terminated.

4- In fig. 5(b) and fig. 7 (b) it can be seen that there is a little fluctuation in the end of the optical pulse, and this is obviously occurs duo to a large designed transition time of the C3355 transistor and this fluctuation comes from remaining charge in the base-emitter junction of it.

5- It can be seen that there was a little difference between the output of the simulation signals and the output of the experimental result, and this happened because of working and environmental conditions for instance the output signal power in simulation was few larger than that gathered in experimental work and that occurred because coupling and transmission losses are not taking in to account, interference with visible light is also can degrade the measuring instruments accuracy, moreover the most important factor in such application is the temperature as an environmental factor which plays very important rule n semiconductor equipments, as the temperature change out of the designed threshold as the central wavelength of the LD shifted duo to generating uncontrolled charges in the semiconductors junctions whether LD or transistor.

6- To allow the detector to detect for wide range of different intensities of the incident light, a variable resistor was used in the detection side of the setup.

7- The optical output spectrum of the LD in fig. 7(a) seemed to be deformed in the Summit, this because the limited resolution capability of the available optical spectrum analyzer which supplied by Thorlab (OSA: 202).

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تنفيذ والكشف عن الليزر النبضي من الليزر الدايودي المستمر

علي احمد داود   تحرير صفاء منصور   ليث محمد

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الخلاصة: يهدف هذا البحث إلى تصميم محرك ديود ليزر عالي السرعة وكاشف ضوئي ، والنتيجة هي تصميم برنامج تشغيل الصمام الثنائي ليزر عالي السرعة مع عرض نبض قصير من ١٠ نانوثانية بتردد ٣٠ كيلو هرتز والحد الأقصى لجهد النبض الذي تم تسليمه هو ٥.٥ م.فولت أيضًا ، تبلغ طاقة الخرج البصرية لبرنامج تشغيل الصمام الثنائي بالليزر حوالي ٢.٥٢٩ ملي واط لطول الموجة المتمركز ١٥٤٦.٧ نانومتر مع عرض نبضة (FWHM) يبلغ ٢٨٦ بيكو متر ويعمل بمنطقة الطول الموجي (١٢٧٠- ١٦١٠) نانومتر. تصميم الدائرة القائمة على الترانزستور ثنائي القطب حيث يتم إنشاء إشارة نبض الإدخال ببساطة عن طريق مجموعة اردوينو مع تردد ١٥ كيلو هرتز ومن ثم استخدامها لتشغيل مكبر الاشارة الذي يستخدم في تكبير الاشارات المنخفضة والتي كانت ببساطة الترانزستور NPN C3355 ومن ثم الاشارة الخارجة المحرك الحالي ل ليزر ديود. تم استخدام برامج المحاكات OptiSystem وأدوات وبرنامج Workbench الإلكترونية لتصميم دارة الكترونية عالية السرعة لتشغيل ديود ليزر والكاشف الخاص به ومحاكاتهما.