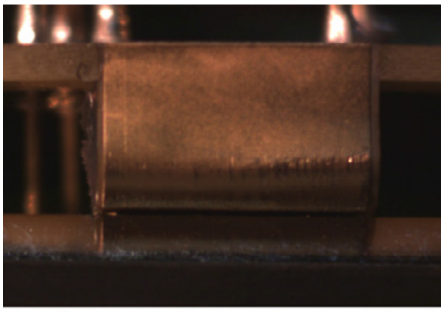
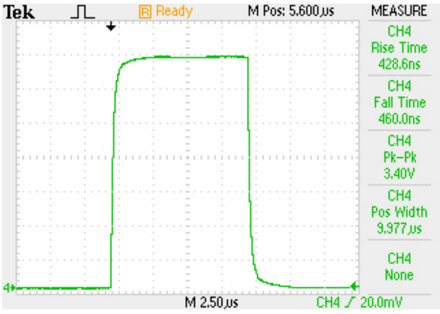
Considerations for Laser Contacting

Preliminary Considerations:

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.

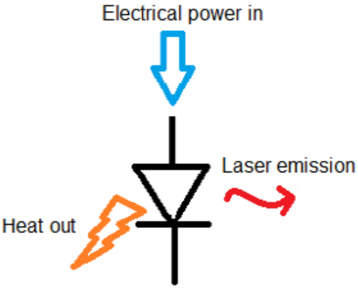




For accurate measurement it is therefore imperative that the set current be well defined during the period of the measurement. This means that the current pulses must be “rectangular” in shape with a flat and suitably long plateau region. Low overshoot is not explicitly necessary for accurate measurement, but is desired in order to not damage the device under test (DUT).

Pulse Duration:

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.
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.



Pulse Duration:

Consider a typical GaAs laser bar of dimensions 10 x 2mm and 100μm thickness, coated with gold contacts of 20μm thickness each.

The total heat capacity of the bar is therefore:

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

$0.33\ Jg^{-1}C^{-1} \times 5.32gcm^{-3}\ (1.0 \times 0.2 \times 0.01)cm^3 + 0.13\ Jg^{-1}C^{-1} \times 19.3\ gcm^{-3}\ (1.0 \times 0.2 \times 0.004)cm^3$

$= 5.5mJC^{-1}$

The maximum pulse duration is given by

$$\tau_{pulse} = \frac{C_p \cdot \Delta T}{I_{laser} \cdot V_{laser}}$$

Consider, for example, driving 200A 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

$$\tau_{pulse} = \frac{5.5mJC^{-1} \cdot 1C}{200A \cdot 2V} = 14\mu s$$

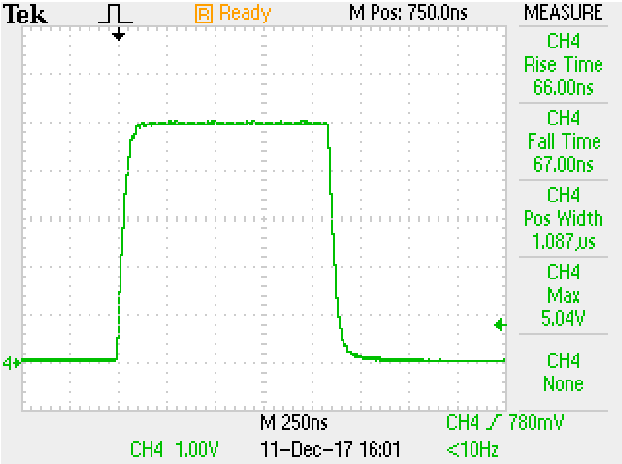
Clearly, single emitters under these conditions would require sub-μs pulses.

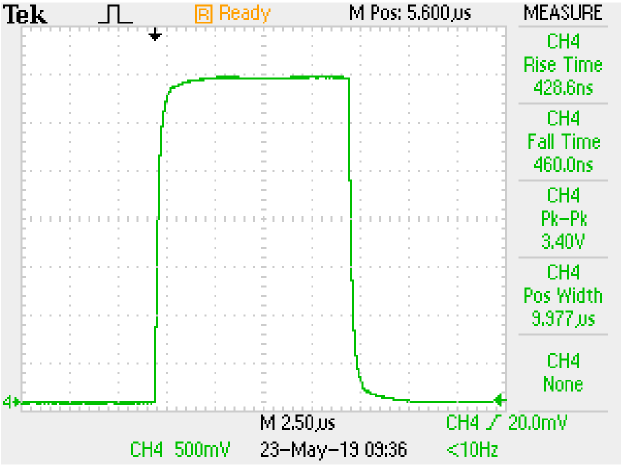
Rise Time:

Having established that the pulse duration must be on a μs time scale, it is apparent that the rise time of the pulses must be short.
However, it is technically not trivial to produce clean, rectangular pulses at high currents with short rise times. The problem lies in inductance.
Inductance opposes change in current by building up an opposing voltage according to the following law:

$$V_{ind} = L\frac{dI}{dt}$$

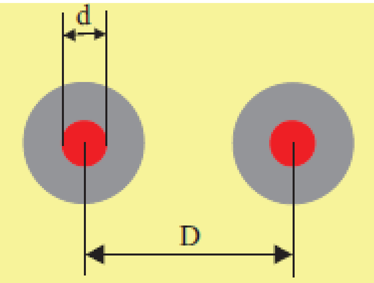
where L is the inductance. This voltage reduces the amount of compliance available to drive the laser diode.
Consider the two examples of pulses at the right.
The upper figure depicts a 10A pulse with 66ns rise time. The lower figure is a 200A pulse with 430ns rise time.



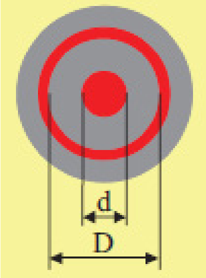


Inductance:

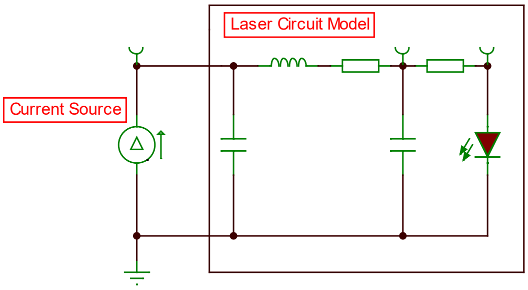
Any electrical device will have some amount of inductance associated with it. Laser diodes have inductances typically in the low nH range.
Furthermore, any electrical connection is also inductive to some extent.
Typical electronic connection configurations are pairs of single wires or coaxial cables. The inductance of these are given as follows:



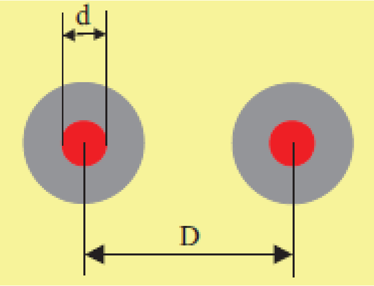
$$\frac{L}{[m]} = \frac{\mu_0}{\pi}\cdot\ln\left(\frac{2\cdot D}{d}\right)$$



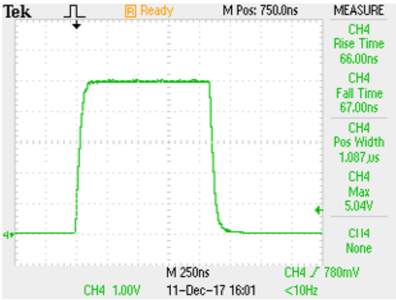
$$\frac{L}{[m]} = \frac{\mu_0}{2\cdot\pi}\cdot\ln\left(\frac{D}{d}\right)$$



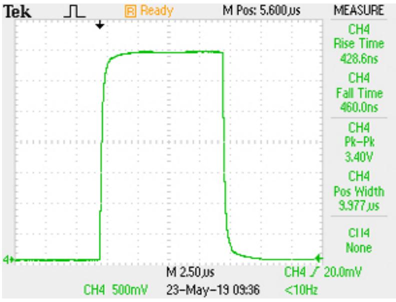
The following values in red show the loss of compliance due to inductance:



d = 0.8mm
D = 3mm
Length: 100mm

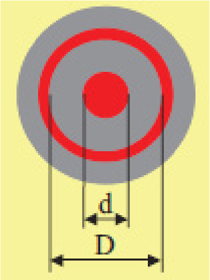


$$V_{ind} = 80nH\frac{10A}{66ns} = \mathbf{12V}$$

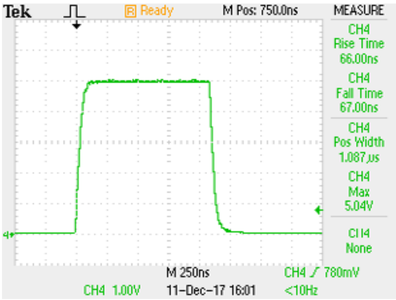


$$V_{ind} = 80nH\frac{200A}{430ns} = \mathbf{37V}$$

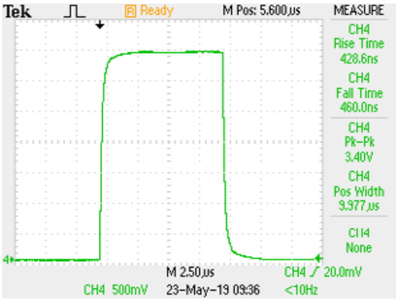
RG58



d = 0.81mm
D = 2.9mm
Length: 100mm



$$V_{ind} = 25nH\frac{10A}{66ns} = \mathbf{4V}$$

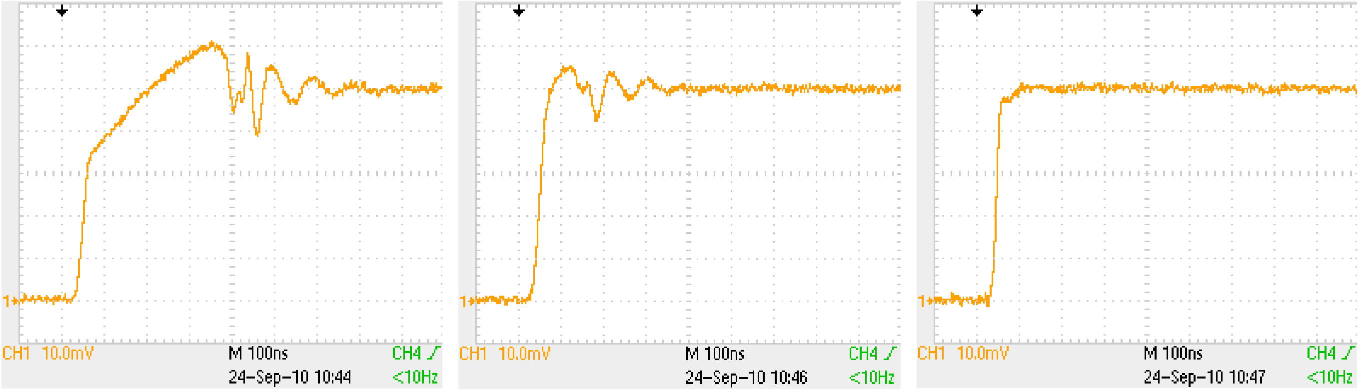


$$V_{ind} = 25nH\frac{200A}{430ns} = \mathbf{12V}$$

Compliance:

The loss of compliance due to inductance results in poor regulation of the laser driver.
This leads to longer transients, overshoot and oscillation. Such effects may reduce the accuracy of the measurement or even damage the DUT.

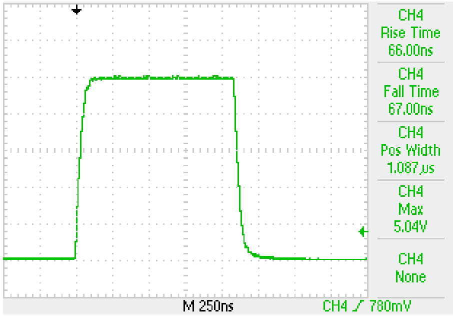
Below are traces of the current transient of 100A pulses at increasing levels of voltage overhead.



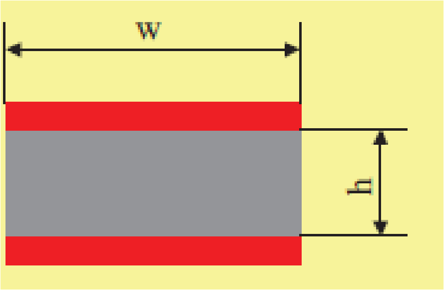
Inductance:

Apparently coaxial cable will only be useful for relatively low currents. Single isolated wire contacts are essentially useless.
There are however, designs for very low inductance electrical transmission. One of the simplest is the strip line. The values given below correspond to standard connector cards from Artifex Engineering.

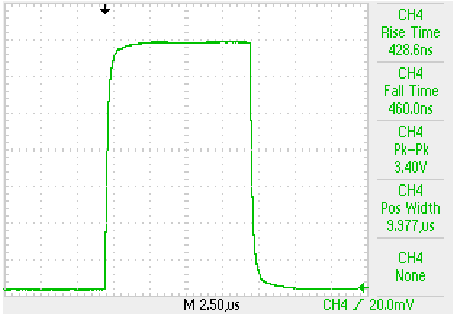
w = 45mm
h = 1.6mm
Length: 50mm



$$V_{ind} = 2nH\frac{10A}{66ns} = \mathbf{0.3V}$$



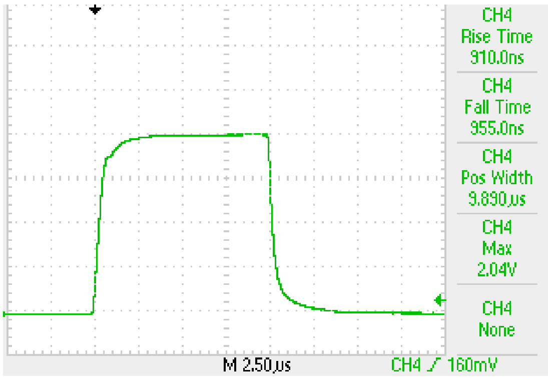
$$\frac{L}{[m]} = \frac{\mu_0}{\frac{w}{h} + 2{,}64 - 0{,}49\frac{h}{w} + \left(1 - \frac{h}{w}\right)^6}$$



$$V_{ind} = 2nH\frac{200A}{430ns} = \mathbf{1V}$$

Compliance:

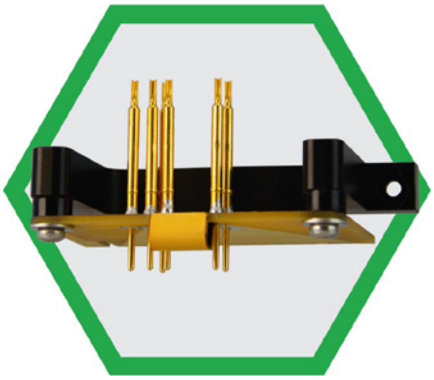
Note that flex board strip lines are even better than solid PCB strip lines since the two layers are closer together which lowers the inductance even further.
Below is an example of a 400A, 900ns rise time pulse transmitted through a 260mm long flex strip line.



Low inductance braided cables are also available for cases where strip lines are impractical.

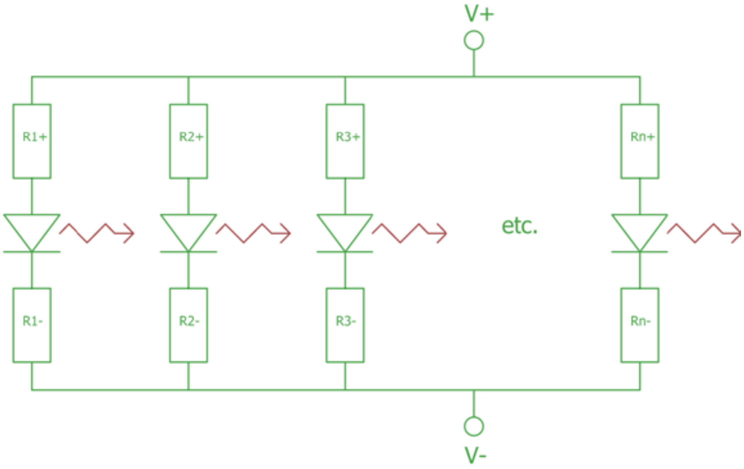
Full Bar Contacter:

Strip line card with gold foil contact strip.
The contact strip is filled with a stiff but resilient polymer mass.
Pogo pins provide the return current path from the device chuck.



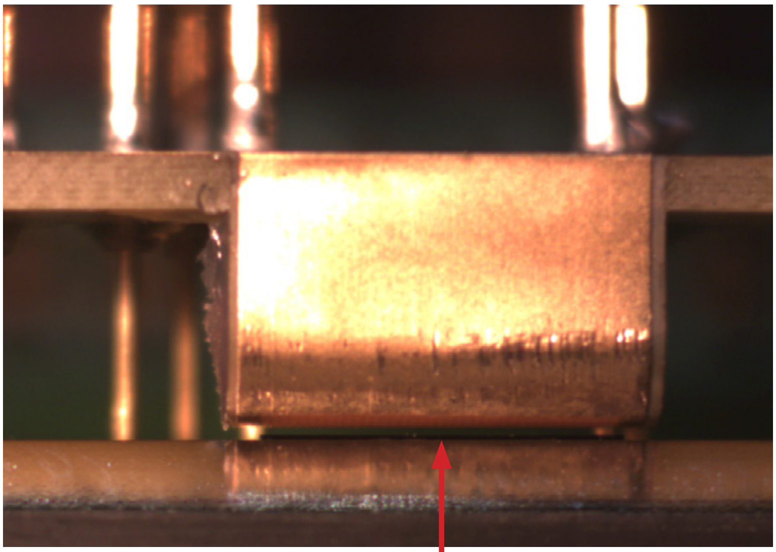
Full Bar Contacter:

Note that when contacting full bars with a strip line, the emitters are being contacted electrically in parallel. Therefore, the voltage is constant across the length of the bar.
Because of this, even if the emitters are well matched with regard to their IV-characteristics, the current through each emitter will depend on the variation of the contact resistances Rn.

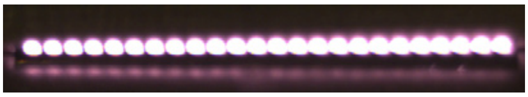


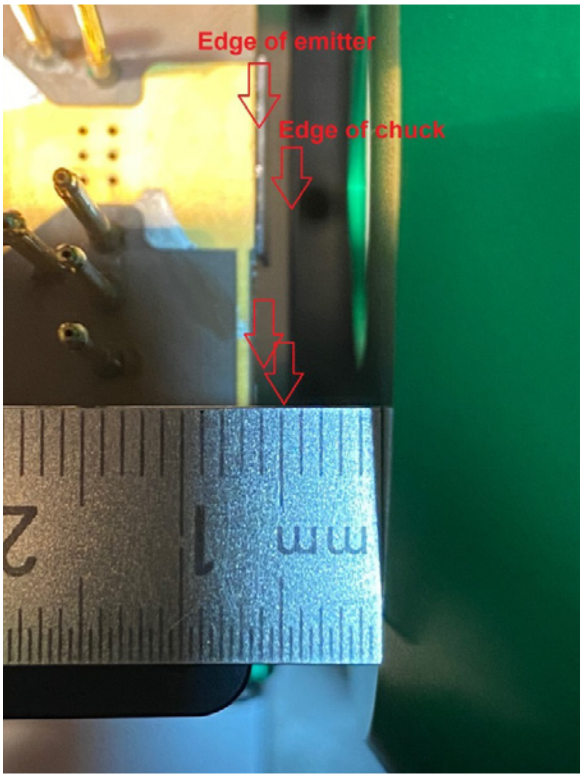
This will affect the power emission consistency from one emitter to another.

Full Bar Contacter (Front View):

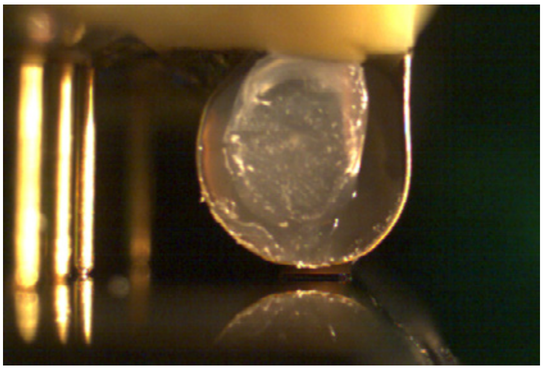


It is very important that the contact strip is aligned parallel to the surface of the laser bar!
This ensures that all emitters will be contacted with equal pressure.

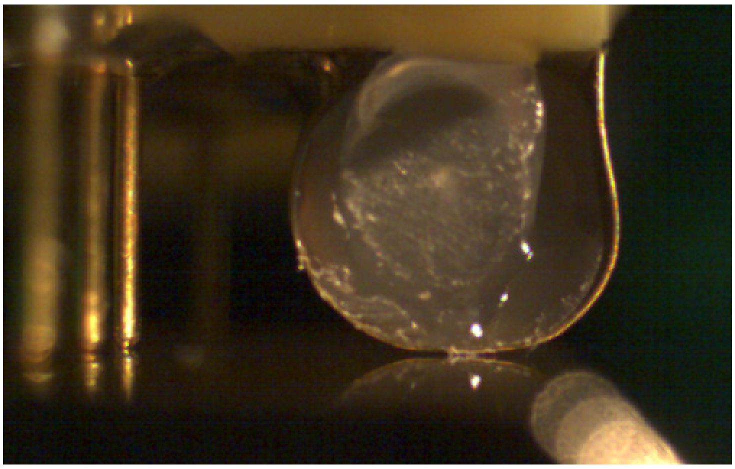




Full Bar Contacter (Side View):



The contact point should be behind the middle ….



… so that when the contact strip deforms under pressure, it will not block the laser beam at the front facet.

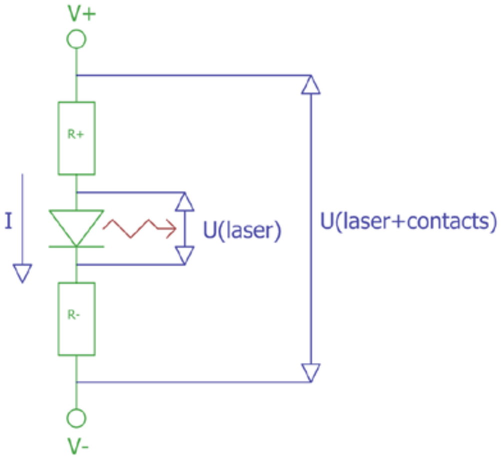
A suitable amount of force on the order of 1000cN is required to ensure a stable contact with low contact resistance.

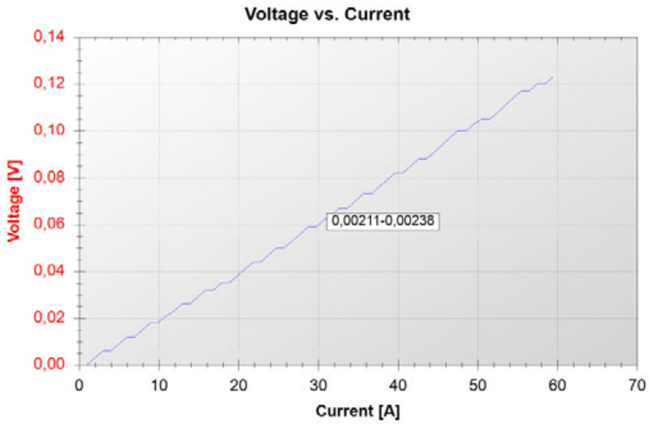
Contact Resistance:

The full bar contacter has an inherent fault in the voltage measurement. The contact resistance between the contact foil and the laser (R+) as well as the resistance between the n-contact of the laser and the chuck (R-) both contribute to the voltage measured. Thus, the real voltage across the laser is unknown.

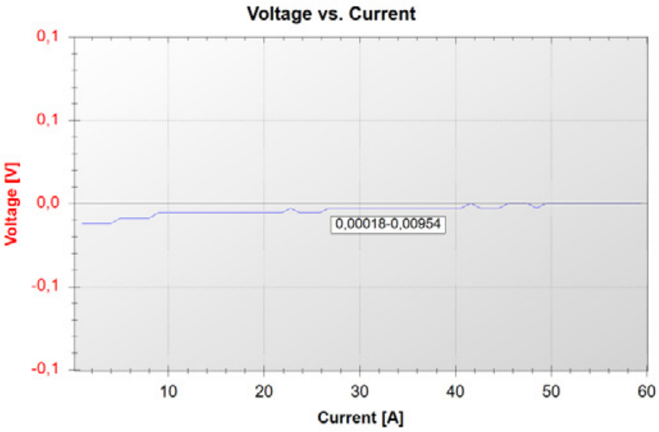
This error can be quite large when testing lasers at high current. For example, a 1mW contact resistance results in 200mV error at 200A drive current.

The full bar contacter is an example of a 2-point contact. For single emitters we offer 3-point and for VCSELs 4-point contact cards.





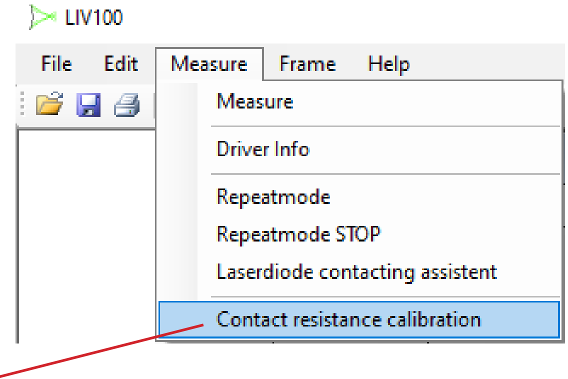
Full bar contacter onto bare vacuum chuck.
Equivalent to 3-point contact (no diode present).
Measured contact resistance = 2.1mΩ.

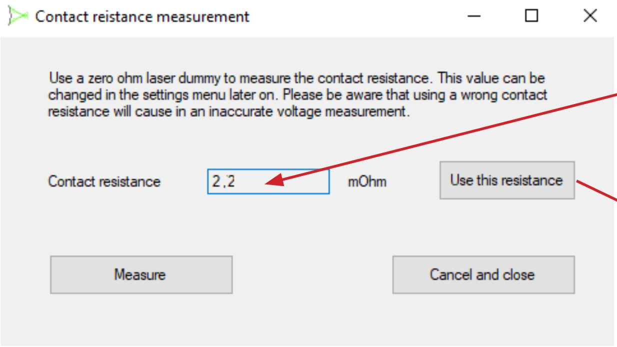


Needle card onto bare vacuum chuck.
Equivalent to 4-point contact (no diode present).
Measured contact resistance = 0.2mΩ.

The LIV100 has a routine for measuring the contact resistance in order to overcome the drawbacks of 2-point and 3-point contact cards.

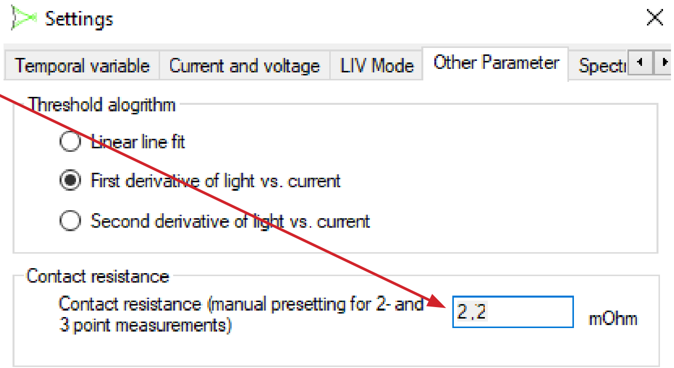
Using this feature, the LIV software will correct all voltage measurements thus removing the effect of contact resistance from the voltage-vs-current data for the laser diode under test.





Use a zero ohm laser dummy to measure the contact resistance. This value can be changed in the settings menu later on. Please be aware that using a wrong contact resistance will cause in an inaccurate voltage measurement.

Contact resistance 2,2 mOhm



Threshold alogrithm

○ Linear line fit

● First derivative of light vs. current

○ Second derivative of light vs. current

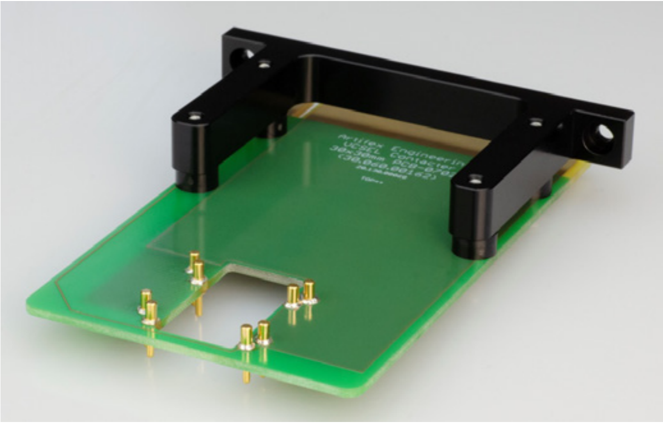
Contact resistance

Contact resistance (manual presetting for 2- and 3 point measurements) 2,2 mOhm

Further Examples of Contact Cards:

Needles for single emitters
(3-point contact)

Needles for VCSELs
(4-point contact)



Pogos for high power VCSELs (4-point contact)

Contact Assistant:

The LIV100 firmware supports implementation of a contact assistant. This feature is available in the GUI supplied with the device. The measurement algorithm is to drive a small current through the laser (0.125% of the max. current of the LIV unit) and measure the voltage across the device.

For applications via direct communication, the following protocol is required:

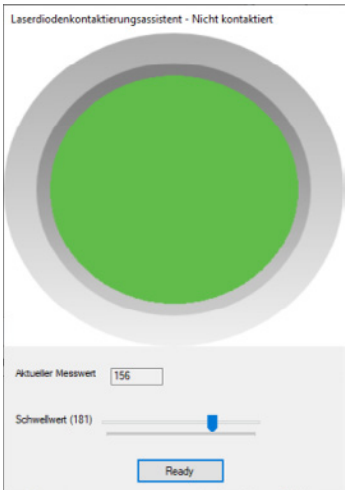
- Initiate operation: @C
- Send to measure voltage (within 200ms of previous command): Byte 234
- Echo: Byte 234
- Answer: $256 - \frac{V_{measured}}{V_{supply}} \cdot 100$

If the laser is not contacted,
the result will be

$V_{measured} \approx V_{supply}$

which results in a response ≈ 156.

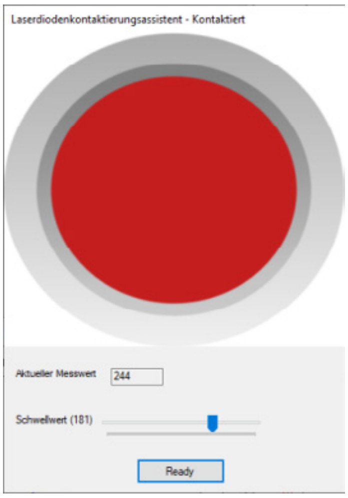
If the laser is contacted, the measured voltage will drop to the laser forward voltage and so the result will jump up to a value nearer to 256.



Laserdiodenkontaktierungsassistent - Nicht kontaktiert

Aktueller Messwert 156

Schwellwert (181)



Laserdiodenkontaktierungsassistent - Kontaktiert

Aktueller Messwert 244

Schwellwert (181)

Take Aways:

- Single emitters typically require sub-µs pulses.
- Bars can handle on the order of 10µs pulses at high current.
- Use strip line conductors where possible.
- If strip lines are not possible, use low inductance “braided” cables.
- Flexible strip lines are even better than solid PCB strip lines.
- Check with a camera for even distribution of emission from all emitters of bars.
- Use 4-point contacting where possible in order to minimize voltage measurement errors.