

PURPOSE

This technical note discusses the effects of inductance when pulsing high power laser diodes with high current. It also discusses cabling and connections between the current source and laser and the effects of cable loop area and increased resistance due to improperly sized conductors and poor connections.

BACKGROUND

An electric current flowing in a circuit produces a magnetic field and hence a magnetic flux throughout the circuit. The ratio of the magnetic flux to the current is called the **inductance**. The voltage developed across an inductance L (in Henries), when the current is changing at a rate given by dI_{Load}/dt (in A/s) is:

$$V = L di / dt$$

The inductance of a circular conductive loop made of a circular conductor can be determined using:

$$L = r\mu_0(\ln(8r/a) - 2 + Y)$$

Where:

μ_0 and μ_r are the permeability of free space and wire respectively
 r is the radius of the loop
 a is the radius of the conductor
 Y is a constant. $Y=0$ when the current flows in the surface of the wire (skin effect), $Y=1/4$ when the current is homogeneous across the wire.

From these equations, it is easy to see that inductance, L , induces a voltage with changing current and is directly proportional to the radius, r , of the conductor loop.

The effect of inductance on a current source is that it resists changes in current, which causes the current source to increase the output voltage resulting in overshoot and ringing as the pulse settles. If there is large inductance in the system, then potentially laser damaging current overshoot will result.

Accounting for the voltage due to inductance is critical in system design as it will, along with cable and connection resistance, determine the compliance voltage needs of the laser driver. When a cable is incorrectly connected (has a loose connection) or has too much resistance due to small gauge wire or small contact area, the compliance voltage of the system can increase beyond the voltage capacity of the current source. For example, when pulsing 220 amps of current, a change in resistance of 100 milliohms (0.100 Ω) due to a poor connection, will cause a voltage drop across that resistance of 22 volts. If unaccounted for in the system, this condition most likely will cause an error in the current source.

The equation for the voltage drop across a resistance by Ohm's Law is:

$$V = IR$$

Where :

V is the voltage drop across the resistor
 I is the current flow through the resistor
 R is the resistance in ohms

Stranded wire cable typically has a resistance specification in ohms per foot of cable. This resistance can be calculated or measured with an appropriate ohm meter.

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Effects of Cabling and Inductance When Pulsing High Power Laser Diodes

ILX offers a low inductance flat copper cable, CC-390, for use with the LDX-36000 Series drivers for connection to a laser diode for optimal pulse performance with low inductance and resistance to minimize voltage drop across the cable. Preferred termination to the laser diode means the laser diode terminals be connected directly to the + and – cable ends of the cable; while this is the best termination method, it is not always feasible or even possible to connect the laser to the cable in this fashion. An equivalent circuit is shown in Figure 1.

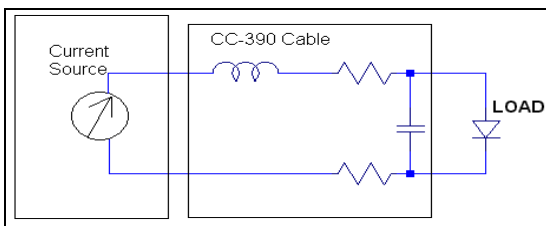


Figure 1. CC-390 Equivalent Circuit

When additional cabling is required for connection and added to the CC-390, additional inductance, resistance, and capacitance must be accounted for in the system. The equivalent circuit for this system is shown in Figure 2.

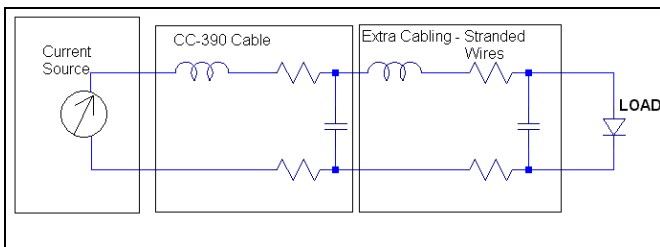


Figure 2. CC-390 and Extra Cabling Equivalent Circuit.

ILX LDX-36000 Series instruments offer some protection against current overshoot due to high inductance and impedance and notify users

through error reporting. In either of these conditions, a high impedance error (E503) or power supply voltage limit error (E528) will be reported.

MEASUREMENT SETUP

A 0.1Ω resistive load was connected to an LDX-36125-24 current driver through an ILX CC-390 flat copper cable and a custom made printed circuit board. The LDX-36125-24 is capable of pulsing up to 220 amps at 24 volts. The flat copper cable provides a low inductance and low resistance current path to and from the test load. The instrument was set to pulse mode, with a current amplitude of 220 amps. The voltage limit was set to 27 volts.

The voltage drop across the 0.1Ω load was measured using a Tektronix TDS400 oscilloscope.

With this set-up the instrument output was enabled, the low inductance cabling pulsed waveform had sharp edges and no overshoot or ringing as shown in Figure 3.

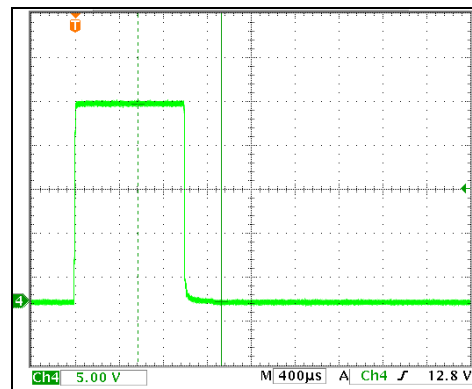


Figure 3. 220A Pulsed Waveform Using CC-390 Connected Directly to Load Resistance

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To see the effects of adding inductance, two 12 inch 8 AWG wires were added to the end of the CC-390 cable, and connected directly to the resistive test load and formed with a 4 inch radius. The output of the LDX36125-24 was enabled pulsing the resistive load at 220 amps. An instrument error occurred indicating the load voltage exceeded the power supply voltage limit (the load voltage exceeded the compliance voltage capacity of the instrument).

The current set-point was adjusted down to 190 amps to keep load voltage under the capacity of the power supply. Also, with the additional cabling added to the flat copper cable, overshoot was observed in the pulse waveform. Figure 4 shows the overshoot with the system configured with 12 inches of additional 8 AWG wire and a 4 inch loop radius.

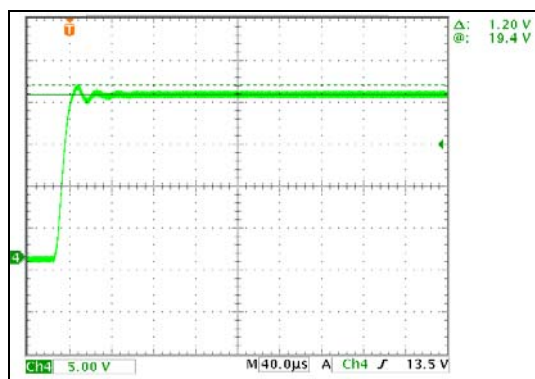


Figure 4. 190A Pulsed Waveform with Added Cabling: 4 Inch Radius

It should be noted that the current overshoot with a 4 inch radius is equivalent to 12 amps over the 190 amp set-point current. The inductance resists the instantaneous current change, forcing the current source to increase the voltage dramatically. When current is finally allowed to pass through the inductor (added cabling), the actual current is greater than the pulsed setpoint by 12 amps. The

instrument will correct the current setpoint causing ripple due to the inductors resistance to changes in current. As the radius of the inductive loop decreases (r from the inductance equation), the current overshoot should decrease. To verify this, the loop radius was decreased from four inches to one inch in one inch steps. With a radius of 1 inch, the inductance created overshoot was 6 amps which is half than with a radius of 4 inches.

As a final test, the wires were twisted together to minimize the effect of radius from the inductance equation. The set-point remained at 190 amps and with the output enabled, it can be seen in Figure 5 there is almost no overshoot with the conductors twisted.

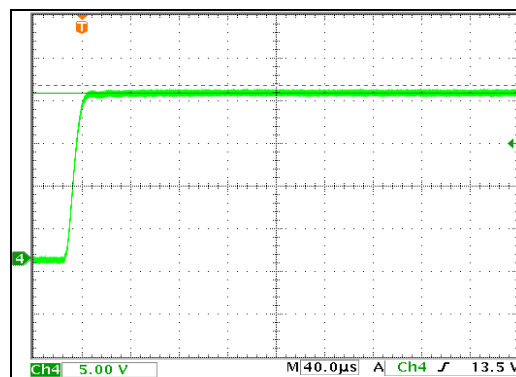


Figure 5. 190A Pulsed Waveform with Added Cabling: Twisted.

CONCLUSIONS

Inductance has a limiting and potentially damaging affect when pulsing high power laser diodes with high current through cabling to the diode. High inductance will lead to increased voltage needs and potentially current overshoot. In pulsed current testing, high power current sources should be used with a low inductance, low resistance cable such as the ILX CC-390 to reduce the compliance voltage needs and overshoot at the

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device under test. When using the CC-390, if extra cabling is required, limit the amount of cable to less than 12 inches. To minimize the inductance from the additional cable, minimize the loop area of the conductors by twisting them together from the end of the CC-390 to as close the device under test as possible.

If proper care has been taken to reduce cabling inductance and an instrument error still occurs, the issue could likely be that the current set point requires more voltage than what the instrument can provide. In this situation, reduce the amount of resistance added from cabling and connections by increasing the size/gauge of the cable and maximize the contact area at any connection points. Make sure connections are tight. If no extra cabling is used or this does not fix the issue, ensure that the compliance voltage of the load does not exceed the compliance voltage of the instrument.