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Laser Diode Pulsed Power Applications – Part 2

Customer Application

Semiconductor laser diode systems are replacing conventional lasers in a wide variety of cutting, welding and other industrial applications. Uses for continuous wave and pulsed types of applications have different requirements. When used in the pulsed or modulated application, laser diode stacks are capable of producing thousands of watts and can be turned on and off instantaneously to control spot heating.

Technical Challenge

When using laser diodes in a pulsed or variable duty cycle application, the pulsing method is critical. The dynamic response must be controlled so that current overshoot is minimized or eliminated. This becomes a challenge with fast rise and fall times or when low duty cycles are required with fast dynamic response.

Technical Approach and Solution

There are two techniques commonly used to achieve a stable optical output from a laser diode: Constant Power mode and Constant Current mode. Constant Current mode combined with precise control of the diodes operating temperature is generally the preferred operating method. The constant current mode provides a faster control loop and a precision current reference for accurately monitoring the laser current. What is required to produce these fast pulses of current to the laser diodes is a wide bandwidth programmable current source.

Due to the variety of applications with laser diodes, we have recently done testing with standard catalog products using a DCS 3KW power supply and SLH series high power DC load (Figure 1) to demonstrate that a custom design may not be necessary for many applications. By programming an SLH load in the constant current mode of operation and using the internal pulse generators and current programming available via front panel control, a series of experiments was conducted to demonstrate the capability of this combination of products. Operation of this solution is fairly simple with no instabilities observed. The only precaution that must be taken into consideration is in keeping the cabling short to minimize the impact of lead inductance on the slew rate. Of particular interest were the rise and fall times that could be achieved since these are critical parameters in pulsed applications to balance laser output and power consumption. Oscilloscope captures were taken that show operation from 100 Hz to 4.7 kHz with various duty cycles to help in evaluating this solution.

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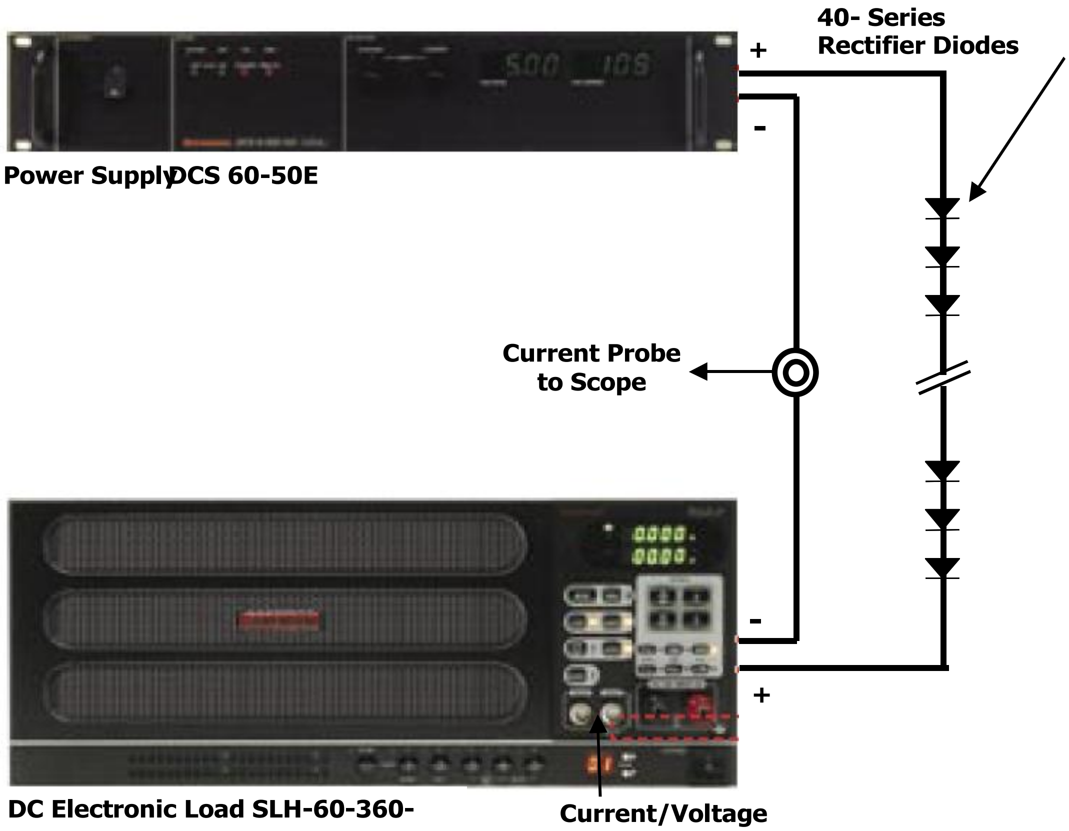

Figure 1. Diagram of DC Supply and Load with "Laser diode" Drive Scheme.

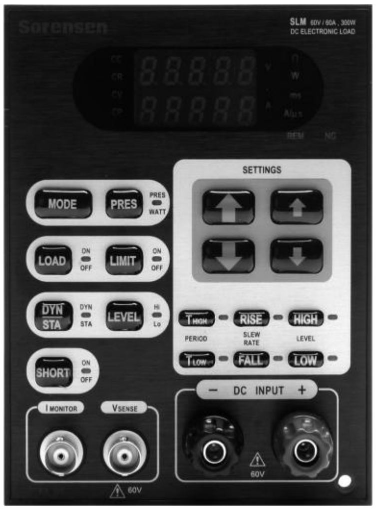

Figure 2. Front panel controller of SLH-Series Load. Full controls of slew rate are also available via GPIB or an external signal generator.

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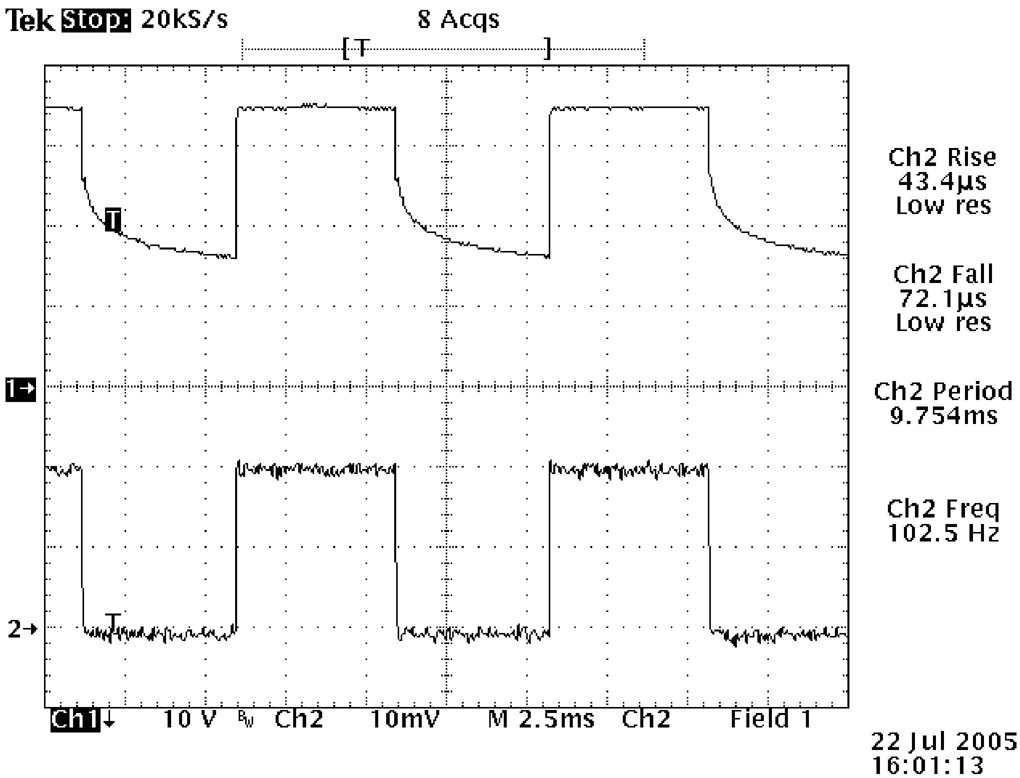

Figure 3. Voltage across the diodes (top) and the current through the diodes (bottom) while pulsing at a 102.5 Hz repetition rate with a 50% duty cycle.

DC Power Supply = 50V
Time/div= 2.5msec
Volt/div=10V
Current/div= 20A
Current rise time =43.2us
Current fall time =72.1us

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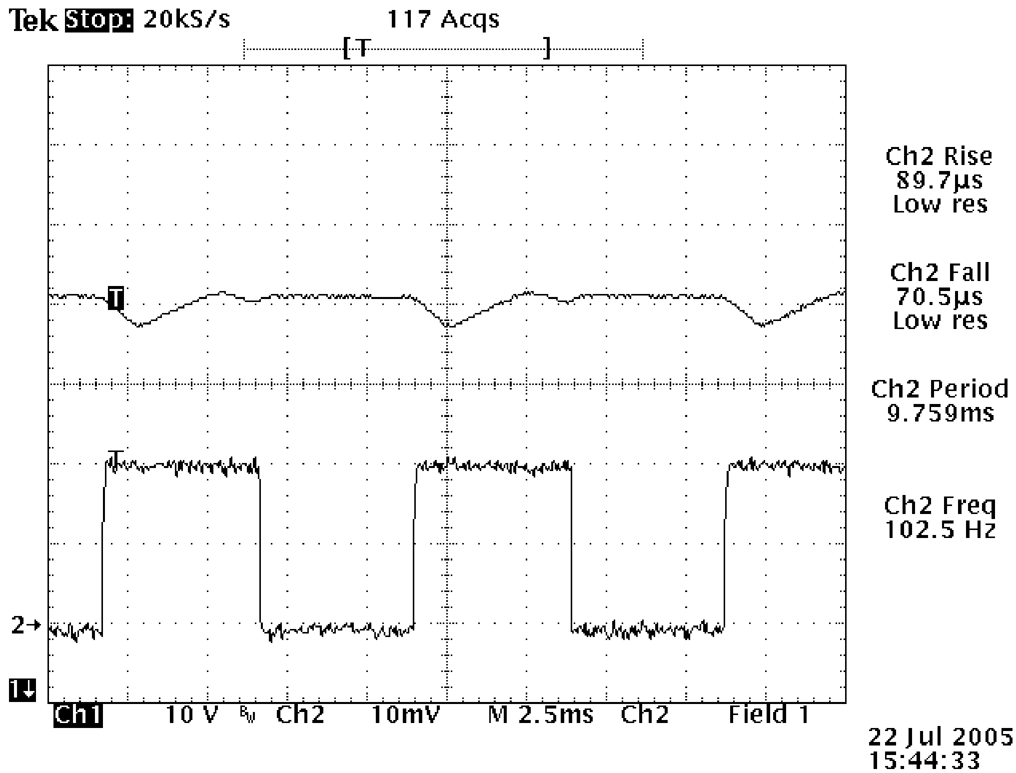

Figure 4. The voltage across the DC supply (top) and the current through the diodes (bottom) while pulsing at a 102.5 Hz repetition rate with a 50% duty cycle. There can be some power supply regulation issues which depend upon the slew rate and frequency. A large drop in the DC supply voltage which may interfere with the constant current operation, if it drops to near the diode voltage. In the case above, the diode voltage is significantly lower than the 46V minimum DC supply voltage so no adverse affects are seen.

DC Power Supply = 50V
Time/div= 2.5msec
Volt/div=10V
Current/div= 20A
Current rise time =89.2us
Current fall time =70.5us

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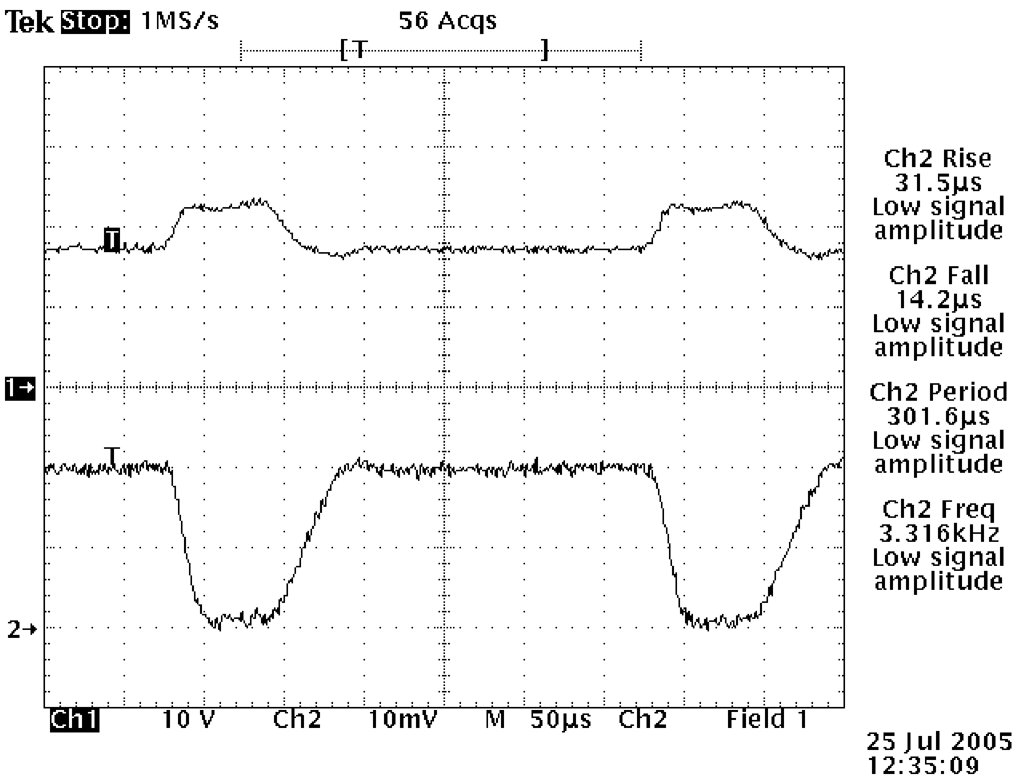

Figure 5. Voltage across to DC Load (top); current through the diodes (bottom) while pulsing 0-20A at a 3.3 kHz repetition rate with an 80% duty cycle.

Time/div= 50usec
Volt/div=10V
Current/div= 10A
Current rise time =31.5us
Current fall time =14.2us

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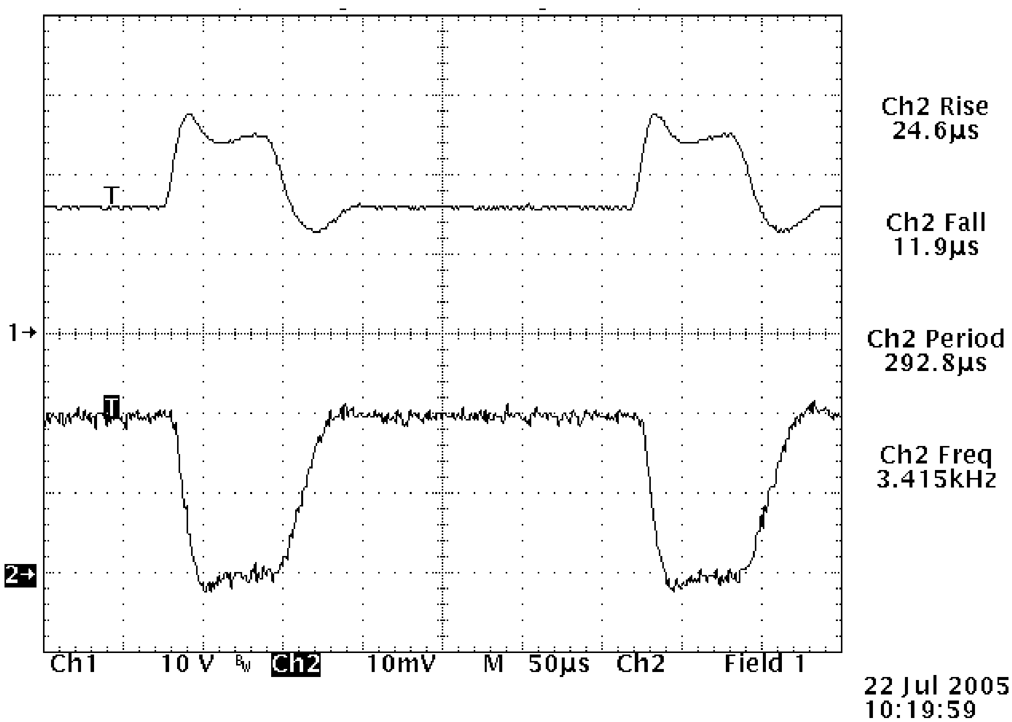

Figure 6. Voltage across to DC Load (top); current through the diodes (bottom) while pulsing 0-40A at a 3.4 kHz repetition rate with an 80% duty cycle with a medium slew rate setting. Note that no current overshoot occurs.

Time/div= 50usec
Volt/div=10V
Current/div= 20A
Current rise time =24.6us
Current fall time =11.9us

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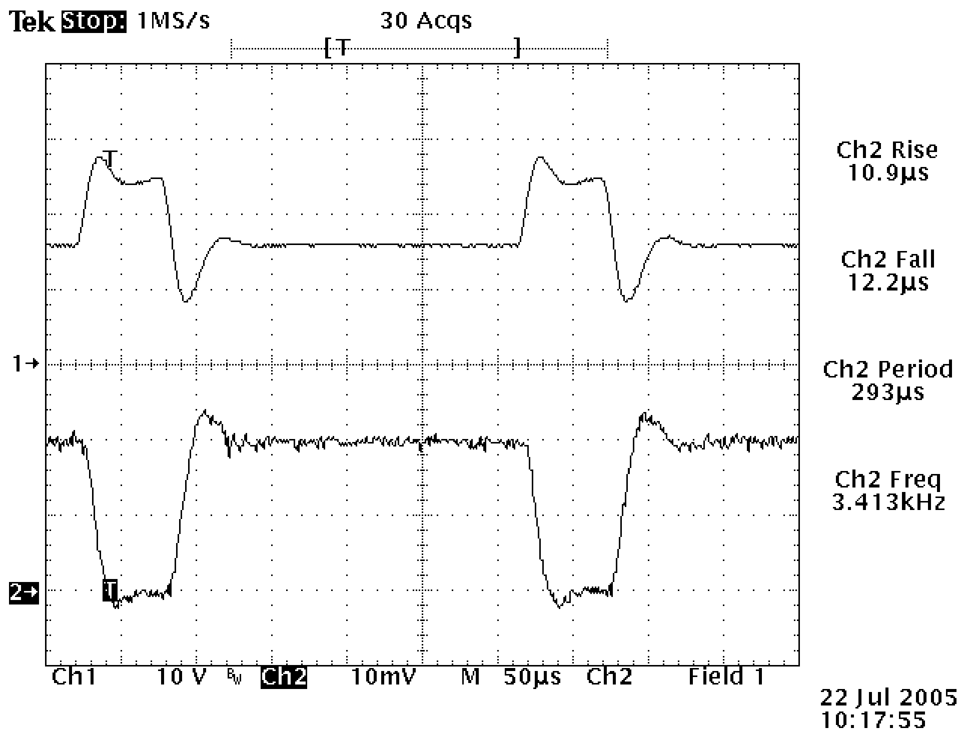

Figure 7. Voltage across to DC Load (top); current through the diodes (bottom) while pulsing 0-40A at a 3.4 kHz repetition rate with an 80% duty cycle with the slew rate set for maximum setting on the DC load. Current overshoot occurs at this slew rate due to the increased di/dt transitions. As the inductance in the cable increases, the slew rate may need to be reduced further to eliminate current overshoot.

Time/div= 50usec
Volt/div=10V
Current/div= 20A
Current rise time =10.9us
Current fall time =12.2us

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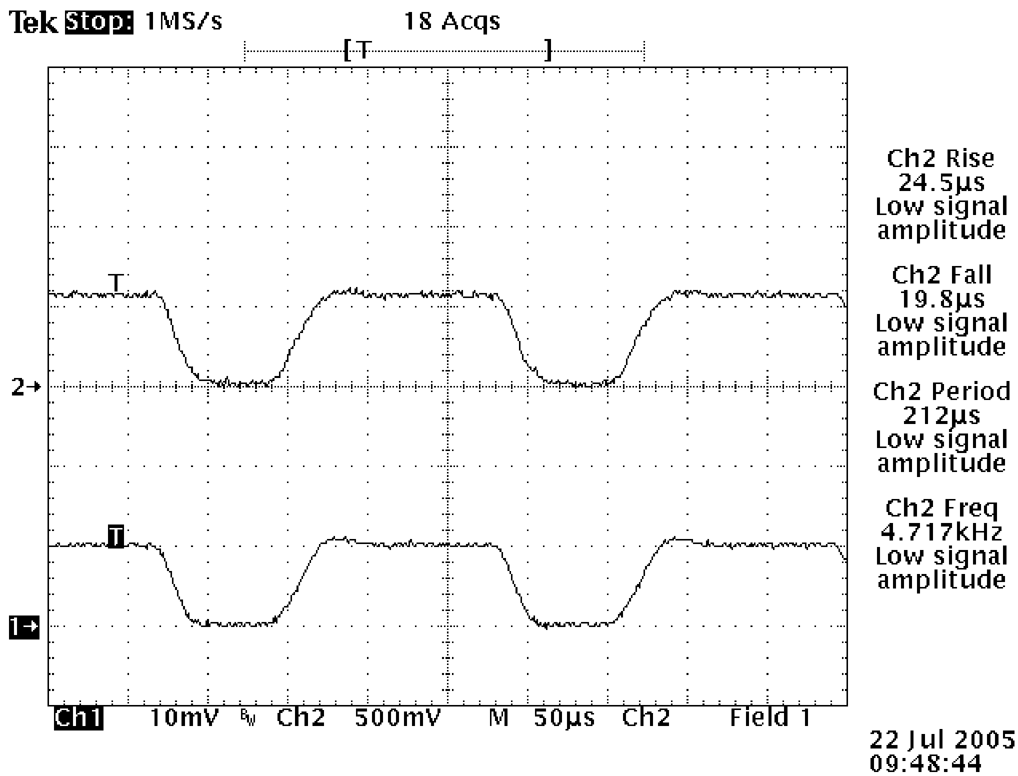

Figure 8. Current monitor output from the DC load (top) and the current through the diodes (bottom) while pulsing 0-10A at a 4.7 kHz repetition rate with a 50% duty cycle. Note that the current monitor closely resembles the waveform from the current probe.

Time/div= 50usec
DC Load Current Monitor Amps/div=10A
Current/div= 10A
Current rise time =24.5us
Current fall time =19.8us

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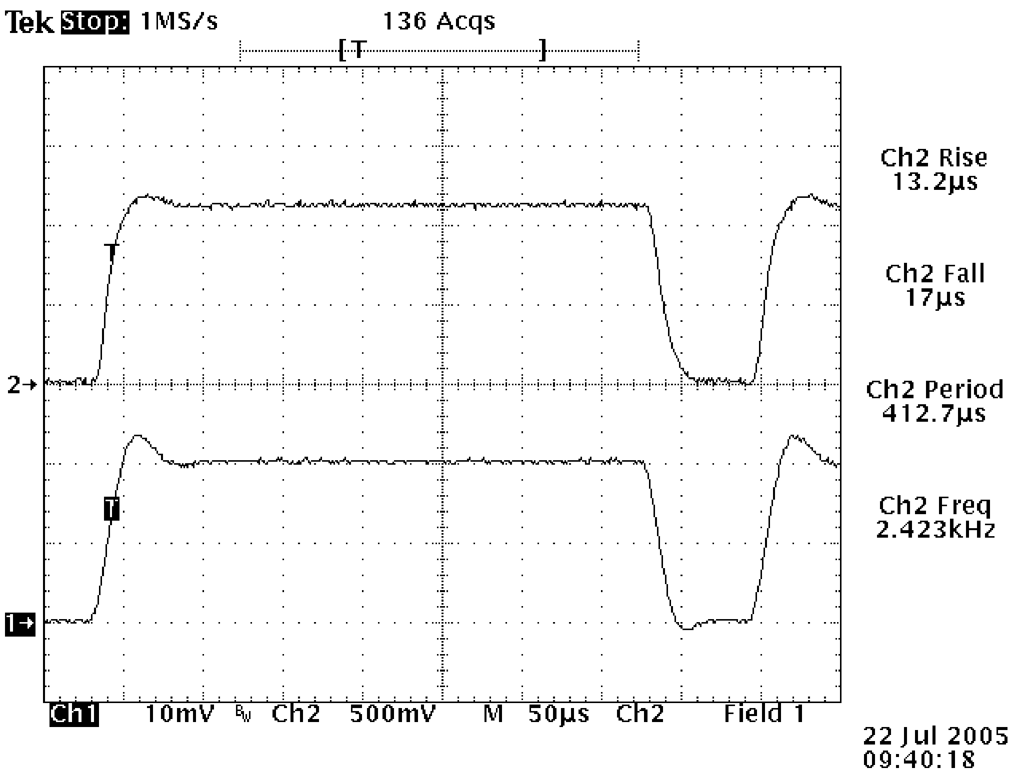

Figure 9. Current monitor output from the DC load (top); current through the diodes (bottom) while pulsing 0-40A at a 2.4 kHz repetition rate with a 20% duty cycle. Note that the current monitor tends to filter the initial overshoot due to internal circuit filtering bandwidth limitations. This needs to be checked with an external probe if high slew rates are to be used in order to not damage the laser diodes if they are being operated near their rated current.

Time/div= 50usec
DC Load Current Monitor Amps/div=20A
Current/div= 20A
Current rise time =13.2us
Current fall time =17us

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Conclusions

Pulsed high power laser diodes at high slew rates is possible using off the shelf programmable DC power supplies and DC Loads. Response times down to 10usec are possible by using the SLH load in the constant current mode with internal pulse generators and high and low current set points for current programming. However, it was noted that rise times of less than about 25us had an increasing amount of overshoot that may not be desirable in some applications. Using an external pulse generator to set the pulse duration and amplitude is also possible.

As the load currents increase, a larger power supply is recommended. Most supplies manufactured by Sorensen are specified for transient response times with a 30% to 50% step load change and then usually starting with at least a 50% initial load. Since the pulsed loading used in this scheme are operating between zero current and some much higher value, care should be taken in the selection of the supply to insure that the transient response times don't interfere with the steady state value of current to the laser diodes. It was found that pulsing with high crest factors using some low repetition rates caused the most problems in this area (as seen in photo #3). Because of this, it is recommended that the power supply be rated for at least 120-150% of both voltage and current so that accurate waveforms are produced under all pulsing conditions and the laser diodes won't be damaged.

In pulse mode, since the load sees either high voltage and no current or high current and low voltage, the load power selection can be much lower than the power supply. As shown, when the diodes are conducting, the majority of the power supply voltage is dropped across the diodes. When the current is off, the majority and in some cases all of the power supply voltage is dropped across the load (but obviously at zero power). Thus, a load should be selected with a maximum voltage rating at least equal to the power supply output and a maximum current rating equal to the diode test conditions. The power rating can be approximately half of the power supply output, depending upon the duty cycle, laser diode voltage and current levels.

Reference Precautions for Laser Diodes (Courtesy of © Optima Precision Inc.)

Operating in the Constant Current Mode vs. Constant Power Mode.

The characteristics of a laser diode are highly dependent on the temperature of the laser chip. For instance, the wavelength of a typical GaAlAs diode will increase on the order of 0.25nm for a 1°C rise in temperature. With a single mode diode, the change in wavelength may produce an undesirable effect known as mode hopping. Other characteristics directly related to laser diode temperature-dependent operation are; threshold current, slope efficiency, wavelength, and lifetime. Perhaps, the most important characteristic is the effect of temperature on the relationship between the diode's optical output and the injection current. In this case, the optical output decreases as the operating temperature increases or, conversely the optical output increases as the operating temperature decreases. Without limits and safeguards built into the laser drive circuit, a wide swing in operating temperature could be catastrophic. However, there are two techniques commonly used to achieve a stable optical output from a laser diode: Constant Current mode combined with precise control of the

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diode operating temperature is generally preferred. The constant current mode provides a faster control loop and a precision current reference for accurately monitoring the laser current. Further, in many cases, the laser diode's internal photodiode may exhibit drift and have poor noise characteristics. If performance of the internal photodiode is inferior, the diode's optical output is likely to be noisy and unstable as well.

Constant Current operation without temperature control is generally not desirable. If the operating temperature of the laser diode decreases significantly; the optical power output will increase and could easily exceed the absolute maximum. Constant Power or APC mode precludes the possibility of the optical power output increasing as the laser diode temperature decreases. However, when operating in the constant power mode and without temperature control, mode hops and changes in wavelength will still occur. Further, if the heat sink upon which the diode is mounted is inadequate and the temperature is allowed to increase, the optical power will decrease. In turn, the drive circuit will increase the injection current, attempting to maintain the optical power at a constant level. Without an absolute current limit, thermal runaway is possible and the laser may be damaged and/or destroyed.

Summary - for stable operation and maximum laser lifetime, temperature control and constant current operation is generally the best solution. However, if precise temperature control of the laser diode is not practical, then an APC circuit should be used.

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