#22

Modulating Laser Diodes

APPLICATION NOTE

ILX Lightwave®

A Newport Corporation Brand

Modulating Laser Diodes

Introduction

The external modulation feature found on many ILX Lightwave current sources is a very flexible circuit that can be used for a wide variety of applications. If the task is to slightly dither the current to produce laser linewidth broadening or wavelength control, small signal analog modulation is easily possible. If the task requires the laser output to be amplitude-modulated at audio frequencies or higher, it can still be easily done by directly modulating the current source. If a digital style of pulse is required where the leading and trailing edges are sharp and discontinuous, modulation of the current source may still be acceptable. The acceptance criteria for this type of modulation centers around the level of ringing in the output that can be tolerated. Careful consideration of the modulation test parameters and instrument specifications will help determine if a bulky bias tee network can be eliminated from the setup and replaced with a laser controller that most likely is already sitting on a shelf or integrated into the test in the lab.

Current sources capable of direct modulation will typically have smaller bandwidths than bias tees because the larger the bandwidth of the current source, the more inherent noise in the output. Even with this limitation, these modulation-capable current sources are more flexible in their usage. Any laser that is connected to the current source may be modulated. In contrast, only lasers with specific wiring configurations may be used in mounts incorporating bias tees. External bias tees may be used to modulate the laser diode, but these devices are typically quite bulky and as large as, if not larger than, the laser to which they are connected. These are only two of the reasons why direct modulation of the current source may be preferred.

Test Setup

Throughout this discussion, oscilloscope traces will be presented to help explain many aspects of laser modulation. These traces were generated using an ILX Lightwave LDC-3724B laser diode controller as the current source and viewed with a Tektronix TDS 3014 oscilloscope. The output was modulated with an Agilent 33120A function generator. An NEL NLK1556STG DFB laser connected to the LDC-3724B via a standard LDM-4984 butterfly laser mount was the object of the modulation. The laser output was observed on the scope using a ThorLabs PDA400 photodetector set to its widest bandwidth. In order to drive the current source over its full range, a JDS-Fitel HA1 optical attenuator was used to prevent detector saturation at all values of laser current.

Configuring a Current Source for Modulation

Each ILX Lightwave current source capable of being modulated externally has a transfer function corresponding to each current output range. In most cases, the transfer function will be displayed on the instrument adjacent to the input connector. These transfer functions, in units of milliamps per volt (mA/V), specify the input signal required to produce a specific output current. For example, the 200mA range of the LDC-3724B has a transfer function of 20mA/V. This means a 1VDC signal supplied to the modulation input connector will produce a nominal DC current of 20mA. This current is *in addition to* that specified by the constant current setpoint. In the present example, if the setpoint were 100mA, the total output would be 120mA. If instead the output is modulated with a 1kHz sine wave centered on 0V, the output will be sinusoidally modulated at 1kHz with a maximum output of 120mA and a minimum output of 80mA.

Along with the transfer function, the modulation circuit is specified by an input impedance value. This impedance will be in the range of 50 to 10kΩ, depending on the instrument. Refer to the instrument's documentation for this specification. This impedance is important when setting modulation voltage levels. If the input impedance is low, the function generator signal will typically be significantly loaded down when connected and cause the output to be different from what is expected. It is best to set the modulation levels with the function generator output connected to the modulation input *with the laser output disabled.* This way, the circuit will be properly loaded, and there will be no risk of damage to the laser from being overdriven.

High Frequency Rolloff & Bandwidth Determination

Most ILX Lightwave laser current sources have a low bandwidth (CW) and a high bandwidth output mode. As described earlier, the low bandwidth mode is designed for very low noise CW output and is typically inappropriate for use with external modulation. The high bandwidth mode, on the other hand, provides a much larger frequency response and is specifically designed to be used in conjunction with an external modulation input.

In addition to the transfer function and input impedence, the final piece of information that specifies the external modulation circuit of an ILX current source is its bandwidth. The bandwidth is the frequency range that can be supported without having a significant change in the output and is dependent on modulation method. Modulation method may be either analog or digital. Analog modulation simply means the waveform is continuously varying in amplitude. A sine wave is a perfect example. Digital modulation, on the other hand, implies a discontinuous change in amplitude. A square wave is the prime example of digital modulation.

The bandwidth of ILX Lightwave current sources is specified as the frequency range over which the output does not change by more than 3dB (a factor of two) when set to 50% modulation at mid-scale output. In other words, with the CW output set to mid-scale and the modulation signal configured to sinusoidally vary the output from 75% of full scale down to 50% of

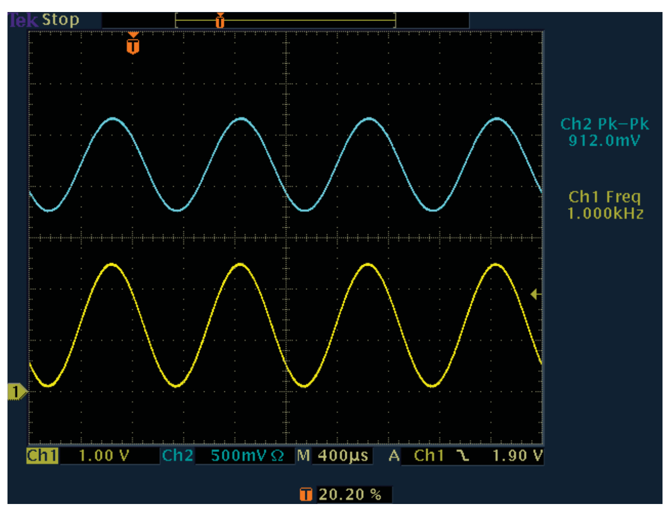

Figure 1. Low Frequency Performance, CW Mode, Analog Modulation

full scale, the maximum bandwidth occurs at the frequency that causes the peak-to-peak variation in output to change by a factor of two (3dB). The following figures illustrate 3dB rolloff.

Channel 2 (blue trace) in Figure 1 shows the photodetector output of a laser being modulated from 100 to 150mA at 1kHz. Channel 1 is the input modulation signal. The LDC-3724B is operating in low bandwidth (CW) mode and 200mA range with a CW setpoint of 100mA.

Figure 2 shows the laser's peak-to-peak output being reduced by a factor of 2 (912mV to 460mV). As can be seen in the figure, the CW mode bandwidth for this specific laser controller is 31kHz. The published specification is 15kHz.

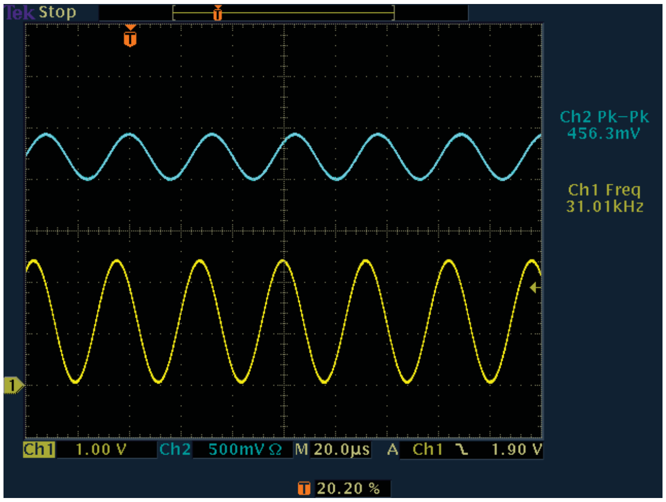

Figure 2. High Frequency Performance, CW Mode, Analog Modulation

Figure 3 illustrates what happens when the modulation input is changed to a square wave in low bandwidth mode. The laser output is severely distorted due to the noise filtering in CW mode. The filtering removes the high frequency components required for a square wave resulting in a rounded sawtooth shape.

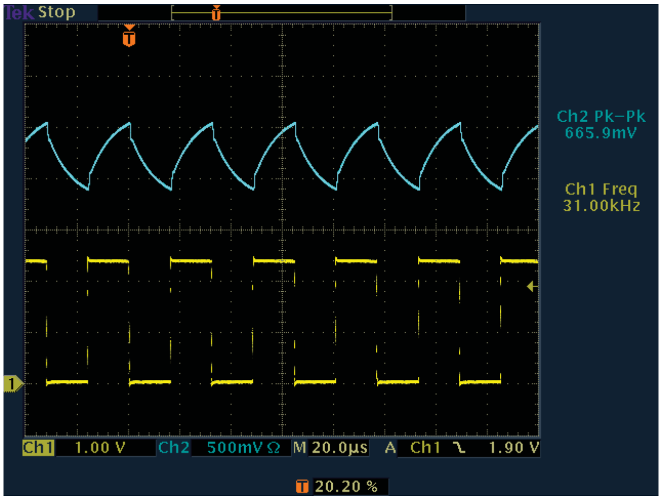

Figure 3. High Frequency Performance, CW Mode, Digital Modulation

If the bandwidth for modulation with square waves (digital modulation) is defined to be the maximum frequency at which the output is still capable of reaching its maximum and minimum output settings without being clipped, the bandwidth must be reduced. As the example in Figure 4 shows, the blue trace of channel 2 just reaches maximum output (the white reference trace) with a maximum frequency of 10kHz.

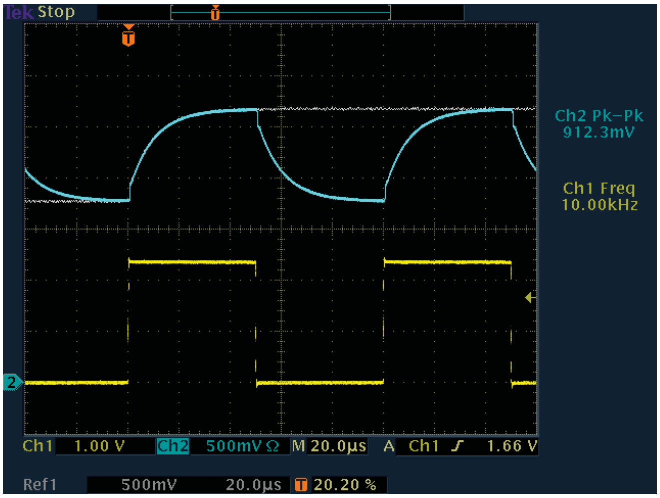

Figure 4. High Frequency Performance, CW Mode, Digital Modulation

Figure 5 shows the 3dB rolloff point while the LDC-3724B is running in high bandwidth mode with a 100mA setpoint in the 200mA range. The bandwidth of I_{HBW} mode is specified to be 1MHz, but, as shown in Figure 5, the controller rolloff occurs at approximately 2.7MHz. Note that at higher frequencies, there is an approximate π-phase shift between modulation input and light output.

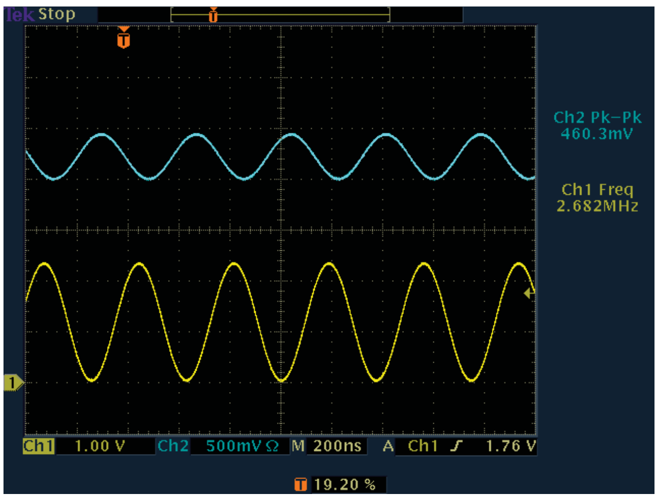

Figure 5. High Frequency Response, High Bandwidth Mode, Analog Modulation

If the modulation frequency response is plotted as shown in Figure 6, then it can be seen that a resonance occurs at approximately 1.9MHz. This is why the phase shift occurs. As frequency increases beyond resonance, modulation drops off as expected.

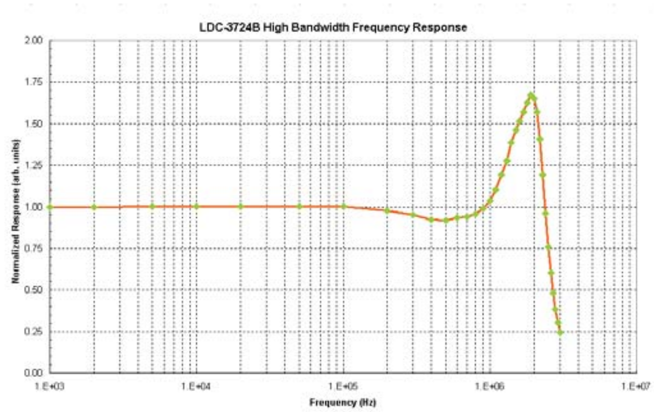

Figure 6. Frequency Response, High Bandwidth Mode, Analog Modulation

Figure 7 shows there is no appreciable difference in light output when the modulation form is changed from analog to digital at high frequencies. This is because the input has exceeded the digital bandwidth by a sizable margin.

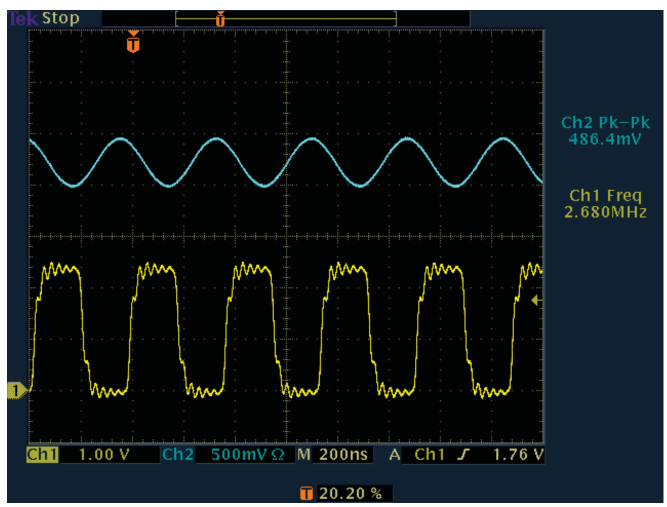

Figure 7. High Frequency Response, High Bandwidth Mode, Overdriven Digital Modulation

Reducing the modulation frequency by an order of magnitude shows how the circuit actually behaves. This is shown in Figure 8.

In this case, the modulation frequency cannot exceed 200kHz even in I_{HBW} mode because of the very large number of frequency components required to build a square wave.

Note that with a square wave input, ringing exceeds the current limit setpoint when modulating at high frequencies. The horizontal cursors for channel 2 shown in Figure 8 correspond to laser outputs at 150mA and 155mA. In this example, the current limit has been set to 155mA.

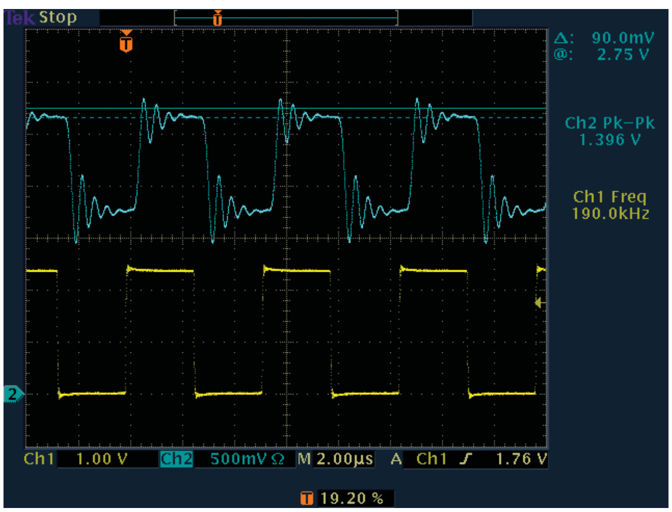

Figure 8. High Frequency Response, High Bandwidth Mode, Bandwidth-Limited Digital Modulation

Pulsed Operation

With a suitable pulse or function generator, the majority of ILX Lightwave current sources with external modulation capability are able to operate in limited capacity as pulsed current sources. In this type of operation, the modulation signal is configured to oscillate between 0V and the maximum specified by the test or laser current limit. By modifying the duty cycle of the modulation signal, output current approaching the characteristics of pulses can be generated. As shown with other high frequency digital modulation examples, the highest frequency attainable (largest bandwidth) is determined by the test's tolerance for pulse shape. If a pulse with very square corners is required, only lower frequencies and smaller magnitude outputs will be acceptable. If more leeway can be given to the resultant pulse shape, higher bandwidths and pulses of higher magnitude are achievable.

Figure 9 shows the result of configuring the modulation input to produce “pulses” with a 50% duty cycle. The ringing is just beginning to settle out. Increasing the frequency and/or reducing the pulsewidth will cause the pulses to be more heavily modulated at their peak. The small pulse seen in the trough of the output is due to ringing that occurs when the current is

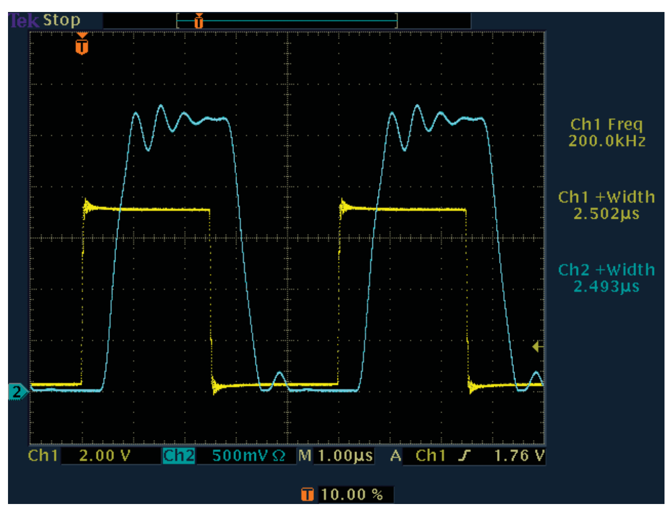

Figure 9. High Frequency Response, High Bandwidth Mode, Quasi-Pulsed Modulation

shut off. The laser protection circuitry designed into the controller prevents current reversal and damage to the laser. However, when the positive cycle occurs, the controller circuitry cannot prevent the output of a small pulse.

The controller can be “tricked” into outputting a cleaner pulse by taking advantage of its reverse-bias protection circuitry. This is accomplished by increasing the modulation amplitude and decreasing the offset to drive the modulation voltage negative. When the voltage goes negative, the output is clamped to zero to protect the laser. If the voltage is driven far enough negative, the troughs will remain flat at zero.

Figure 10 shows an example of this configuration. The output is a series of 2.3μs wide pulses at 200kHz. The drive current as indicated by the blue horizontal cursor is 150mA.

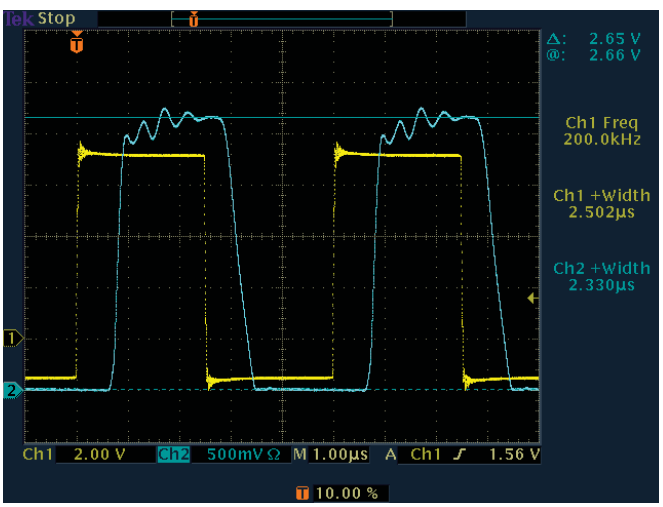

Figure 10. High Frequency Response, High Bandwidth Mode, Pulsed Modulation with 50% Duty Cycle

Conclusion

The majority of ILX Lightwave laser diode current sources are capable of being externally modulated. This external modulation signal can take any form as long as it remains within the bounds of three parameters of the circuit: the transfer function, the input impedance, and the modulation bandwidth. Each of these parameters will affect how the output responds to the input signal. By a judicious choice of CW setpoint, modulation signal level, and frequency, one can perform such tasks as linewidth broadening or fine wavelength control of their laser source. These tasks typically require modulation that is a small percentage of the total drive current and make up the type known as small signal modulation.

Larger amplitude signals, configured to drive the output up to 100% of the total drive setpoint, may be used for what is called large signal modulation. Modulation of this type may either be with a continuously varying signal to perform simple amplitude modulation or it may be discontinuous for digital types of signals. When attempting to modulate the current source with digital type (square) waveforms, being aware of the modulation bandwidth of the source is very critical. Waveforms with sharp leading and trailing edges have a very large number of frequency components that must be replicated by the current source in order to create a true representation of the input waveform. Because of this, the usable bandwidth will be lower than that seen when the source is modulated with an analog signal (a single frequency or very limited number of frequencies). How low the usable bandwidth will be will depend on the application. Ringing will be very evident at high frequencies, and, while acceptable for some applications, it will necessitate an order of magnitude or more drop in the modulation frequency if the test requires the output to settle at its maximum value for some amount of time.

The external modulation circuit can be a very versatile feature once it is understood. This Application Note describes several configurations, how they can be used successfully, and when they should not be used.

For application assistance or additional information on our products or services you can contact us at:

ILX Lightwave Corporation
31950 Frontage Road, Bozeman, MT 59715
Phone: 406-556-2481 • 800-459-9459 • Fax: 406-586-9405
Email: sales@ilxlightwave.com

To obtain contact information for our international distributors and product repair centers or for fast access to product information, technical support, LabVIEW® drivers, and our comprehensive library of technical and application information, visit our website at:

www.ilxlightwave.com

ILX Lightwave®
A Newport Corporation Brand

 Rev01.060305