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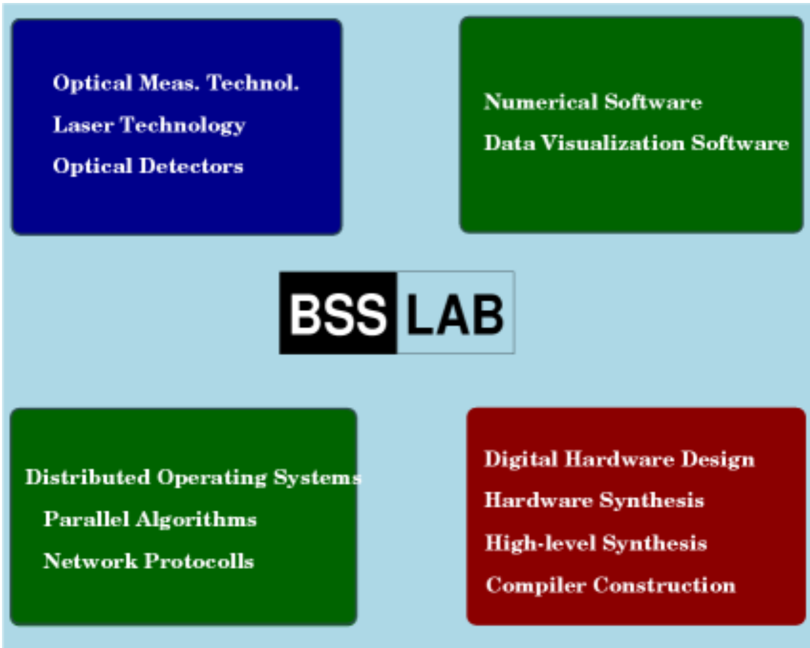

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Laserdiode Current Control using a FPGA

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Introduction

Laserdiodes have an eletrical behaviour similar to generic semiconductor diodes. They have an exponential relationship between a supply voltage (applied in forward direction, typically 2−4 V) and the resulting current flow (in the range 40−5000 mA). There is a weak dependency between the generated photon field and the current flow. Damaged laser mirrors can result in a different current characteristic compared with a well operating laser diode.

To get constant output power, a laserdiode must be operated with a constant current, though there is a temperature dependency between the diode current and the output light power.

The control of a laserdiode with a constant current is not simple to realize due to the exponential current characteristic. In contrast to normal semiconductor diodes the distance between the operating and the maximal limit current is small, typically about 2−3 times.If the current exceeds the limit current, the laser mirrors can be damaged due to the high light intensity, and rather the diode itself.

Due to the critical current limit condition, the current control must not create current spikes (overshots) during operation. This condition leads to high demands in the construction of control electronics. Conventional analog control electronics needs a carefully dimensioned circuit concept tuned for a special laserdiode. For each new laserdiode (mainly characterized by their operating current), the circuit must be recalculated. Due to the exponential current characteristic, oscillation of the control circuit can occur.

The realization of current control with digital systems leads to a more flexible solution. Any kind of controller type can be implemented, not possible with analog systems. Additionally, different security check mechanisms can be easily implemented, like overcurrent and overvoltage protection. An overvoltage can for example occur due to a broken cable, which leads to an increasing voltage without current feedback.

The usage of microcontrollers or specialized digital signal processors (DSP) for current control is possible, but due to the sequentiel execution of control code there is a limit in the maximal control frequency. A reaction time in the range of 100ns − 1us is desirable. The controll frequency at which the preset and actual current values are compared on the input side and an output signal is generated is therefore in the range of 1−10MHz.

The controller requires on hte input side the actual laserdiode current and the preset value. On the output side the laserdiode supply voltage is generated depending on the control error. To achieve constant light output power it is necessary to acquire the laserdiode temperature. The interface between the analog and the digital world is realized with digital−to−analog− (DAC) and analog−to−digital−converters (ADC).

The implementation of a controller with limit checking using programmable digital logic (here a FPGA − Field Programmable Gate Array) is simple to realize and FPGAs are best suited for this job. Controller frequencies up to 100 MHz can be achieved, and the controlling, limit checking and parameter control with external communication can be executed in parallel.

The ramp controller type is the only one which is free from over− and undershots phenomena. This controller generates an output signal which is a sum of a differential value DO depending on the actual error value ERR=I_{set} − I_{meas} and the previous output signal O(n−1):

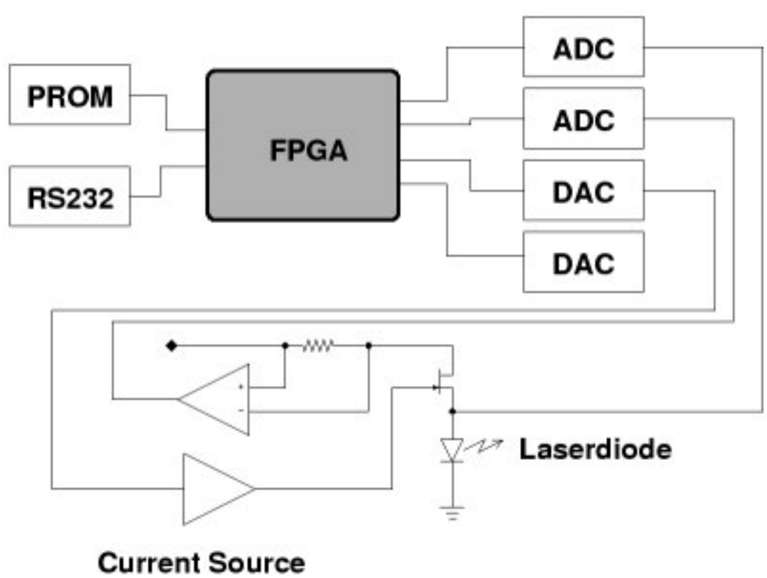
DO(ERR) = if ERR > 0 then (+D) else if ERR < 0 then (−D) else 0

O(n)=O(n−1)+DO

Therefore, the output signal can only change by a unit D during each control loop iteration. At least if the controller frequency f is smaller than the frequency bandwidth of the analog measuring and control electronics, over− and undershot phenomenas are negligible, and caused only by this electronic and the DA−converter.

Components and System Description

The central digital component consists of a FPGA (Xilinx, Spartan II). It contains the current regulator, limit checking and support for external communication. Communication with the controller circuit takes place over a generic RS232 serial line interface. Using the serial line, registers inside the controller can be read and wrote using commands. For example the command "W014F" sets the register 0 with the hexadecimal value 0x14F. In this case, this is the register holding the preset current value. Analog signals are acquired using two AD−converters with 12 bit resolution. Analog signals are generated using two DA−convertes with 12 bit resolution, too. The ouput signal voltage genertaed by the current controller is fed into a MOSFET powertransistor in drain arrangement. The actual current flow through the laserdiode is measured by a voltage drop over a low impedance resistor.

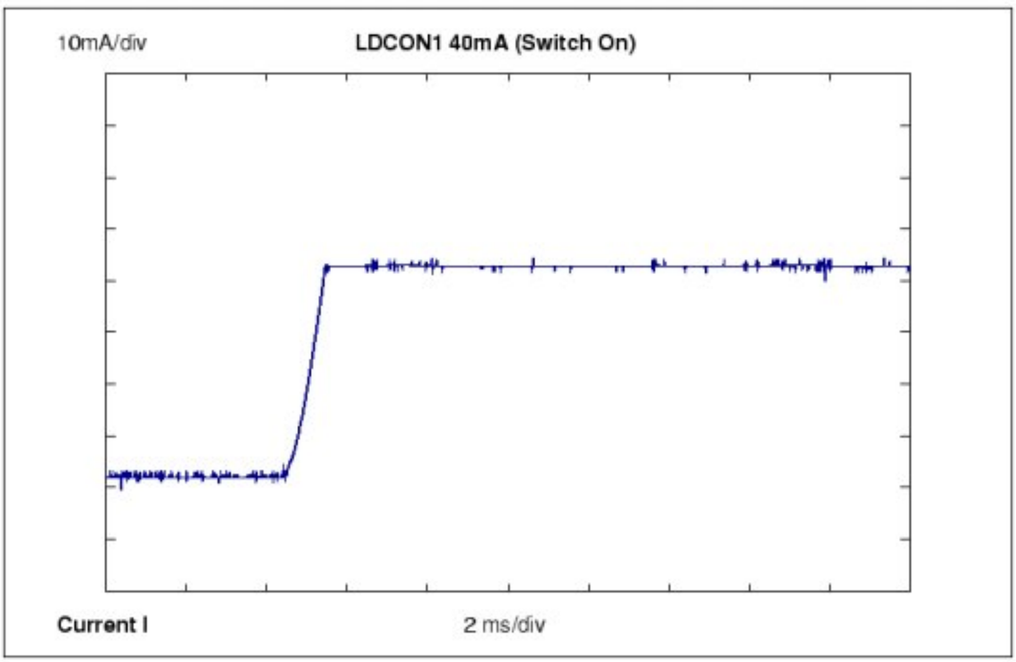


The ramp current controller, the control of the data acquisition from and to the AD− and DA−convertes and the communication is realized with Moore state machines executed parallel inside the FPGA. The limit check operates idependently from the controller and can influence directly the output drive voltage. The actual laserdiode current and the actual voltage is measured and monitored. For example an electrical short−circuit can cause a fast current jump, or a broken cable (open circuit) can cause an increasing drive voltage without an increasing current. Both cases lead to an emergency stop of the controller.

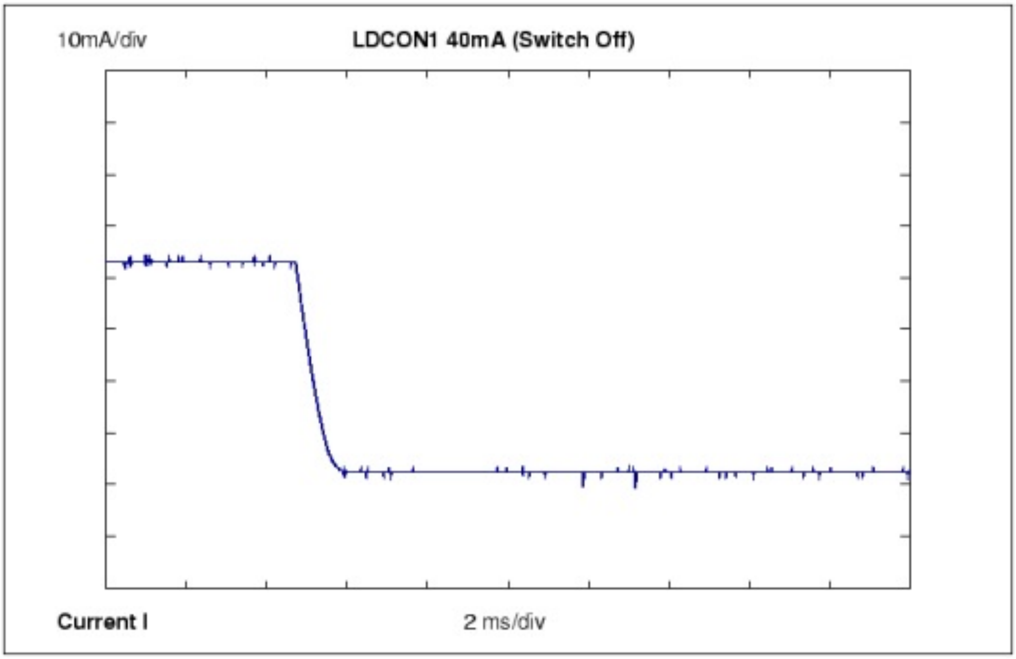
The voltages of the AD− and DA−convertes ranges from −2.5 to 2.5 V, which results in 1.2 mV resolution with 12 bit digital units.

Results

The following figure shows the current plot during the laser diode was switched on. The constant laserdiode current was regulated to I=40mA. The current plot of the laserdiode is free of current over− and undershots, especially during the switch transition. The noise in the current measurement results from digital noise and the used measuring technique.



There are no current over− and undershots during the switch−off event, too, shown in the following figure.



Digital noise emitted from digital systems due to different discerete frequencies used inside the digital system has an important impact on the quaility of current regulation of laserdiodes. A small variation of the suplly voltage results due to the exponential current−voltage characteristic of laserdiodes to relative large current and laser output power variation. If we assume a typical 1mA/10mV slope, an output noise voltage of 1.2 mV (Resolution limit of the DA−Converter) creates a current change of about 0.12 mA. A resistor in series with the laserdiode reduces the current−voltage slope and increases noise immunity. Noise in the current measurement can lead to a (weak) oscillation of the controller.