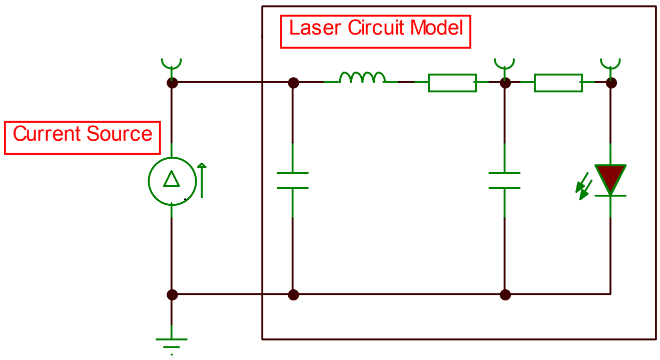
Choice of Compliance Voltage in Current Sources

Artifex Engineering

In circuit theory, an ideal current source is a circuit element where the current through it is independent of the voltage across it. It is a mathematical model, which real devices can only approach in performance. The voltage across an ideal current source is completely determined by the circuit it is connected to. When connected to a load resistance, the voltage across the source adapts such that the current flow is that set by the source. No real current source is ideal and all have a finite internal resistance (none can supply unlimited voltage). This limiting voltage is referred to as the compliance voltage of the current source.[1]

When dealing with high current, high speed current sources, it is important to realize that it is not sufficient to choose the compliance voltage of the source to match the voltage drop of the laser load alone. Consider the following model of a typical laser diode. Not only does this model involve an ideal diode with its inherent voltage drop. In addition to this, the laser diode shows some capacitance, resistance and inductivity. In fact, in a real situation, the inductivity of the connection between the current source and the laser load will usually turn out to be the limiting factor.



Consider the fact that a high speed current source results in a fast transient of the current to the load. Now if the load involves some inductivity in series, then the voltage drop across the inductive element will be given by

$$V_{Ind} = L\frac{dI}{dt}$$

When using the LDD100-F120 fast current source from Artifex Engineering with 100A pulses and 50ns rise time, this will result in a voltage across a 4nH inductivity of approximately

$$V_{Ind} = 4nH\frac{120A}{50ns} = 9.6V \approx 10V\ .$$

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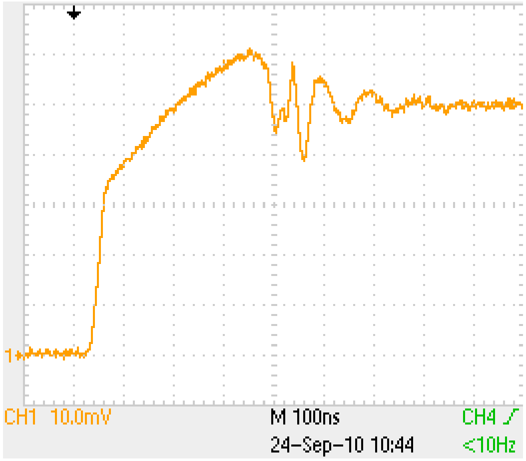
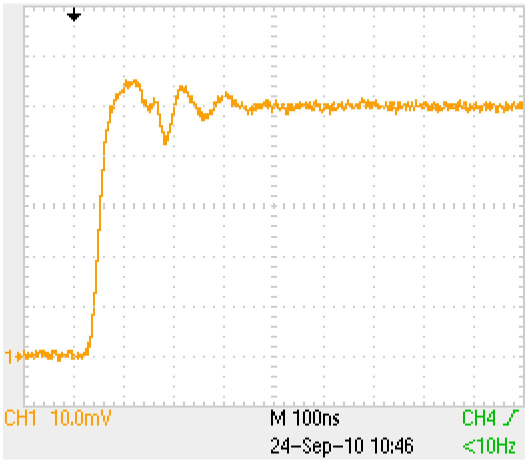
Note that this voltage drop only occurs during the rising and falling edges of the current pulse (transients). Thus, if the laser diode itself has a typical voltage drop of about 2V, then the current source must have a compliance voltage of 10V+2V=12V in order to produce a clean, square wave current pulse.

If this compliance is not available, then the current source will begin to slew the current towards the desired end value. The inductivity will generate opposing voltage as described above until the compliance is fully exhausted. After this point, the slew rate of the current will drop, freeing up voltage from the inductance to drive more current. In this manner, the current does eventually slew up to the desired level, however at a much slower rate.



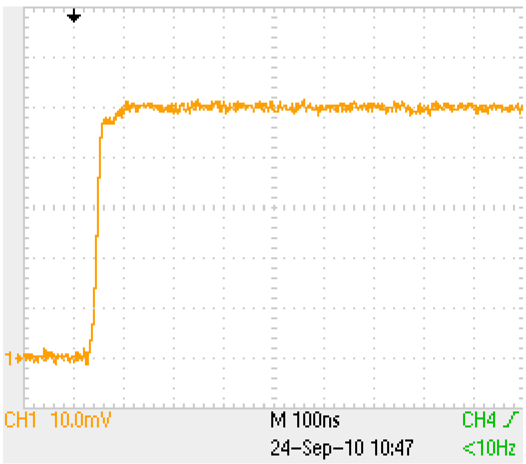
100A Pulse at 3.8V compliance

Increasing the compliance voltage of the source results in a faster rising edge with no kink. However, oscillation will still occur, if the compliance voltage is not high enough.



100A Pulse at 5V compliance

With enough compliance voltage, the system will result in a clean transient with no overshoot and no oscillation. Note that each trace shown here represents the measured current of a 100A pulse.



100A Pulse at 12V compliance

Thus, it is absolutely imperative that the connection between the current source and the laser be of minimum inductivity. As an example, consider the inductivity of a single, straight piece of wire which is given as follows[2]:

$$L_{wire} = 2l\left[\ln(4l/d) - l + \frac{\mu}{4} + \frac{d}{2l}\right]$$

where l is the length, d the diameter and μ the permeability of the wire.

As an example, a 1mm diameter, 10cm long piece of wire will have an inductance of about 100nH. Clearly, this is not a suitable medium for transmitting such fast, high current pulses.

Instead, the load must be connected via a broad, flat strip line with the source and drain leads laminated together to avoid any gap between them. This will typically be realized as follows:

In this case, a 4cm broad strip line of 1.6mm thickness (standard circuit board) with 10cm length introduces an inductivity of 4.3nH which is approximately the value used in the example calculation on page 1 of this note.

Note that in principle the capacitance of the strip line can shunt the current away from the laser diode during the transients. However, in practical situations, this effect is completely negligible, as the following calculation shows. Here the transient is modelled as a linear voltage rise with 2V drop over the laser diode. The capacitance of the strip line is estimated as:

$$C = \frac{\varepsilon A}{d} = \frac{(8.8 \cdot 10^{-12} F/m) \cdot (40cm^2)}{1.6mm} = 22pF$$

resulting in a shunt current of:

$$I_{shunt} = C\frac{dU}{dt} = 22pF\frac{2V}{50ns} = 0.9mA$$

which, as assumed above, is negligible compared to the 100A pulse being driven into the laser diode.

In summary, driving high current loads with very fast transients requires the use of low inductance leads between the current source and the load. Typically this lead will be a strip line with inductance of the order of 2-5nH. Even with this low inductance, the source must provide enough compliance to overcome the self-induced voltage within the inductance in order to provide fast, clean transients with no overshoot and oscillation.

Please feel free to contact us for consultation for your particular application.

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[1] http://en.wikipedia.org/wiki/Current_source

[2] Handbook of Chemistry and Physics, 44th Ed., Chemical Rubber Publishing Co., Cleveland, OH, 1962.