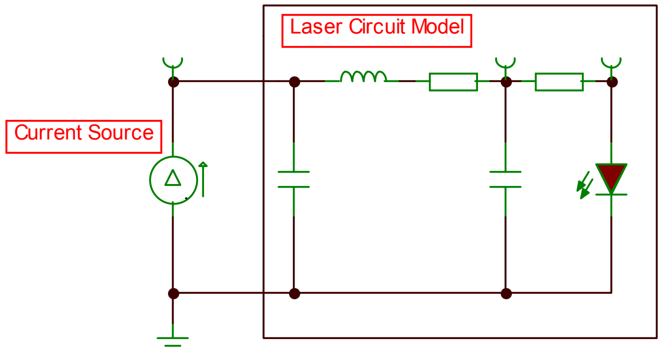
Comparison of Voltage and Current Sources

The interest in current sources for laser testing lies in the fact that the optical power output of a laser diode is governed by the current through the device. Above the threshold current at which the recombination of electron-hole pairs occurs at a sufficient rate to sustain coherent emission, the differential optical power output is linearly proportional to the differential current change. No such linear dependance exists for the voltage drop across the laser diode.

Most sources of electrical energy (mains electricity, a battery, ...) are best modeled as voltage sources. Such sources provide constant voltage, which means that as long as the amount of current drawn from the source is within the source's capabilities, its output voltage stays constant. Conversely, a current source provides a constant current, as long as the load connected to the source terminals has sufficiently low impedance.

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]

In order to illustrate the difference between a current source and a voltage source, consider a model of a typical laser diode which was conceived for the purpose of studying the frequency response of such diodes[2].



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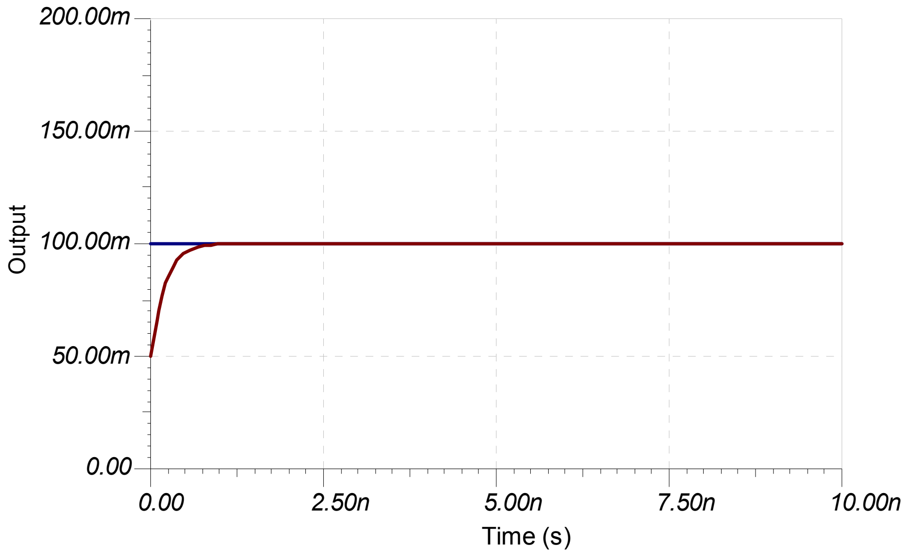
Artifex Engineering e.K.
Dortmunder Str. 16-18
26723 Emden, Germany

General Manager: Dr. Steven Wright
Registry number: HRA 200036

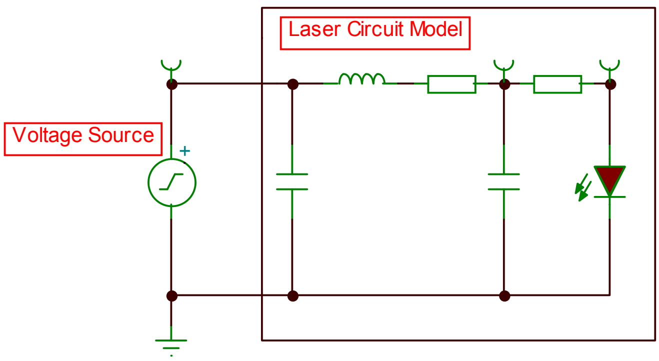
Tel: +49-(0)4921-58908-0
eMail: info@afx-eng.com
Web: http://www.afx-eng.com/

A SPICE[3] analysis of this circuit using an ideal current source generating an ideal step transient output results in the following current response through the light emitting semiconductor element.

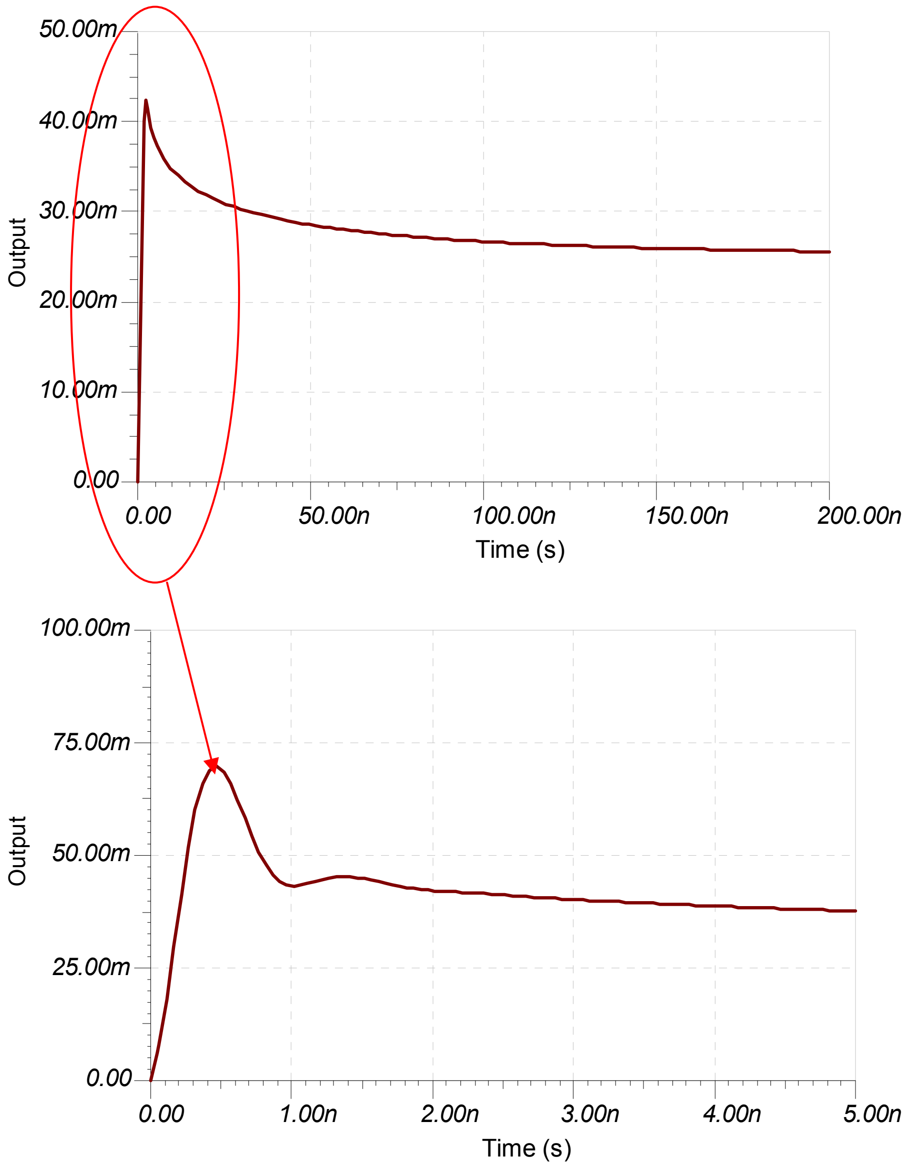


The analysis shows a fast, clean rise to the steady state with no overshoot. The transient response is found to be essentially due to the shunt capacitances – as to be expected from an ideal current source.

In contrast, consider the identical circuit with the ideal current source replaced by an ideal voltage source.



The SPICE analysis indeed shows a markedly different response.



In this case, the current transient through the light emitting semiconductor section shows strong current overshoot. This overshoot arises from the non-ohmic reaction of the load due to its inductance and capacitance. In order to accomodate this, the load may be impedance matched by adding suitable bulk inductance and capacitance to the load circuit. This procedure is somewhat complex and must be performed for each type of laser diode to be tested.

Voltage sources are therefore not as flexible as current sources when testing different types of laser diodes.

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

[2] M. S. Ozyazici, “The Complete Electrical Equivalent Circuit of a Double Heterojunction Laser Diode Using Scattering Parameters”, Journal of Optoelectronics and Advanced Materials Vol. 6, No. 4, December 2004, p. 1243 - 1253

[3] Laurence W. Nagel and D.O. Pederson, “SPICE (Simulation Program with Integrated Circuit Emphasis)”, EECS Department, University of California, Berkeley, Technical Report No. UCB/ERL M382, April 1973