LIV-testing with SpecWin Pro

For the electrical and optical characterization of laser diodes, various electronic and optical measuring instruments have to be combined. Use in the laboratory environment places special demands on the flexibility and the available measurement scope of the equipment. With SpecWin Pro software application, Instrument Systems offers a comprehensive analysis tool for the optical characterization of laser diodes. The software is the central interface for optical and electrical measurement instruments as well as for data analysis and graphical display of results. With its flexible and modular structure, the software brings together everything needed for optical laser diode testing, eliminating the need for expensive software development. In the following, the basic structure of laser diode electrical and optical characterization system is described and typical measurement results are presented using VCSEL samples.

APPLICATION
NOTE

\\ 1. SYSTEM DESCRIPTION

Determination of electronic parameters as well as the optical characterization of laser diodes play a major role in the different steps of the manufacturing process as well as in diverse R&D tasks. A common system for determining basic optical parameters, e.g. peak / centroid wavelength or the radiant power, consists of an integrating sphere in combination with a high-resolution spectroradiometer. The complete system should be calibrated to assure correct and traceable radiometric results. A photodiode with fast response time allows short overall measurement times – which are important in production environment – and an investigation of the temporal waveform when the laser diodes are operated in pulsed mode. Furthermore, and depending on the specific application, it may be necessary to confirm the optical properties at a specific temperature or over a specified temperature range, e.g. when light modules are used in automotive applications. This can be accomplished by using a TEC-element attached to the DUT. Figure 1 depicts relevant hardware equipment necessary for optical laser diode inspection and testing. An additional auxiliary light source attached to the integrating sphere can be used to correct for self-absorption effects of the device under test (DUT).

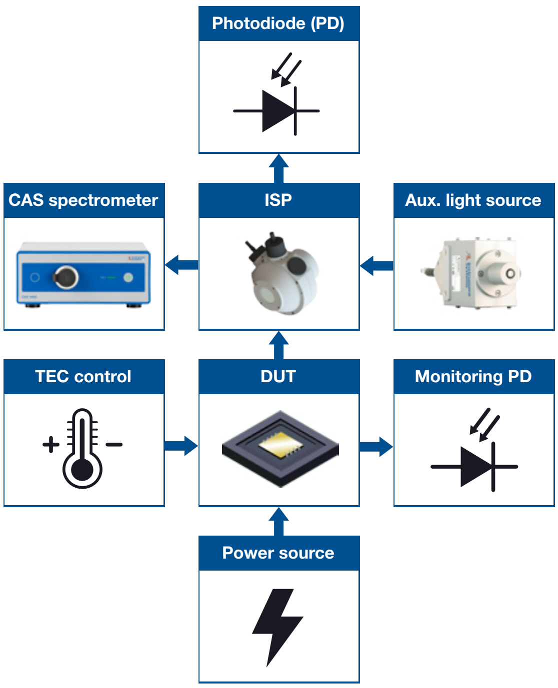

Figure 1: LIV system hardware configuration.

\\ 2. POWERFUL SPECWIN PRO SOFTWARE

The SpecWin Pro software enables comprehensive optical characterization of laser diodes by integrating the necessary measuring instruments in one software solution. SpecWin Pro is a very powerful and easy to handle light measurement application, developed for Instrument Systems high-end spectroradiometers. In addition to the control of various source-measure-units (SMUs), up to two photodiodes can be read out via digital multimeters (DMM) and the temperature of the DUTs can be precisely controlled via a TEC controller. The precise synchronization of the equipment is ensured by use of a hardware trigger, controlled by the software.

SpecWin Pro is the key for all advanced features of Instrument Systems' spectrometers and light measurement technology. Application-specific modules make sure that all relevant information is easily accessible and clearly displayed. The Spectral Analysis module (see figure 2) is the central measurement window for optical testing and control of the connected hardware. The Commander module allows easy programming of more complex measurement sequences with a graphical display of the results and data export. It accesses the Spectral Analysis module for execution of the measurement. For further analysis of the sequence data, the results can easily be transferred to the Spectral Analysis window with just one click.

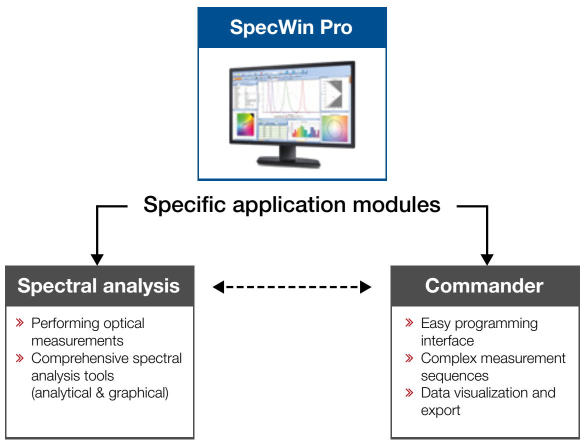

Figure 2: SpecWin Pro software and application modules.

2.1 DC test and LIV-testing of laser diodes

Typical specifications required for laser diode testing are supported by the Instrument Systems measurement system. Operating modes including DC, Single Pulse, and Continous Pulse are available enabling measurement repeatability testing and validation.

The most common subset of the direct current (DC) parameters can be measured in a test known as the “LIV test sweep”. LIV-curves are a fast and inexpensive method to identify failed laser diodes early in the test process. The LIV-curve is basically a combination of two curves, the L/I curve and the V/I curve. The L/I curve plots the drive current (I) applied to the laser diode against the optical light intensity L. This curve is used to determine the operating point and the threshold current. The V/I curve plots the drive current (I) against the voltage drop across the laser diode. LIV-curves are usually measured using a spectroradiometer in combination with an integrating sphere and an SMU for the required drive current. Depending on the type of laser diode or application specific requirements, different types of SMUs might be necessary. For example, some VCSELs require testing with short current pulses in the microsecond range to limit self-heating. To shorten measurement times, the photodiode attached to the ISP can be used to acquire LIV-curves as well. Figure 3 shows a typical LIV-curve of a single VCSEL emitter. The data are taken using the Commander module in SpecWin Pro.

2.2 Slope efficiency and kinks – indicators for VCSEL defects

For further analysis it is typical to use derivative curves calculated from LIV-data sets. The most commonly used derivative is the first derivative dL/dI, the instantaneous slope efficiency. From this curve the linear range of the diode and the slope efficiency can be determined. When currents are too high, the L/I curve usually deviates significantly from the linear behavior at some point. Typically, the maximum operating current is specified so that it is still in the linear range. In addition, a kink analysis is often carried out throughout the applied current range, as it is extremely sensitive to non-linearities. Anomalies (“kinks”) in the first derivative in the linear range indicate defects in the VCSEL. During early production it is therefore important for laser diode characterization to capture these undesirable phenomena as early as possible to improve production yield.

Figure 4 shows the L/I-curve of a 2D VCSEL array (blue line) together with the slope efficiency (red line). Important to note here is, that the noise may bury the kink phenomena on the characteristics if the LIV-curve is taken under too much measurement noise. Thus, it is very important to choose a suitable sweep current step size in order not to miss any kink phenomena and to keep the measurement noise as low as possible.

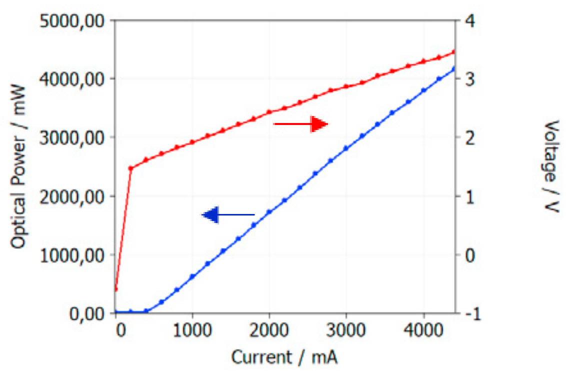

Figure 3: LIV-curve of a 2D VCSEL array.

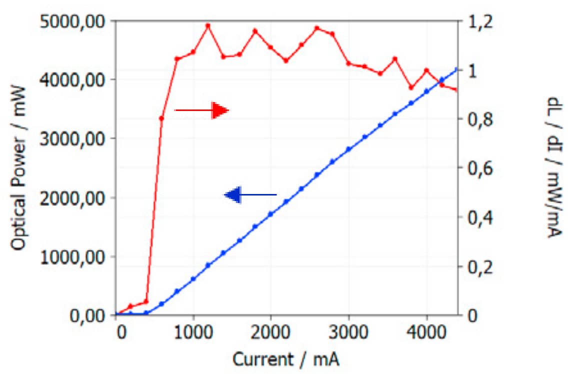

Figure 4: Slope efficiency (red line) derived from the LI-curve (blue line) to capture kink phenomena.

The data in Figure 4 are determined using an Instrument Systems spectroradiometer. For the “kink analysis” usually the photodiode attached to the ISP is used to determine the optical power as it allows a much faster measurement speed.

2.3 Threshold current

There are several ways to find the threshold current of laser diodes. SpecWin Pro supports the most commonly used technique: calculate the second derivative of the L/I-curve, d^2L/dI^2 and then determine the maximum of this second derivative curve. Figure 5 shows the second derivate (red line) together with the L/I-curve. A clear maximum can be observed. For an exact determination of the threshold current, however, a significantly higher data point density is necessary. To avoid long measurement times, the use of a photodiode is recommended to capture the optical power.

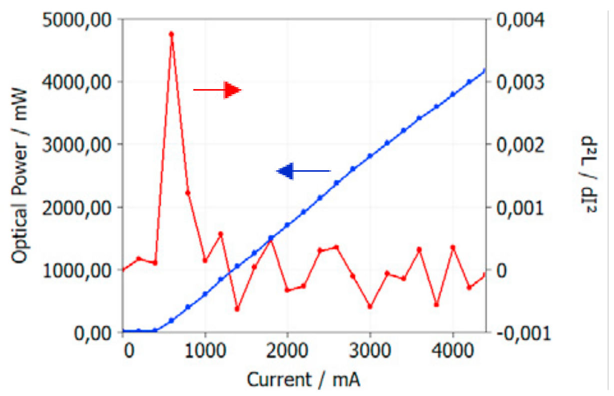

Figure 5: Second derivative (red line) derived from the L/I-curve to determine the threshold current.

2.4 Optical characterization

SpecWin Pro offers a comprehensive selection of spectral analysis tools. Important results for the optical characterization of laser diodes are typically radiant power, peak wavelength and FWHM. Figure 6 shows the evolution of a VCSEL spectrum with increasing drive current (upper graph) together with the peak wavelength over applied drive current (lower graph). Starting from the threshold current, a shift in the peak wavelength from around 942.2 nm to 944.0 nm can be observed.

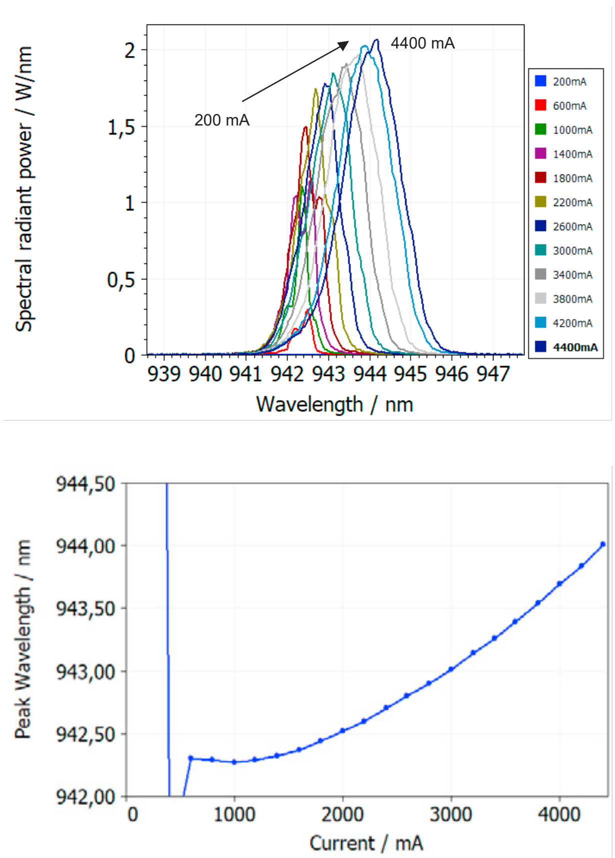

Figure 6: Evolution of VCSEL spectra vs. drive current (top graph) and peak wavelength vs. drive current (buttom graph).

2.5 Cooling / heating

Laser diodes characteristics are strongly affected by temperature. The threshold current varies significantly with temperature and the laser efficiency also falls off with increasing temperature. During production testing, it is therefore important to make the measurement time as short as possible to avoid self-heating, which can affect the measurement results. Besided these time-critical issues, a temperature-dependent analysis of the laser diode characteristics is important for certain applications, for example to test a specific use case, e.g. in automotive applications, or for quality assurance. As an example, Figure 7 shows the shift of the peak wavelength over the temperature of a VCSEL. The shown temperature values refer to the temperature of the TEC-element on which the pcb of the VCSEL is mounted. Within 3D sensing applications, laser diodes are often used in combination with narrow-band filter to increase sensitivity and avoid interference effects. In this case the temperature-dependent behavior is important for the optical design of the module. SpecWin Pro supports TEC-controllers and TEC-mounts from Arroyo to apply temperatures from 15° C up to 150° C to the laser diode.

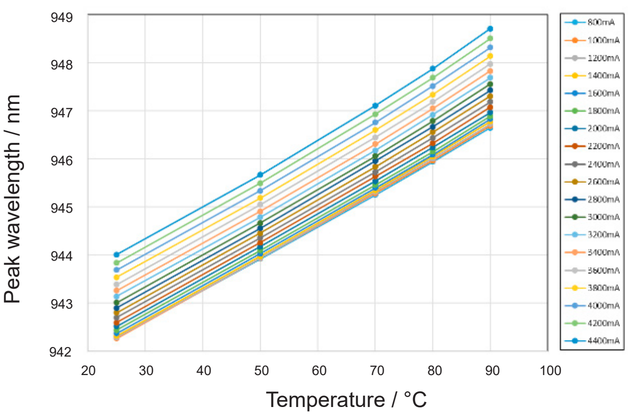

Figure 7: Temperature-dependent behaviour of the peak wavelength for different drive currents.

2.6 Pulsed mode operation

The L/I characteristics may also be acquired in pulsed mode operation of the laser diode. Large differences between the continuous wave and pulsed L/I-curves may indicate poor die attachment or a leaky junction and are therefore often used as an indicator of poor laser quality. Depending on the source-measure-unit (SMU) used in the measurement, different pulse lengths are possible. SpecWin Pro supports a broad range of SMUs from Keithley and Vektrex, both in DC and pulsed mode operation. All SMUs are stored with the respective accessible power ranges, preventing incorrect parameterization of the devices. With the new SpikeSafe SMU from Vektrex, pulsed mode testing with pulse lengths down to 1 µs are possible eliminating temperature dependence. Figure 8 shows the optical power of a single pulse with a parametrized pulse length of 100 µs measured with the photodiode attached to the ISP.

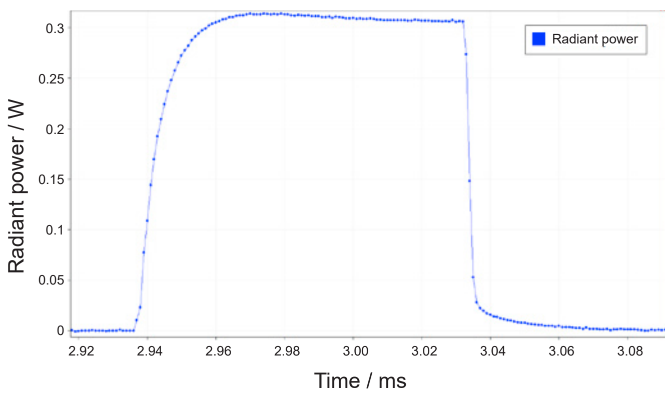

Figure 8: Time course of the optical power of a 100 µs pulse.

2.7 Monitoring photodiode

Usually, a laser diode module is a combination of a laser diode and an additional photo detector or photodiode. Often the photodiode acts as a feedback source for the laser to stabilize its output power. In this case the current of the photodiode is proportional to the output light. An important parameter here is the tracking ratio, which is the measured current divided by the light output [mA/mW]. As the laser diode ages, the tracking ratio might decrease over time. A control circuit is used to monitor the emission and to control the current to keep the light output constantly.

Figure 9 shows the output current of a monitoring photodiode of a 2D VCSEL array (red line) together with the voltage output of the photodiode attached to the ISP (blue line), both recorded with a sampling rate of 1 MHz. SpecWin Pro allows the control and read-out up to two digital multimeters (DMM) in parallel. With a calibrated photodiode attached to the ISP, the tracking ratio can be easily determined.

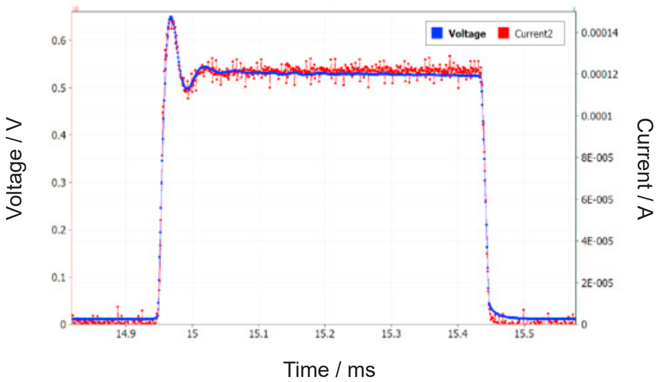

Figure 9: Current output of a monitoring photodiode (red line) together with the voltage output of the photodiode attached to the ISP.

\\ 3. SUMMARY

For the optical characterization of laser diodes various electronic and optical measurement instruments are necessary. SpecWin Pro provides the user with an easy way to combine the necessary instruments into an effective measurement system that can determine temperature-independent LIV curves using both spectroradiometers and photodiodes, and to analyze the resulting curves further to determine and display key device characteristics graphically.

Depending on the external hardware, e.g. source-measure-units, pulsed testing down to 1 µs is possible. The VTC system additionally allows spatially resolved single emitter measurements for far- and near-field configuration. For further information please refer to the application note “Testing Solutions for VCSELs”.

\\ 4. APPENDIX

Example system configuration	
Software	SpecWin Pro
Spectroradiometer	CAS 120B-HR » Spectral range: 902 nm – 982 nm » Spectral resolution: 0.12 nm » Data point interval: 0.05 nm » Minimum integration time: 4 ms
Integrating sphere	ISP 250 » 250 mm diameter » Integrated photodiode with adjustable gain settings » Integrated auxiliary light source
Source measure unit #1	Vektrex SpikeSafe SMU » One channel » DC 10 A @ 180 V » Minimum pulse width 1 µs
Source measure unit #2	Keithley K2602B » Two channel » DC 1 A @ 40 V / 3 A @ 6 V » Minimum pulse width 200 µs @ 6V
Digital multimeter	Keithley DMM7510 » 1 MHz sampling
Temperature control	Arroyo TEC-Source 5300-08-24 and TEC-Mount 286-01-150 » Temperature range: 15 °C up to 150 °C
Additional hardware	CAS trigger box » Synchronized measurement using hardware trigger
Calibration	Factory calibration of the input port of ISP 250. Determination of spectral responsivity of photodiode in CAS wavelength range.

Instrument Systems
KONICA MINOLTA Group

Instrument Systems GmbH
Kastenbauerstr. 2
81677 Munich, Germany
ph: +49 (0)89 45 49 43-58
fax: +49 (0)89 45 49 43-11
info@instrumentsystems.com
www.instrumentsystems.com

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