Artifex
Engineering

Application Note

Heating of Laser Bars During Testing with the LIV 100

The LIV100 is designed for measuring the electro-optical characteristics of laser diodes. This is done by generating a staircase of increasing drive currents and measuring the voltage drop as well as the optical output power of the laser for each current.
For accurate measurement it is therefore imperative that the set current be well defined during the period of the measurement. This means that the current pulses must be “rectangular” in shape with a flat and suitably long plateau region.
Low overshoot is not explicitly necessary for accurate measurement, but is desired in order to not damage the device under test (DUT).

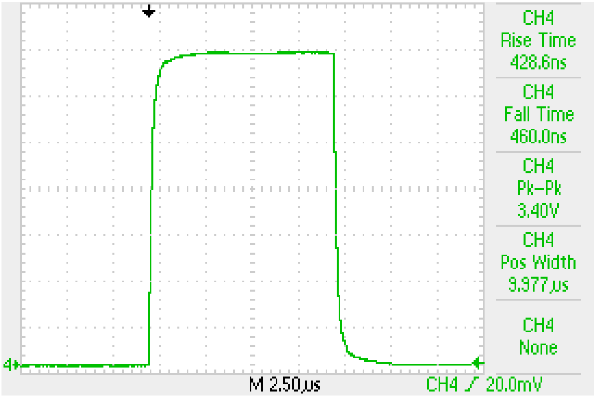

Fig. 1: 10μs, 200A pulse from an LIV100-L200

The choice of pulse duration is important to ensure that the measurement results will be indicative of conditions relevant to the final product.
In general, we can assume that the final product will be designed with sufficient cooling capacity so as to allow operation of the laser at a specific, well defined temperature.

Fig. 2: CS-mount laser diode: efficient thermal extraction

Therefore, during device testing at the unmounted level, the pulse duration should be chosen so as to minimize heating of the DUT while allowing a long enough pulse for accurate measurement.

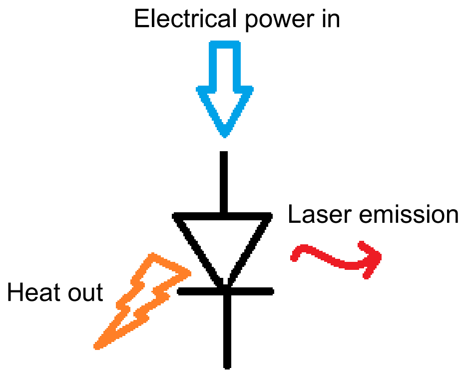

Fig. 3: Schematic illustration of power flow in a laser diode

Typically a laser diode in the NIR will shift in wavelength approximately 0.2-0.3nm per °C temperature change.

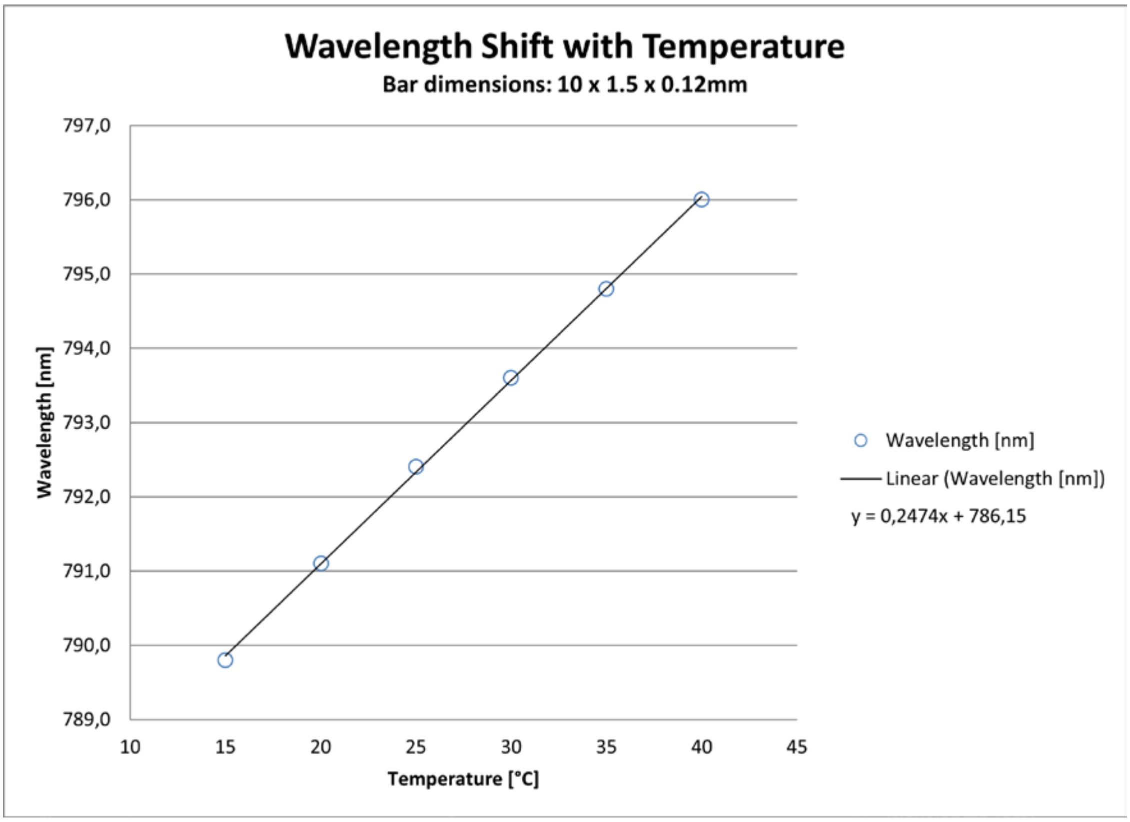

Fig. 4: Measured data for the wavelength shift with temperature of a laser bar

This data was measured by obtaining the spectrum via a fast diode array spectrometer using short pulses (1µs) to avoid any significant heating of the laser bar during the pulse. The temperature of the thermal support chuck was controlled to <0.02°C by a TEC controller.

The slope efficiency of a laser diode is relatively unaffected by temperature for small temperature changes. However, the threshold of the laser diode will increase approximately 3mA/°C. Due to this, the output power of the laser will drop with increasing temperature at a given drive current. Finally, physical damage to the laser diode due to an abrupt thermal expansion during a current pulse may occur.

Therefore, before beginning a test sequence, the operator should consider the maximum temperature rise which could be accepted during the measurement. From the above considerations, a temperature increase of 1°C seems to be a reasonable compromise.

Consider a typical GaAs laser bar of dimensions 10 x 1.5mm and 100μm thickness, coated with gold contacts of 10μm thickness each for a total thickness of 120μm.

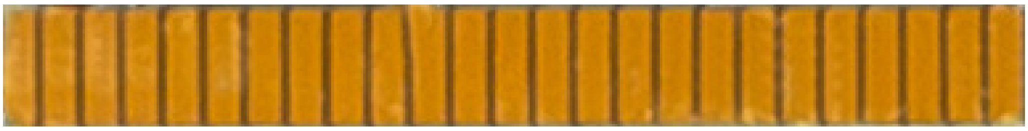

Fig. 5: Typical high power laser bar showing gold coated anode contacts

The relevant physical data are:

$Cp(GaAs) = 0.33\ Jg^{-1}C^{-1}$
$\rho(GaAs) = 5.32\ gcm^{-3}$
$Cp(Au) = 0.13\ Jg^{-1}C^{-1}$
$\rho(Au) = 19.3\ gcm^{-3}$

The total heat capacity of the bar is therefore:

$0.33\ Jg^{-1}C^{-1} \cdot 5.32\ gcm^{-3}\ (1.0 \times 0.15 \times 0.01)cm^3 + 0.13\ Jg^{-1}C^{-1} \cdot 19.3\ gcm^{-3}\ (1.0 \times 0.15 \times 0.002)\ cm^3 = 3.4mJC^{-1}$

The temperature rise due to the sudden injection of heat from a current pulse is given by

$$\triangle T = {}^{E_{pulse}}/_{C_{p,bar}}$$

Rearanging this equation and assuming a perfectly rectangular shaped pulse, the maximum pulse duration is given by

$$\tau_{pulse} = \frac{C_{p,bar} \times \triangle T}{I_{laser} \times V_{laser}}$$

Consider, for example, driving 80A with a voltage of 2V across the laser bar. If the temperature rise is to be limited to 1C during the pulse, then the maximum pulse duration is given by

$$\tau_{pulse} = \frac{3.4mJC^{-1} \times 1C}{80A \times 2V} = 21\mu s$$

Note that the fact that the laser wavelength correlates with temperature allows us to measure the temperature within the laser diode itself – even on a µs timescale during the actual laser pulse. Measurement results from such as laser bar are shown in Fig. 6 below.

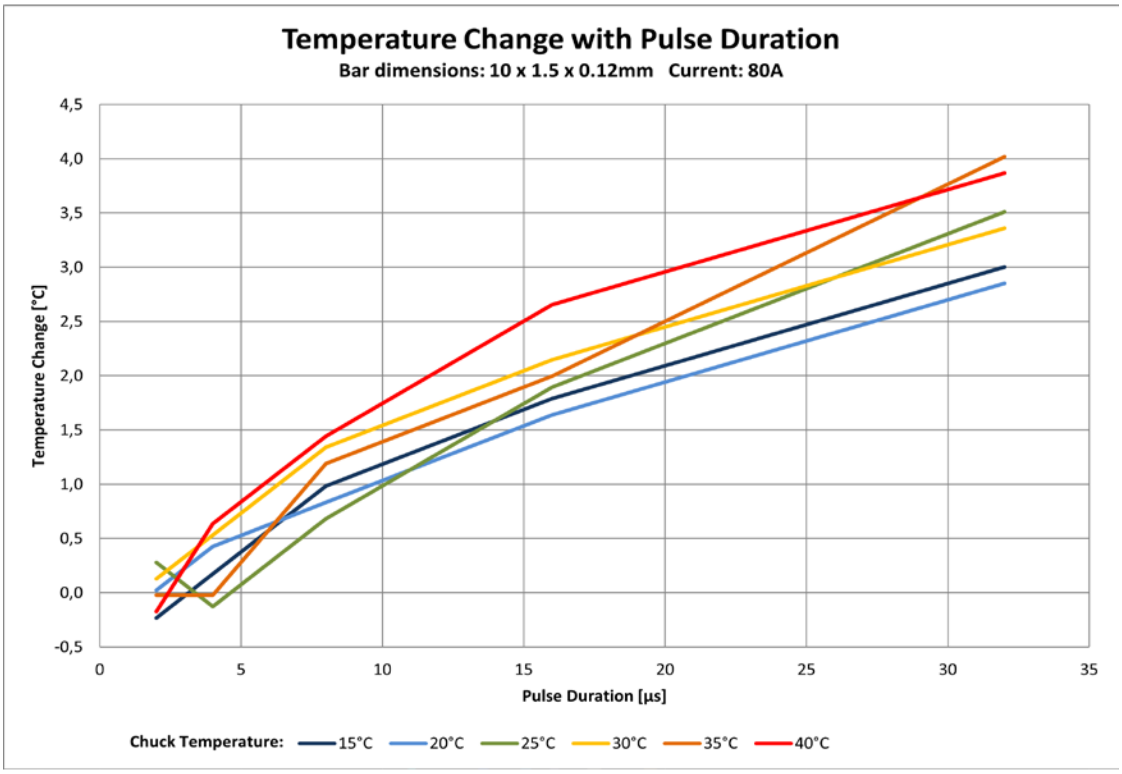

Fig. 6: Measured data for the temperature rise of a laser bar vs. pulse duration at a fixed drive current of 80A

The temperature rise is roughly a linear function of the pulse duration, as expected. Also the temperature rise depends on the initial temperature of the laser which should be taken into account in practical applications. From the data above, the operator should limit the pulse duration to about 10µs at room temperature for these 80A pulses.
Clearly, single emitters under these conditions would require sub-µs pulses. For example, the bar shown above has a total of 25 emitters. Therefore when testing single emitters diced out of this bar, the pulse duration should be limited to

The LIV100 F-series from Artifex Engineering produces current pulses as short as 150ns. From the above considerations it is clear that shorter pulses are not required when considering the effect that heating of the laser diode will have on the results of the LIV measurement. On the contrary, it is best to use pulses as long as possible (without heating) in order to receive as many measurement data points within each laser pulse as possible. This increases the signal-to-noise ratio of the measured data for more reliable results.

Take Aways:

When testing high-power laser bars and chips, the pulse duration should be chosen to be the longest possible, without undue heating of the device under test. Typically this means:
~10µs for bars
~500ns for single emitter chips