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Characterization of High Power Laser Diode Bars

APPLICATION NOTE

This application note describes high-power diode laser bars, and how to characterize them with a current source such as the ILX Lightwave LDX-3690.

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Introduction

As one of the most efficient sources of near infrared radiation, semiconductor diode lasers play a crucial role in manufacturing, defense, and communications. Optimization of quantum well structures and the reduction of parasitic voltage losses have pushed electrical-to-optical power conversion efficiencies (PCEs) of state-of-the-art devices beyond 70%. This makes the semiconductor diode laser an attractive candidate for materials processing and laser pump applications.

Diode lasers optimized for high continuous wave (CW) power operation are typically sold as a 1D array of emitters, known as a *laser bar*. The array contains tens of emitters, which are spaced physically apart to ensure sufficient thermal isolation between adjacent elements. Figure 1 shows laser bars in a Gel-Pak® carrying case prior to packaging.

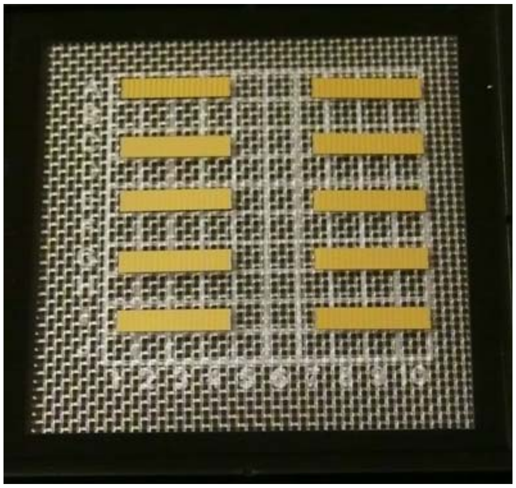

Figure 1: Unmounted laser diode bars

Since the light emission from a diode laser is highly divergent compared to solid state and gas lasers, lenses must be used to collect the light. In the vertical ("fast") axis, the light is collimated by a single cylindrical or aspheric rod. In the lateral ("slow") axis, a specially designed optic collimates the output from each emitter individually. The emitter geometry of a laser bar is shown in Figure 2.

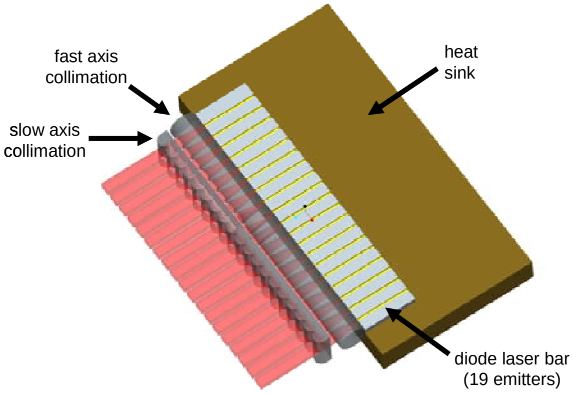

Figure 2: Geometry of high-power diode laser bar; Image courtesy of J. Schuette

The diode laser bar is mounted onto a heat sink to remove the waste heat generated by the device under operation. The cooling for high-power diode laser bars can be passive or active. A typical passively cooled diode is sold on a CS mount, a standard package that is compatible with a thermoelectric-cooler (TEC) based mounting fixture such as the ILX Lightwave LDM-4415. An example of a CS mount is shown in Figure 3(a). The CS mount, used by numerous vendors, is appropriate for quasi-CW (QCW) and medium power CW operation. For high power CW operation (more than 80 W), active water cooling using micro-channeled heat sinks is required. An example of a 100 W CW, single bar package sold by Coherent is shown in Figure 3(b).

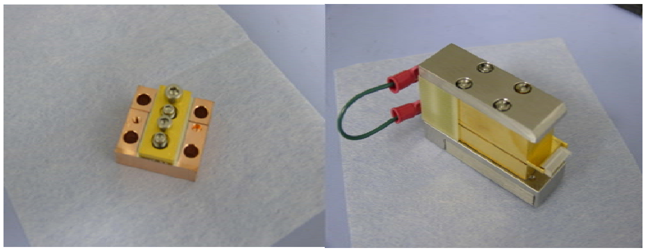

Figure 3: Example of (a) conductively cooled CS package; (b) Coherent actively cooled package

Current and Voltage Characteristics

Due to their nonlinear IV characteristic, laser diodes are typically driven by a current source rather than a voltage source or generic power supply. Given the PCE of commercially available devices, this means that the supply current for 100 W of CW power must be at least 100 A. One way to increase the power of a diode laser system is to vertically stack multiple laser bars within a single water-cooled array. Electrically, this means that the individual diode laser bars are operated in series. With a typical operating voltage of 1.5 – 2.0 V per bar, a 5-bar stack capable of 500 W of power would require a current source capable of 1 kW of electrical output power. An example power-current-voltage (PIV) characteristic of such an array, driven by an ILX Lightwave model LDX-3690, is shown in Figure 4. The PIV characteristic yields not only the output power of the device, but also the electrical-to-optical PCE.

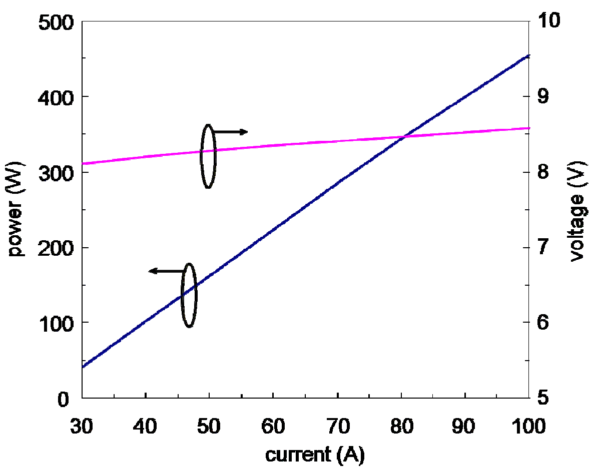

Figure 4: PIV characteristic of high-power diode laser stack

The characteristic shown above represents more than 50% electrical-to-optical PCE at a current of 100 A. The PCE has a direct impact on the cooling requirements of the diode laser, since potentially hundreds of watts of waste heat must be constantly removed from the package. For high power applications, the laser efficiency is much more important than other performance metrics such as threshold current. In fact, the above measurement was taken with 10 A current steps – well beyond threshold current of a telecommunications laser, and even beyond the compliance of most low power laser drivers!

Transient Protection

The 3600 series current sources provide a significant level of protection circuitry for electrical transients. This is required when testing high-power devices since ΔI/Δt and the inductance in thick cables can be quite large, leading to potentially damaging voltage transients. The electronic current control is designed to balance loop response time and load inductance. The control loop must handle dynamic load conditions, such as a single diode failure in a series connection of multiple devices. If the loop response is too slow to handle such a condition, the voltage across the remaining diodes could suddenly spike, allowing the current to increase far above the intended set point. This single event could destroy every laser diode in the series connection. Nevertheless, as the loop response is reduced, the protection circuit stability becomes more sensitive to load inductance. In an extreme case, instability could cause potentially damaging oscillations to both the LDX-3600 series driver as well as the laser diode. The LDX-3600 series drivers are designed with this tradeoff in mind to ensure reliable high-power operation of multiple laser diodes.

System Connection

We have selected several LDX-3690 units for CW, high-power testing of laser diode bars in our R&D lab at Coherent Direct Diode Systems. Although this unit also has QCW capability, in our applications we typically use CW operation exclusively. The QCW operation is useful for optical alignment since the average power can be kept low while manipulating optics and the beam. The main attractive features of this current source are high current compliance up to 120 A, high CW power, transient protection, remote operation, and voltage/photocurrent monitoring. At the power levels typical in our applications, a thermopile must be used to avoid detector damage. When optical power is incident onto the surface of the thermopile, the absorption of radiation causes a temperature increase. This increase is converted into a calibrated electrical signal that can be displayed by a power meter. Commercially available units, such as the Coherent PM10K, can handle up to 10 kW of optical power. However, for single laser bars, an integrating sphere offers decreased measurement time and the ability to simultaneously measure the optical spectrum of the device. The voltage and current monitoring capability of the LDX-3600 series, along with remote access of instrument functions through GPIB software such as LabVIEW®, enables automation of the PIV characteristic testing of high-power diode lasers. Shown in Figure 5 is an example of a setup that is used in one of the our labs. The device under test is driven by and LDX-3690 unit, and the laser light is captured by an integrating sphere. The sphere has separate ports for an optical fiber patch cord and a mounted photodiode. To avoid saturation of the detector, the mechanical housing has a small pinhole for attenuation. The photocurrent measured by the detector is then a scaled version of the actual optical power, and can be calibrated against the NIST-traceable thermopile. The built-in voltage and photodiode current monitors in the LDX-3600 series allow for rapid measurement of the electrical and optical characteristics of the laser.

Conclusion

There are many details of the system implementation that need to be considered when testing high-power diode laser bars. The different packages that are commercially available typically require custom electrical connections as well as either a chiller for micro-channel cooled packages, or a cold plate (or TEC) for conductively cooled packages. The laser PCE has a direct impact on the requirements of the power supply. In addition, since the lasers in a high-power stack are connected in series, it is important that the source implement some form of transient protection to balance the loop response with the load inductance. This is necessary to avoid voltage transients that could destroy an entire array of devices. A calibrated thermopile can handle up to 10 kW of optical power; however, for single bar testing an integrating sphere can offer a quicker and more convenient measurement. The LDX-3600 series has the automation capability through LabVIEW® and voltage/photocurrent monitoring to enable remote collection of the diode PIV characteristic data.

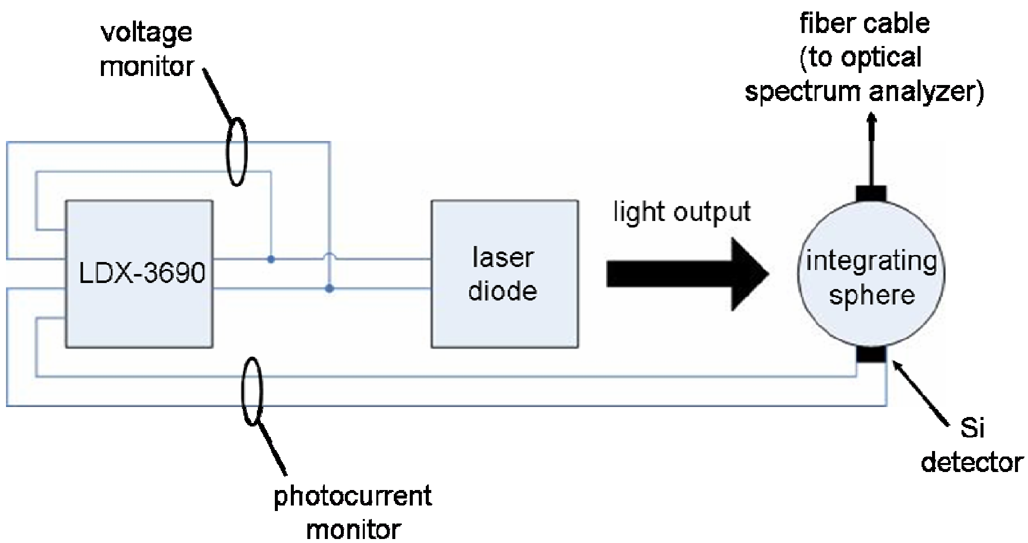

Figure 5: Automated testing setup for PIV characteristic and optical spectrum of high-power diode lasers

The following publications are available for download at www.ilxlightwave.com.

White Papers

- A Standard for Measuring Transient Suppression of Laser Diode Drivers
- Degree of Polarization vs. Poincaré Sphere Coverage
- Improving Splice Loss Measurement Repeatability
- Laser Diode Burn-In and Reliability Testing
- Power Supplies: Performance Factors Characterize High Power Laser Diode Drivers
- Reliability Counts for Laser Diodes
- Reducing the Cost of Test in Laser Diode Manufacturing

Technical Notes

- Attenuation Accuracy in the 7900 Fiber Optic Test System
- Automatic Wavelength Compensation of Photodiode Power
- Measurements Using the OMM-6810B Optical Multimeter
- Bandwidth of OMM-6810B Optical Multimeter Analog Output
- Broadband Noise Measurements for Laser Diode Current Sources
- Clamping Limit of a LDX-3525 Precision Current Source
- Control Capability of the LDC-3916371 Fine Temperature Resolution Module
- Current Draw of the LDC-3926 16-Channel High Power Laser Diode Controller
- Determining the Polarization Dependent Response of the FPM-8210 Power Meter
- Four-Wire TEC Voltage Measurement with the LDT-5900 Series Temperature Controllers
- Guide to Selecting a Bias-T Laser Diode Mount
- High Power Linearity of the OMM-6810B and OMH-6780/6790/6795B Detector Heads
- Large-Signal Frequency Response of the 3916338 Current Source Module
- Laser Wavelength Measuring Using a Colored Glass Filter
- Long-Term Output Drift of a LDX-3620 Ultra Low-Noise Laser Diode Current Source
- Long-Term Output Stability of a LDX-3525 Precision Current Source
- Long-Term Stability of an MPS-8033/55 ASE Source
- LRS-9424 Heat Sink Temperature Stability When Chamber Door Opens
- Measurement of 4-Wire Voltage Sense on an LDC-3916 Laser Diode Controller
- Measuring the Power and Wavelength of Pulsed Sources Using the OMM-6810B Optical Multimeter
- Measuring the Sensitivity of the OMH-6709B Optical Measurement Head
- Measuring the Wavelength of Noisy Sources Using the OMM-6810B Optical Multimeter
- Output Current Accuracy of a LDX-3525 Precision Current Source
- Pin Assignment for CC-305 and CC-505 Cables
- Power and Wavelength Stability of the 79800 DFB Source Module
- Power and Wavelength Stability of the MPS-8000 Series Fiber Optic Sources
- Repeatability of Wavelength and Power Measurements Using the OMM-6810B Optical Multimeter
- Stability of the OMM-6810B Optical Multimeter and OMH-6727B InGaAs Power/Wavehead
- Switching Transient of the 79800D Optical Source Shutter
- Temperature Controlled Mini-DIL Mount
- Temperature Stability Using the LDT-5948
- Thermal Performance of an LDM-4616 Laser Diode Mount
- Triboelectric Effects in High Precision Temperature Measurements
- Tuning the LDP-3840 for Optimum Pulse Response
- Typical Long-Term Temperature Stability of a LDT-5412 Low-Cost TEC
- Typical Long-Term Temperature Stability of a LDT-5525 TEC
- Typical Output Drift of a LDX-3412 Loc-Cost Precision Current Source
- Typical Output Noise of a LDX-3412 Precision Current Source
- Typical Output Stability of the LDC-3724B
- Typical Output Stability of a LDX-3100 Board-Level Current Source
- Typical Pulse Overshoot of the LDP-3840/03 Precision Pulse Current Source
- Typical Temperature Stability of a LDT-5412 Low-Cost Temperature Controller
- Using Three-Wire RTDs with the LDT-5900 Series Temperature Controllers
- Voltage Drop Across High Current Laser Interconnect Cable
- Voltage Drop Across High Current TEC Interconnect Cable
- Voltage Limit Protection of an LDC-3916 Laser Diode Controller
- Wavelength Accuracy of the 79800 DFB Source Module

Application Notes

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- App Note 3: Protecting Your Laser Diode
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- App Note 6: Choosing the Right Laser Diode Mount for Your Application
- App Note 8: Mode Hopping in Semiconductor Lasers
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- App Note 22: Modulating Laser Diodes
- App Note 23: Laser Diode Reliability and Burn-In Testing
- App Note 25: Novel Power Meter Design Minimizes Fiber Power Measurement Inaccuracies

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