Technical Standard #**LDC-00196**

A Standard for Measuring Transient Suppression of Laser Diode Drivers

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Introduction

Semiconductor lasers are sensitive to transient (or very fast) voltage or current pulses. A transient of relatively large amplitude can damage a semiconductor laser. Protection from these transients is a compelling reason to choose a current supply designed for driving laser diodes over a constant current-mode voltage supply.

Measuring the suppression of potentially damaging transients from a laser driver requires an understanding of what these transients are, how transients occur, and how they are coupled to the laser. Once an understanding of transients is achieved, a standard testing method is required to ensure that valid comparisons of laser drivers can be made.

We have developed a standard test procedure to measure the effects of transients on laser diode drivers. This standard establishes a consistent test that yields repeatable measurements. These measurements can be used to evaluate the relative effectiveness of various transient protection strategies.

Transient Classification

Laser diodes can suffer catastrophic facet damage (CFD) if the optical energy densities at the output facet exceed 10^4 W/mm^2. Typical laser diodes have rise times in the 80 ps range. Mirror damage is the most rapid form of laser degradation, and whenever the critical optical field intensity is exceeded, the destruction of the laser mirror can be virtually instantaneous. Laser diodes are therefore very sensitive to fast overshoot events, such as electrical transients.

Transients come in many shapes and sizes. In order to effectively evaluate the ability of a current source to protect a laser diode, transients must first be classified. At ILX Lightwave, we have classified transients based on their source. We can then concentrate on generating consistent, repeatable transients. We have identified three classes of transients: *Operational Transients, Surge Transients, and EFT.*

Operational Transients - These types of transients are generated in the laser current source itself, due to circuit topology and design. Current sources typically use a feedback control loop to achieve precision control of the output current. Any change in the steady state input of the control loop results in an output step response. For purposes of our testing, this step response is defined as a control loop transient. If the loop does not have enough phase margin, a critical response, or worse, underdamped response will result[1]. (See Figure 1) This momentary over current will often damage a laser diode.

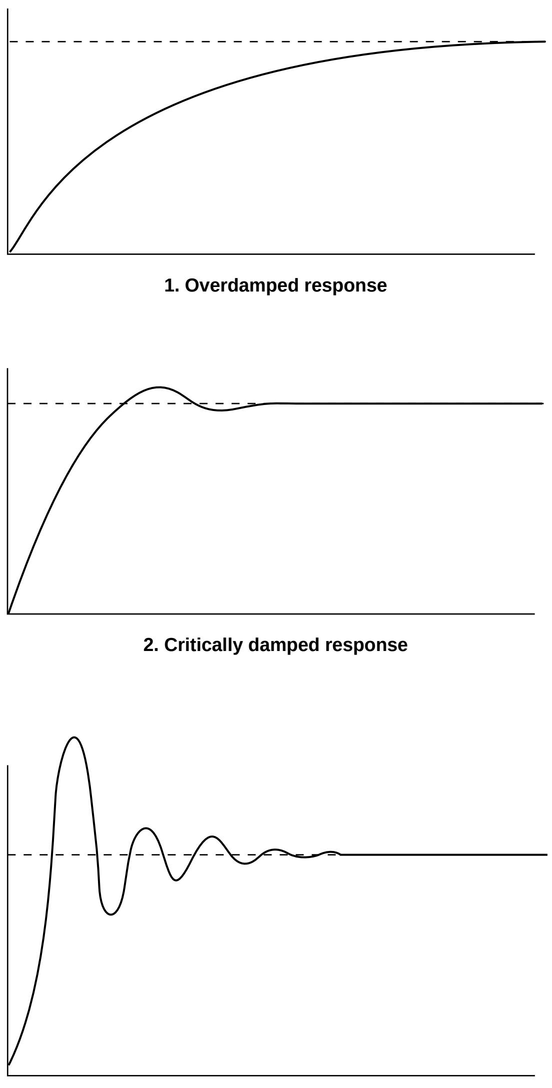

Figure 1 Types of response to a step change in load or setpoint

Operational transients tested for include those generated by turning the output on and off while in various control modes. A slow start circuit is often used to guarantee an over damped loop response at turn-on. Care must be taken during output shut-off as well. Additional causes of loop transients include changes in the loop bandwidth, range, or control mode (i.e., constant power or current). Another potentially damaging control change can occur if AC power is shut off while the current output is on. Testing of all these control transients is critical in order to ensure safe laser operation.

Surge Transients - Surge transients are characterized by their relatively long periods and considerably high energy. The most common cause of a surge transient is electrical storms. Typically, lightning will strike in close proximity to a building or power line leading to a building. The strike will then induce a transient in the AC power grid for the building. Other sources of surge transients are power system or substation disturbances. Surge transients can be coupled into electronic equipment either through power lines or earth ground. They can also be radiatively coupled into a laser through the laser driver cable or mount.

We have chosen IEC (International Electrotechnical Commission) standard 801-5 for testing surge transients.[2] This standard is well-defined, offers reliable and repeatable testing, and is well-suited to this application. In addition, commercial equipment is available that will generate the specified waveform (Figure 2).

The 801-5 specification is based on IEC evaluations of surge transients that one might see on an AC power line.

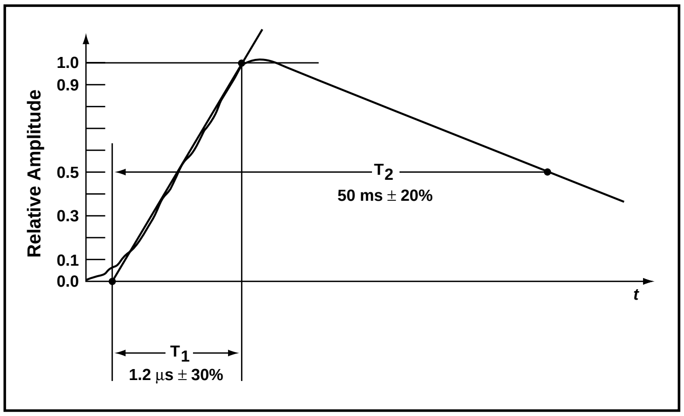

Figure 2 IEC 801-5 surge waveshape

The IEC 801 standards are defined to test for human safety as well as equipment reliability. Testing to this standard ensures that the laser current sources are deemed safe for the operator, as well as the laser.

EFT (Electrical Fast Transients) - These transients are commonly produced by electronic equipment plugged into the same AC power line as the equipment under test. Switching power supplies will generate EFT transients on AC power lines during initial power up, as well as during the charging cycle of their operation. This class of transient noise is becoming increasingly prevalent in laboratories, especially with the growing use of switching supplies in computers and other electronic instruments.

The duration of EFT transients is much shorter than that of surge transients. The high frequency content makes them more capable of leaking through enclosures or line filters.

An IEC standard was also used to define this class of transient. Specifically, IEC 801-4 is the testing standard developed to evaluate equipment sensitivity to EFT transients[3]. This standard specifies the pulse profile (figure 3), test duration, and coupling modes for EFT testing. This standard establishes a repeatable, well-defined EFT transient input. Direct comparison of transient performance can be made without the uncertainty and inconsistency among techniques used to generate test transients.

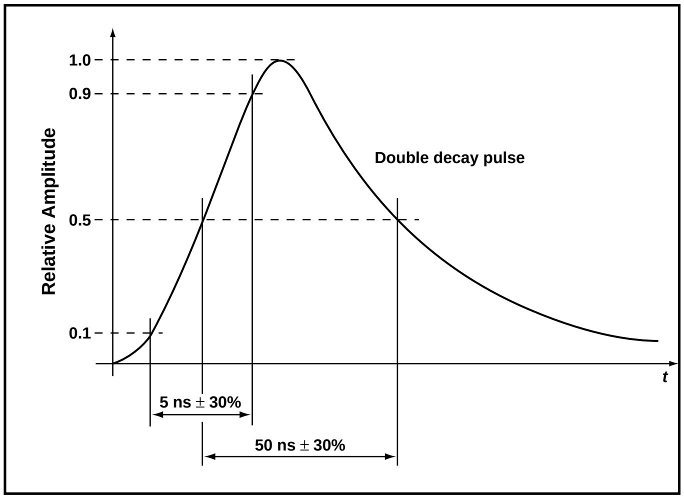

Figure 3 IEC 801-4 single-pulse EFT transient waveshape

Transient Test Procedure

System Configuration

At ILX Lightwave we have been testing our instruments for transient suppression for a number of years. In our experience, two important issues must be addressed before reliable data can be obtained.

First, the transient pulse applied to the instrument must be repeatable. Lab-made test fixtures and transient generators have not yielded the desired reproducibility in line transients. We have remedied this problem with the adoption of the IEC 801-4 and IEC 801-5 standards. Commercial surge generators designed to produce the pulse profile specified by the standards are commercially available from several companies. This equipment allows repeatable transient pulses and fixed coupling modes.

The second issue concerns isolation of the applied transient from all equipment other than the specific instrument under test. Failure to properly isolate the measurement system from the induced transient will lead to non-repeatable and inaccurate results. In our test setup, isolation is accomplished by making an optical measurement of the current transient. A photodetector is aligned to the light output of a laser diode which is powered by the equipment under test (EUT) (Figure 4).

A transient is applied to the EUT, and the resulting optical pulse is measured to determine the magnitude of the response. A current spike amplitude is then calculated using the calibrated transfer function for the system. This configuration eliminates test transient waveforms from coupling directly into the oscilloscope input.

Steps must also be taken to prevent transients from coupling directly onto the measurement system (oscilloscope) through the power line. To accomplish this, an

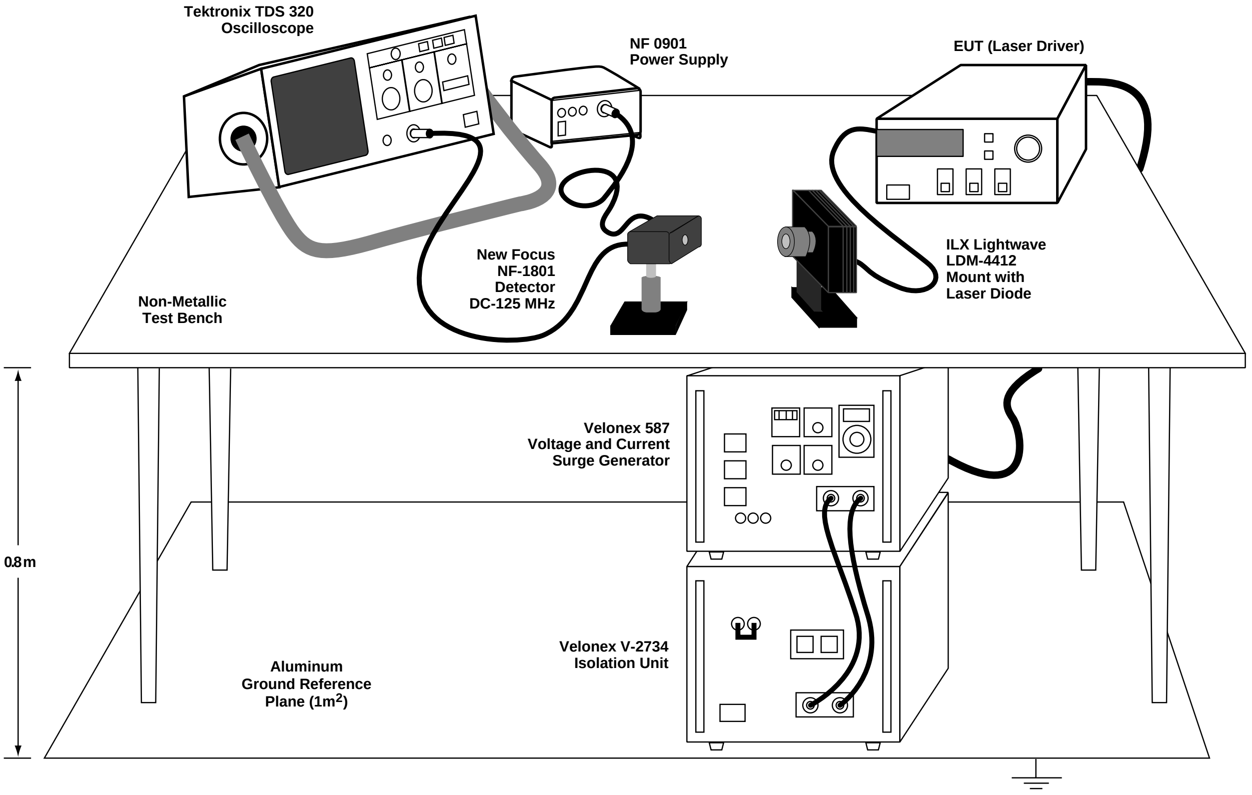

Figure 4 Basic transient test setup, illustrating optical isolation.

isolation transformer is used as part of the transient generator test setup.

A typical measurement error involves connecting the scope directly across the laser diode or test load. Measurement of transients in this way will cause tens of millivolts of transient voltage to be picked up on the scope input. This may lead to the conclusion that many milliamps of current are flowing into the low resistance load. In fact, the transient is picked up by the high impedance input circuits of the scope.

To measure the transient response of the EUT, a digital storage oscilloscope is adjusted to trigger just above the steady state (DC) photodiode voltage. The control transient is generated in the power line to the EUT and the scope records the resulting optical response.

The measurement system bandwidth is important in this measurement. A test setup bandwidth of 100MHz provides full transient detection without system risetime rolloff. To achieve this bandwidth, the diode bandwidth must be maintained through the transimpedance amplifier. Care must also be taken in the choice of photodiode. For our testing, the New Focus 1801 detector was used. This detector provides the required bandwidth and sufficient responsivity at the laser's wavelength.

Earth reference grounding is also important to eliminate stray coupling paths from static mats and cables. For this reason the IEC 801 test configuration is used (Figure 5).

This specification defines a ground plane, one meter square, as the ground (floor) reference plane. Reliable and repeatable testing is accomplished when these precautions are taken.

Another consideration in the test setup is the selection of laser diode. We use inexpensive 780nm T0-5 can laser diodes driven just above threshold. (Due to the nature of testing, the potential for damage to the laser diode is great. Although the ultimate goal is protection of laser diodes, we often test new instrument topologies with excessive transient voltages to determine failure levels.) Panasonic and ALPHA both make diodes suitable for this type of testing.

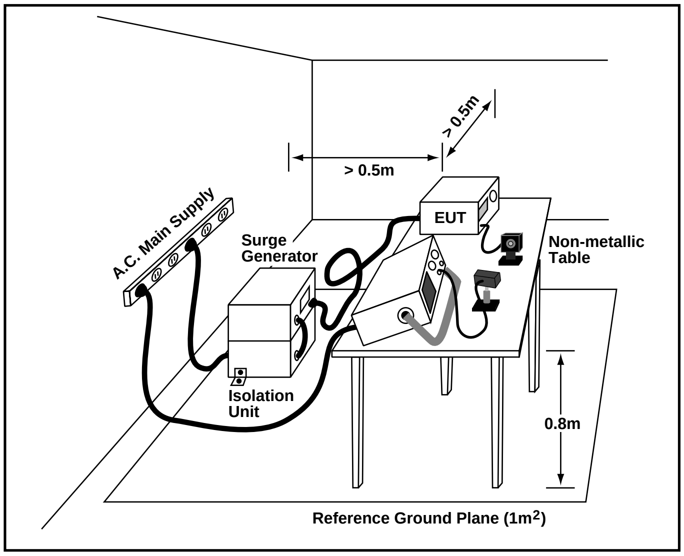

Figure 5 IEC 801 test configuration. Note ground plane.

System Calibration

The optical system must first be calibrated to obtain an accurate measurement of the light output of a laser and an accurate representation of the transfer ratio of laser drive current to light output.

The Equipment Under Test (EUT) is turned on and the laser diode is driven at a few milliamps above the laser threshold (the point at which lasing begins). The drive current is changed by 2 mA and the corresponding change in detector output is measured. This change in detector output divided by the change in drive input represents the measurement system's optical gain. This transfer gain is then used to calculate the surge current that results from the induced transient. This test setup is used for all classes of transient testing.

Operational Transient Test

Figure 6 illustrates the detailed test setup for measuring of all classes of transients. For operational transient testing the transient generator is not used. Control transients are initiated by changing EUT operational modes. Since the resulting transient can vary, five successive control transients are induced.

A turn-on transient is induced by turning the laser current source (EUT) output on (while connected to the test laser). Turn-off transients are induced by turning the

EUT output off, switching operational modes (on the EUT), and by turning off the AC power of the EUT while the laser is being driven.

The number of operational transient tests for a given EUT depends on the number of operational modes which may cause the current source control loop to change states. For each mode change, any resulting optical transient is measured. Using the calibrated optical transfer ratio (see “system calibration” above), an absolute measurement is made. The worst-cast transient (greatest peak amplitude) is recorded.

Our specifications for operational transients (as published in product literature) state that the absolute magnitude of the allowable maximum transient under all instrument control conditions will not exceed the specified value.

Surge Transient Test

For surge testing, a Velonex Model V-587 surge transient generator and Model V-2734 isolation unit are used to couple the surge transient directly into the AC power line of the EUT (figure 6). This generator is designed to produce a transient with the parameters specified in IEC 801-5. Note that the surge voltage used in testing is 1KV. The IEC 801-5 standard defines test conditions and specific requirements for transient coupling into all possible combinations of line inputs. It also requires that the transient be induced 5 times per coupling configuration.

As in the operational transient testing, the worst-case resulting optical transient is recorded. Our specification states that the induced surge transient, in all coupling modes, will not produce a laser current transient greater than the specified value.

EFT Test

For EFT Testing, the same setup is again used (figure 6). The EFT transient is generated, according to the IEC 801-4 specifications, using a Haefly Trench PEFT-JR EFT generator. This instrument is designed for compliance testing according to the IEC 801-4 requirements. This standard specifies a repetitive transient, along with an applied transient signal duration of one minute. The IEC-801-4 standard also defines the transient pulse profile (voltage level is 1KV), as well as the coupling modes, as described above. Under these conditions, the resulting optical pulse is measured. The specification for this type of transient indicates that under all coupling modes, the resultant current transient will be less than the specified value.

Test Results

The amount of test data accumulated during testing of a single instrument for each transient type and coupling mode is large. Not only is the pulse amplitude of interest, but often the waveform shape is useful in predicting laser susceptibility. In order to reduce the amount of data for this discussion, we have summarized our results as follows:

Operational Transient Test- The results of this test are listed in Table 1 under “Operational.” This number represents the greatest-amplitude drive current transient (worst case, in mA) measured under all Operational transient tests for a particular EUT.

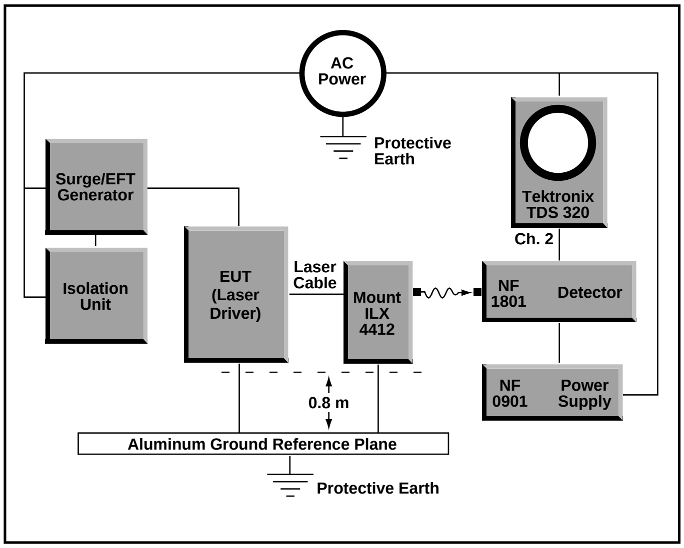

Figure 6 Transient Test Block Diagram

In most control situations, the operational transient response may be an over-damped exponential rise. This is considered a 0 mA transient. (Figure 7).
The operational function that typically generates a transient is at AC power-down (while the laser current output

is on). Figure 8 shows a resultant transient under this condition. Table 1 shows the worst case operational transient specifications for many of ILX Lightwave's laser current sources.

Surge Transient Test - The worst case transient for each injection mode is listed in Table 1, for all ILX Lightwave laser current drivers.

Oscilloscope traces in Figure 9 and 10 illustrate the resultant optical transient for two units. As shown by these graphs, the resultant amplitude and pulse shape can differ greatly between units. Resulting transient characteristics also tend to vary with coupling mode. ILX Lightwave specifications represent the worst case transient under all different injection modes for the Surge Transient test.

EFT Test - The EFT surge testing was conducted in compliance with the EC 801-4 requirements. In this standard a repetitive transient is specified, along with an applied transient signal duration. During the specified time interval (one minute) the worst-case resulting transient was recorded. The magnitude of this worst-case transient is listed in Table 1. Figures 11 and 12 depict typical resultant transients for ILX Lightwave products. As with the lightning surge transients, the mode of injection also affects the transient response. As expected, this type of transient is significantly faster that the surge transient response.

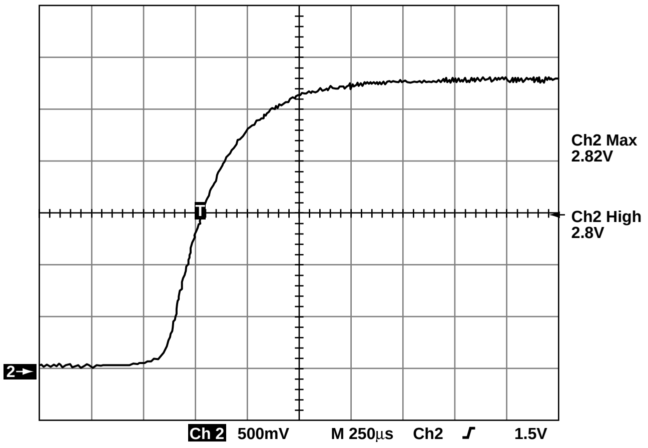

Figure 7 Operational turn-on transient test result. (LDX-3525)

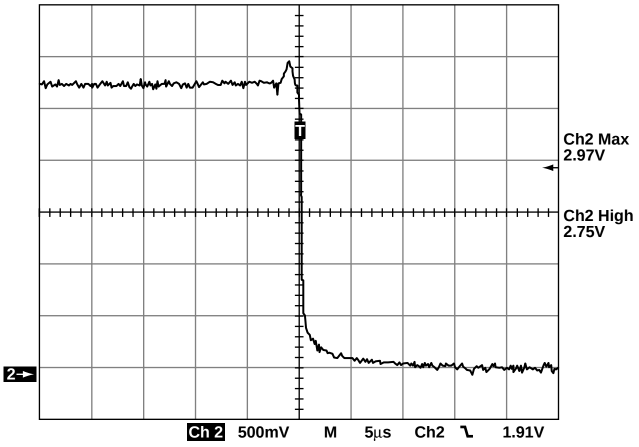

Figure 8 Operational turn-off transient test.
ΔI = .4 mA (LDC-3712)

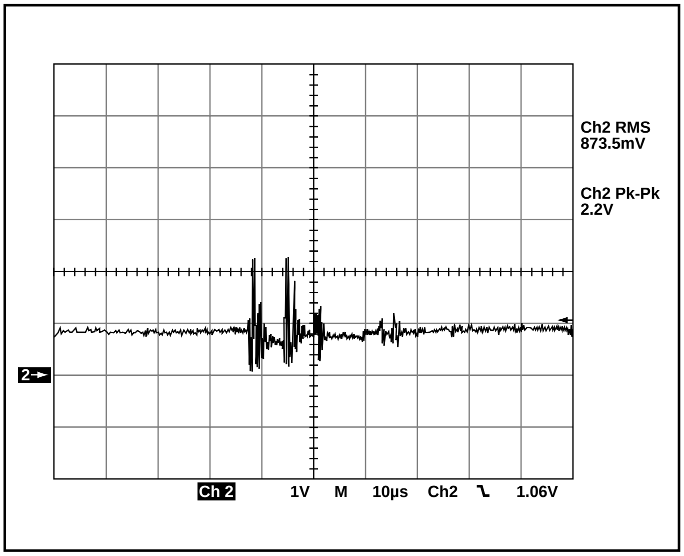

Figure 9 LDC-3712 surge response.
(1kV input surge - approx .5 mA /div.)

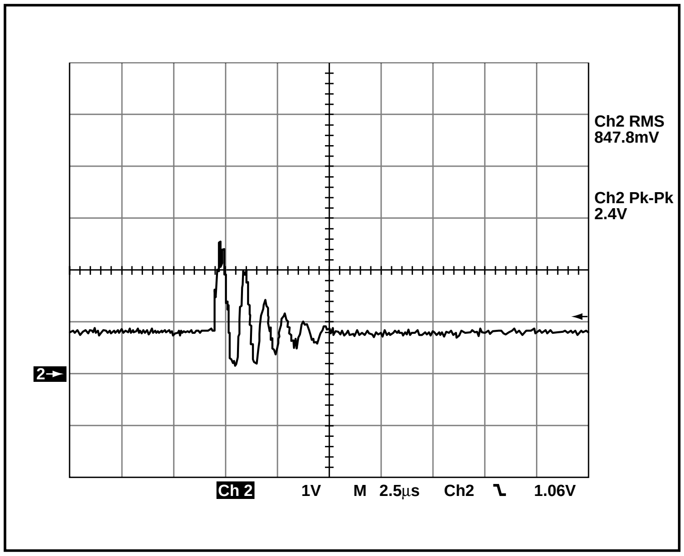

Figure 10 LDX-3525 surge response.
(1kV input surge - approx . 5 mA /div)

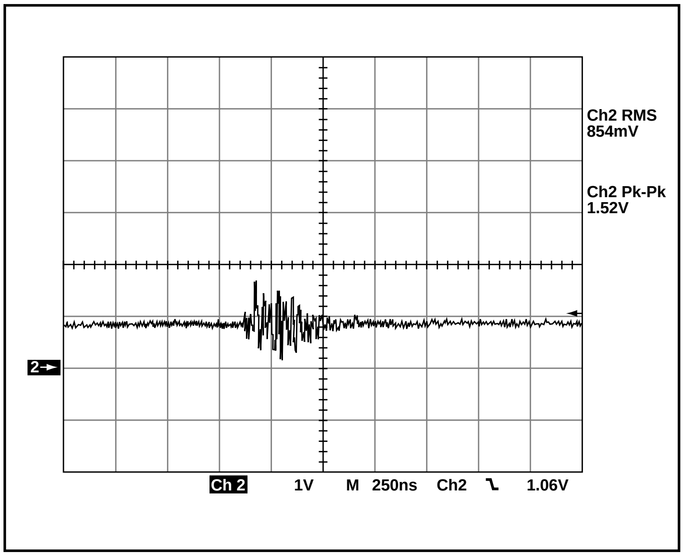

Figure 11 LDC-3712 EFT response
(1kV input surge - approx . 5 mA /div)

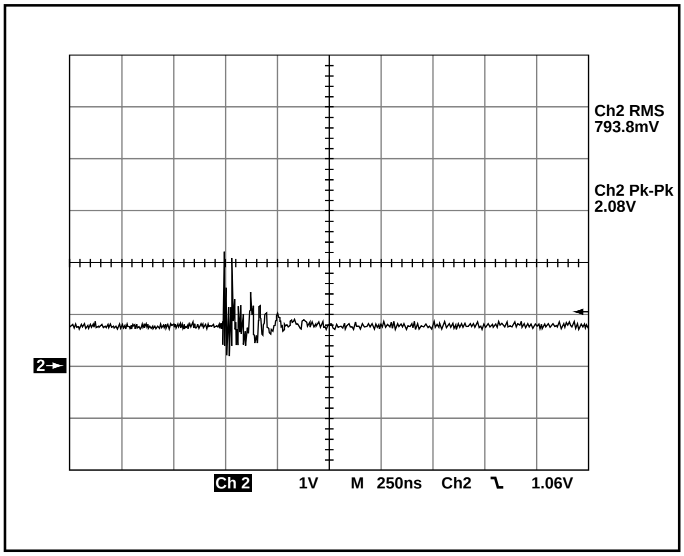

Figure 12 LDX-3525 EFT response.
(1kV input surge - approx . 5 mA /div)

Transient Test Data

Resulting worst-case output transient (mA)

		Input Transient	
Product	**Operational**	**EFT (1 kV)**	**Surge (1 kV)**
LDX-3525	0.3	7.6	7.1
LDX-3545	1.0	10.8	7.7
LDX-3565	2.5	9.5	7
LDC-3712	0.6	8	8
LDC-3722B	0.6	5.4	6
LDC-3742B	0.4	5.8	8.8
LDC-3900			
39010	0.4	4.2	7.5
39020	0.6	4.6	6.5
39050	0.6	4.2	6.7
39420	0.5	4.0	6.5
LDX-3207B	0.2	7.8	4.5
LDX-3412	0.1	11.7	2
LDX-3620	0.1	20	20

Table 1. Results of transient tests performed on various ILX Lightwave laser diode current sources and controllers, as defined by this document. Data represents worst case output transients (mA) from regular production-run instruments.

Summary

A thorough procedure for evaluating the effectiveness of power-line transient suppression of laser diode drivers has been presented. This procedure includes tests for suppression of three classes of electrical transients — operational, surge, and EFT. These transients are based on and defined by appropriate IEC transient standards. Test system parameters and calibration, and procedures for testing each class of transient is described. Test results for several ILX Lightwave laser diode current sources is also presented with transient suppression specifications for these instruments.

A well-defined test method is required to demonstrate the usefulness, validity, and limitations of laser driver instrumentation and its ability to suppress power-line transients. Only with accurate, repeatable data can useful decisions be made regarding the effectiveness of instrumentation and setups on transient suppression. The above testing represents a thorough, repeatable test methodology, by which laser protection strategies can be evaluated. We believe that exhaustive testing that addresses the specifications of laser diode protection is useful. To this end, we at ILX Lightwave strive to do everything possible to help protect laser diodes.

Special Note

Requirements for laser diode protection are complex. Furthermore, there are many varying modes of transient coupling and diode configurations. For these reasons, the entire laser control system must be taken into account when determining the actual transient response. Even if the laser driver does not generate a transient, other transient coupling paths usually exist. The laser diode mount and cable, as well as the laser current source must be considered as a system.

To address these issues, ILX Lightwave has created Application Note #3, *Protecting your Laser Diode*. This application note provides general guidance, and includes information on the effect of setup and configuration issues in regard to protecting a laser from the types of transients discussed in this document.

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rev. 3/27/03