A DC - 5 MHz 100 A Laser Diode Driver

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Abstract

A new high power laser diode driver has been developed and tested. The possibilities for driving high power laser diode bars and stacks at high frequencies has been shown. The driver is with 0.05% noise and ripples at DC , and can be modulated with 15 ns rise / fall times at 100 A , with maximum frequency for square wave modulation up to 5 MHz. The spikes for the optical output at switching on / off are not exceeding 5 % . The limitation of the used scheme with the existing commercial components allows frequencies up to 25 MHz and currents to 400 A to be reached.

The driver opens new applications for high rate data transmission at long range, fast scanning designators, materials processing, etc. with laser diodes with more than 100 W output power, which will be discussed.

Key words : Laser Diodes, Power Supplies

1. Introduction

Most of the power supplies for driving laser diodes on the market are designed, following the traditional design : low voltage power supply with current limiting circuit / 1 / . The output of the power supply is a voltage one with current limitation . The feedback is taken as a voltage drop over a shunt component, and thus it became a regulated current source. In order to achieve low ripples and noise, a capacitor is used as an output filter component. This design works well under CW operation, with very slow “start / stop “, but it can not be switched faster than the recharging time of the output filter circuit, which is in the order of several kHz. The option for faster switching and short pulses duration is to place a very high capacitance as energy source, and a series switch, mostly with high power FET MOS , IGBT transistors , fast thyristors. This design can not work with high repetition frequencies (several hundreds kHz) , but still satisfy the needs for pulsing the laser diode bars and stacks with low duty cycle - 2 – 5 % . The main problem is the inductance of connecting wires which induces current spikes and reverse voltages over the laser diode during switching off. This may lead to failure of the expensive laser diode.

Integrated Optical Devices, Nanostructures, and Displays,
edited by Keith L. Lewis, Proceedings of SPIE Vol. 5618
(SPIE, Bellingham, WA, 2004) · 0277-786X/04/$15 · doi: 10.1117/12.578425

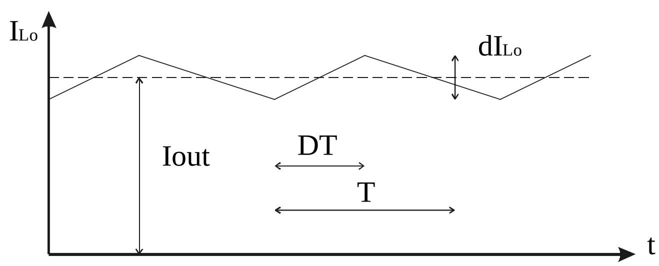
2. Circuit description

A new idea for obtaining high switching frequencies of the high power laser diodes, has been utilized and tested. The scheme allows optical pulses with rise / fall times in order of several ns and switching frequencies DC - 10 MHz and higher to be obtained. The idea is based on a power supply, which has to be a true current source and a special switch, located close to the laser diode. The big difference between a true current source and a voltage source with current limitation is the output filter. In case when a voltage source is used, the output filter is a capacitor, while in the case when a current source is used , the filter is an inductor. Working at high switching frequencies of the inverter (normally more than 150 KHz) the inductance may be very low.

The idea for designing a pulse width regulated current source is based on the theoretical dependence that the change of the current through an inductance is an integral function from the applied voltage.

The current through the inductance, as shown in Fig.1 is with direct component Iout and alternative component dILO determined from :

$$dI_{Lo} = \frac{U_L.DT}{L_O}$$



If U_L is the difference between the Uconst and the voltage over the load, then the value of the output current may be regulated by changing the fill factor DT, whether by frequency or by pulse width. This leads to the possibility of fine regulation of the output current by changing the differential increase of Iout for every sequent pulse.

For pulse width regulator " Half Bridge " the rectified output current from the secondary coil of the transformer repeats the primary current through the pulse DT with mistake from the magnetizing transformer current Iu as it is shown in Fig.1 This enables the output current regulation to be carried by changing the momentary value of primary current. To increase the regulation range of the PWM regulator, the summed voltage over the capacitors C2 and C3 is kept constant. This is done through a PFC regulator designed by L1 , Q1 , D1 and the capacitors C2 and C3 from the " Half Bridge " circuit. This improves the power factor value and gives the possibility to work with wider range of input voltages.

The circuit of the PWM current regulator is shown on Fig.1 . To decrease the dependence of the slew rate of the output current dI_{Lo} on the regulation characteristics of the PWM regulator two additional feed backs through the inductance Lo and for the output voltage are included. They follow by " prediction " the value of the output current and regulate the DT of the regulator for every next duty cycle.

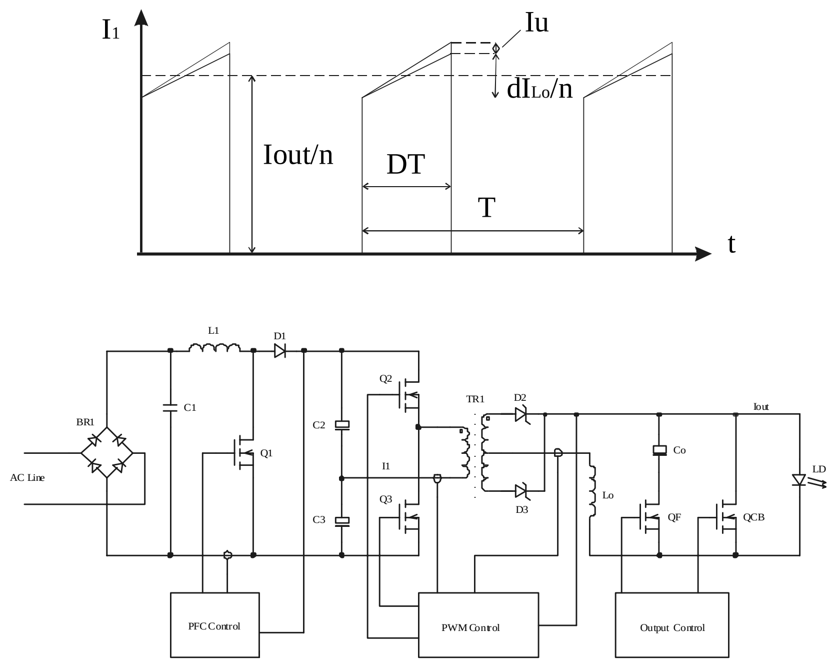


Fig. 1 Current controller

The module " PWM control " follows the value of the output voltage, the current through the inductance Lo through the non regulated cycle (1 - DT) . The width of the pulse inside DT is kept that , the momentary value of the primary current for the time DT / 2 to be constant. This is satisfied for both states on / off of the transistor QCB . Simultaneously the information of the output voltage enables to correct the mistake from the transformer TR1 magnetizing current, which proportional to the output voltage.

The low value of the filter inductance determines the stored energy in the output stage of the inverter. For 50 A CW laser diode current, and inductance of 10 mH the energy is 12.5 mJ. In most of the cases this energy can not destroy the laser diode for a single pulse. The concept also allows the inductance of the connecting wires between the power supply and the laser diode to be included in the total inductance of the output filter. Of course, when the modulation switch is located inside the power supply, the maximum frequency (rise / fall times) will be determined by the inductance of connecting wires, and can not exceed several hundreds KHz , when stripes are used. But when the switch, is located very close to the laser diode, then the limiting factor is the internal inductance and construction of the laser diode. The switch is a combination of parallel and series switching elements / 2 , 3 / and do not contain inductance or capacitance – only active components. It means that its dimensions are very small and the switch may be located inside the protective box of the laser diode chip Fig.2. The parallel and series switching elements are synchronized with appropriate delay between them. Thus, the current from the power supply is not interrupted, during switching on and off , and is regulated independently. Additionally, the voltage drop over the parallel switch may be chosen equal to the voltage drop over the laser diode. There are no spikes in current and reverse voltage over the diode during the transient times because there is no energy storage component. The switch can work only with current source – a source delivering constant output current, independently of the voltage drop at the output stage. Normally, from engineering point of view, we define that the maximum allowed output voltage should be at least 10 times than the expected voltage drop over the load at the maximum output current. In the case for a laser diode bar the voltage drop is 1.85 – 1.95 V at 20 – 60 A . If we accept the ideal case then for a 120 W consuming device , we have to develop a 1200 W power supply. That is why normally a compromise is done and the power supply turns to be a " power source ".

The scheme allows, according the commercial components parameters, switching currents in the order of 200 A and higher, voltages over the laser diode stacks to 400 V , rise / fall times in the order of 5 ns and switching frequency for square wave pulses DC – 30 MHz. The limitations for higher frequencies come from the delay times of the switching elements the phase delay of the circuit and the internal
(constructive) inductance of the laser diode.

3. Performance of the driver

A cheap version of the scheme (low cost and commercial switching elements) has been tested with a 40 A fiber coupled laser bar Fig.2. This diode was chosen because of the excellent non inductive coupling , very good thermal coupling, ease of operation and enough space for the switch inside. At the experimental, the control for the switch is directly through 50 ohm cable, but may be located on the back side of the laser diode cover on a small connector. The current source was LDCS – 100 DC. This is a current source delivering 100 A DC max, with 3 V maximum output voltage and galvanically isolated outputs. The noise and ripples are lower than 0.5 % at maximum DC current . On Fig. 3 a, b ,c the optical pulses at 40 A are shown. It is seen the rise / fall times for 200 ns pulse duration. For this switch version the rise / fall times are 18 ns / 25 ns . It is seen also that the spikes are not exceeding 5 % . The reverse pulse (interrupting the laser emission) with current – 35 A , is shown. For 200 ns the laser diode is stopped . On the next photo the square wave 1 MHz optical pulses are also shown. This version allows max. 5 MHz switching frequency for square wave optical pulses at maximum currents 96 A . The laser diode was not driven with over currents, besides that this is possible for low duty cycles . The switch is a DC one, i.e. when there is no driving TTL / CMOS pulse, the laser diode runs at CW mode. This opens the possibility to leave the laser diode to run at 100 A DC,

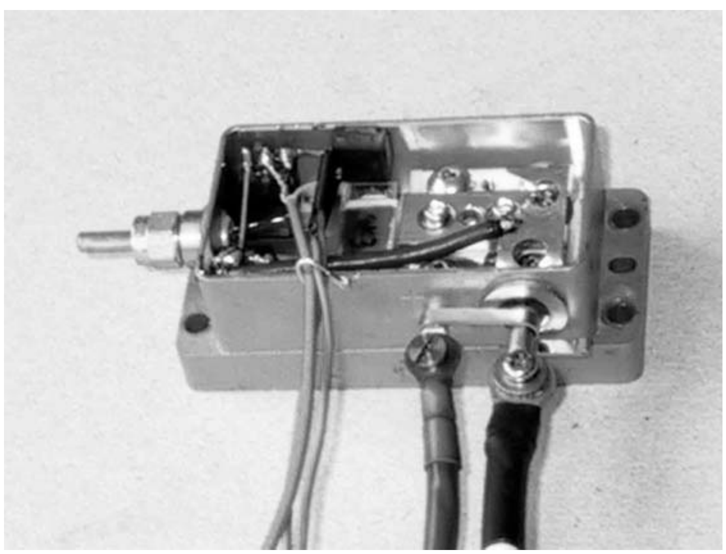


Fig.2 Laser Diode with switch inside

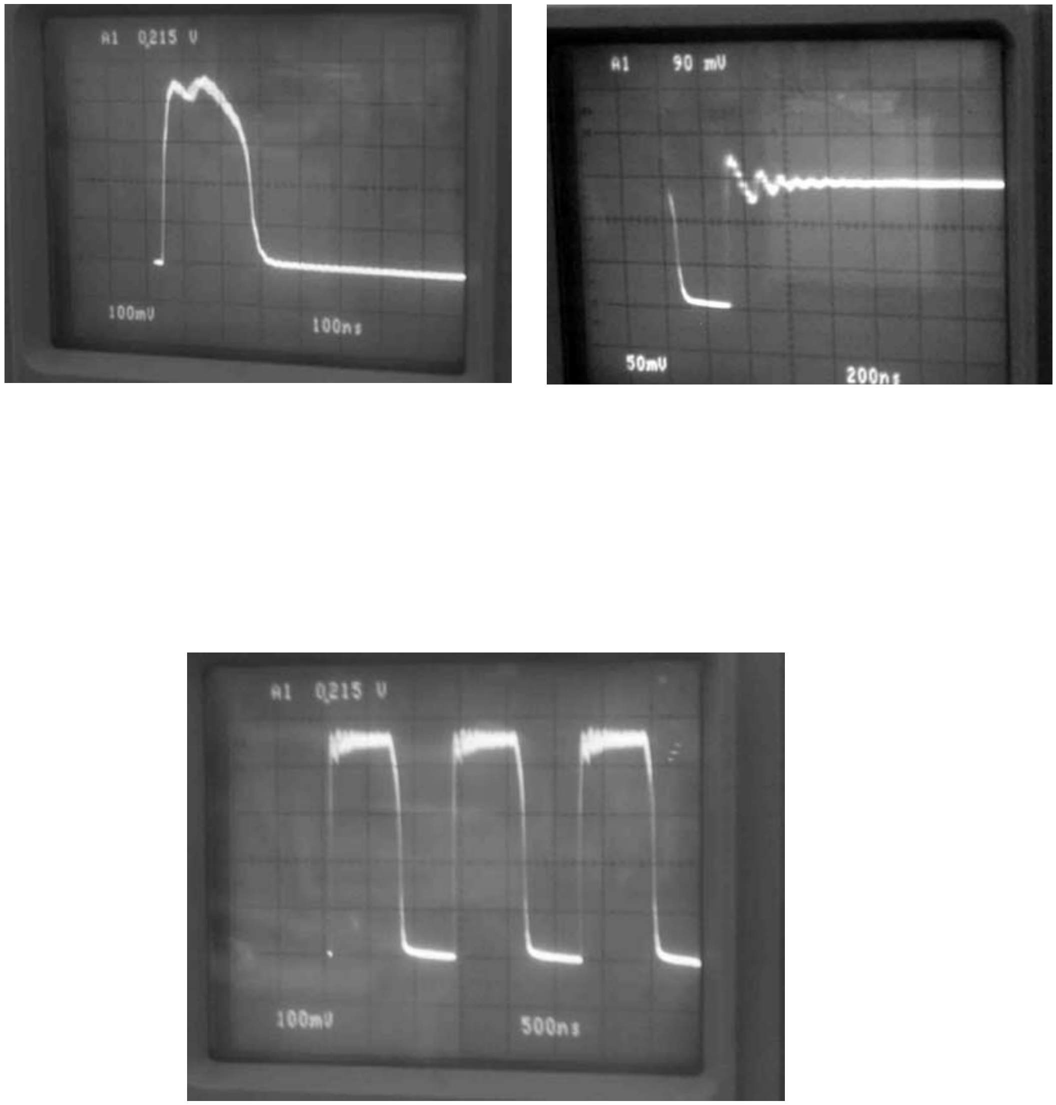


Fig.3 a , b , c. Waveforms of the optical output which is beyond the diode parameters, and we put a current limit of 40 A. The power supply has been tested with a different load at maximum output of the current source. The parameters of the load (combination of fast Shottky diodes and capacitors) were chosen and tested under a SPICE simulation scheme. The simulation under 40 A show the same behavior as the laser diode in real situation. The switching parameters remain the same at 96 A current though the Shottky diodes.

4. Conclusions

This example shows the possibility to drive high power (more than 100 W CW) laser diodes at high switching frequencies. This output power means hundreds km free space communication at 20 Mbit/s , possibility for a 3D range finder with 15 km distance (without retro prism) and 0.3 cm distance accuracy , new possibilities for micro machining , synchro pumping solid state lasers or other semiconductor lasers and etc. On Fig.4 the military version of the current source , without hermetic housing is shown. The dimensions are seen according the standard D-25 connector for direct PC control.

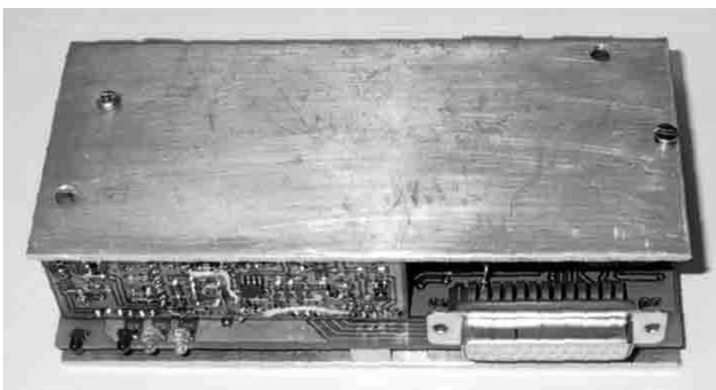


Fig. 4 . Diode driver. Military version without hermetic housing 24 V / 48 V input

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