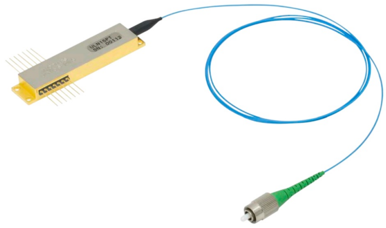
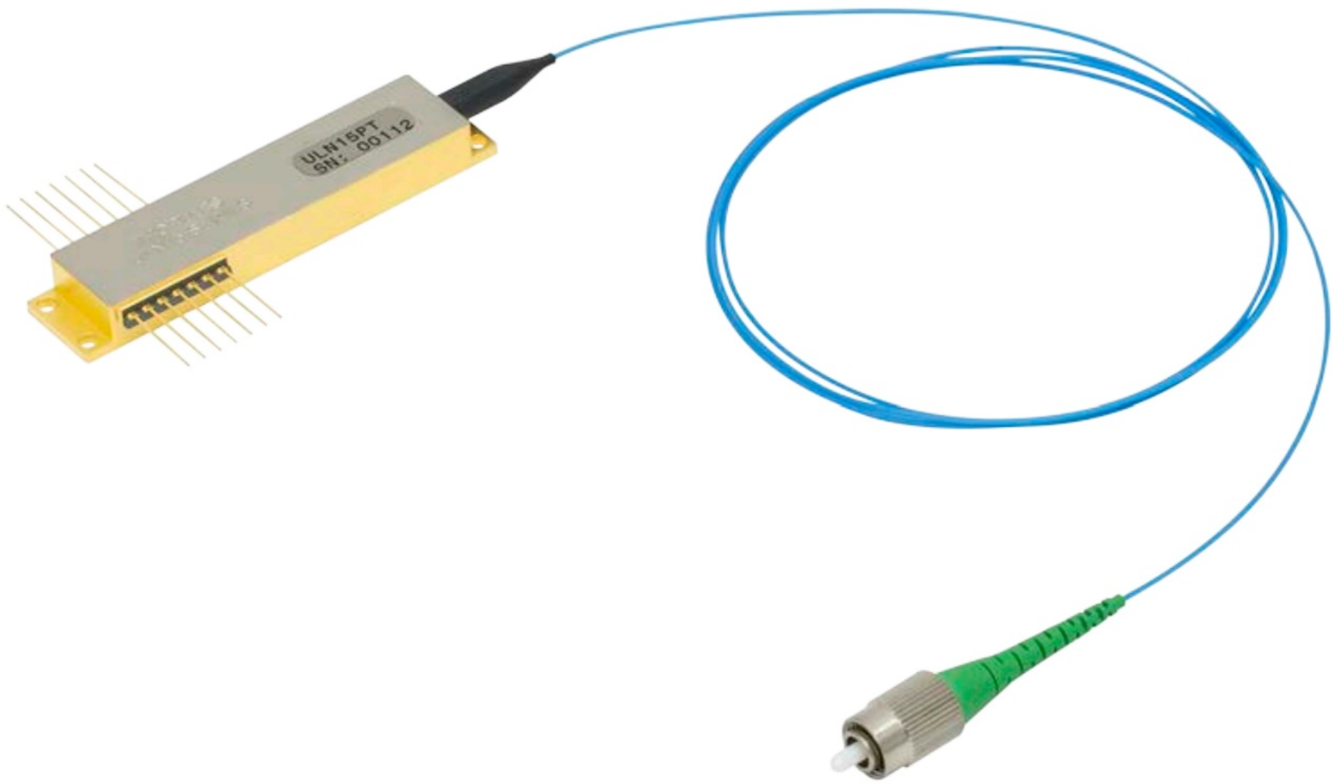


THORLABS ULN15 Series Ultra-Low-Noise Lasers User Guide

THORLABS ULN15 Series Ultra-Low-Noise Lasers



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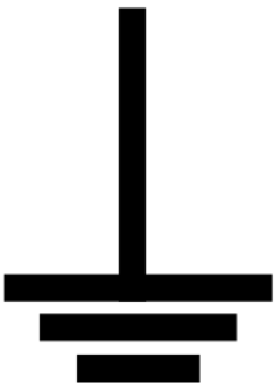
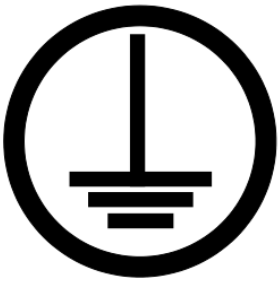
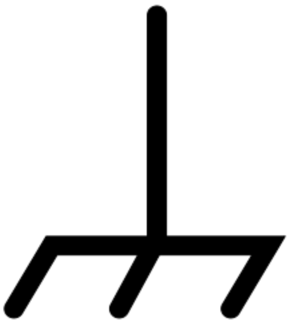
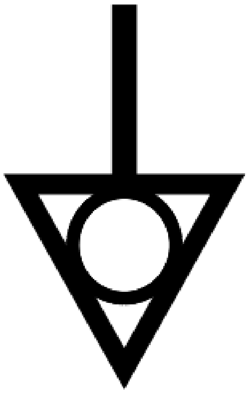
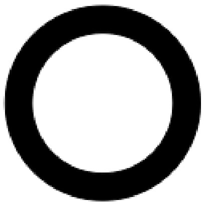
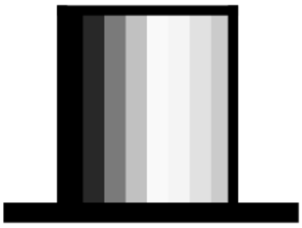
Chapter 1 Warning Symbol Definitions

Below is a list of warning symbols you may encounter in this manual or on your device

Symbol	Description
	Direct Current
	Alternating Current
	Both Direct and Alternating Current
	Earth Ground Terminal

	Protective Conductor Terminal
	Frame or Chassis Terminal
	Equipotentiality
	On (Supply)
	Off (Supply)
	In Position of a Bi-Stable Push Control

	Out Position of a Bi-Stable Push Control
	Caution: Risk of Electric Shock
	Caution: Hot Surface
	Caution: Risk of Danger
	Warning: Laser Radiation

	Caution: Spinning Blades May Cause Harm

Chapter 2 Safety

Adequate instructions for the safe installation of this laser component are the responsibility of the party assembling a complete laser system from it. This item is designated for use solely as a component of such a system, and therefore does not comply with the requirements of the U.S. Code of Federal Regulations, title 21, sections 1040.10 and 1040.11.

A laser system based on the ULN component is capable of producing sufficient radiation to be classified as a Class IIIb laser. Avoid eye or skin exposure.

 **WARNING**
Device emits invisible laser radiation. Avoid eye or skin exposure

 **CAUTION**
The ULN component should be properly mounted to a thermally conductive surface to prevent heat buildup. See Chapter 4 for additional details on the proper setup of for the ULN component.

Chapter 3 Description

General Characteristics

Thorlabs' Ultra-Low Noise (ULN) laser (US Patents 10193306, 10483718, 10476233, and 10454248) is an external cavity diode laser consisting of a single angled facet gain chip coupled to a fiber Bragg grating (FBG). The laser's output is provided through a fiber pigtail. The ULN laser features ultra-low frequency and intensity noise, along with high optical power. This product is provided in a hermetically-sealed, 14-pin, extended butterfly style package. The ULN laser includes two integrated thermoelectric cooler / thermistor pairs (one each for the gain chip and the FBG), an auxiliary thermistor for monitoring the case temperature, and a photodiode for monitoring the back facet power.

The ULN15PC and ULN15PT lasers operate in the ITU C band (1530 – 1565 nm). The center wavelength of each device is tested and reported on a serialized data sheet. Most devices will operate at or near 1550 nm. Customers that require a specific wavelength may contact technical support to place a special order (see Chapter 10).

ULN lasers are available with polarization-maintaining fiber; please contact technical support for a single mode pigtailed fiber. The lasers are available in either a current tuning or a temperature tuning configuration, and details on the configurations are discussed in the following sections.

Further details of the design of the ULN laser are available in the following publication:

Paul A. Morton and Michael J. Morton, “High-Power, Ultra-Low Noise Hybrid Lasers for Microwave Photonics and Optical Sensing”, Journal of Lightwave Technology, vol. 36, no. 21, pp. 5048—5057, 2018.

Operating Characteristics

For any given choice of temperature setpoints, the ULN operates as a single mode laser over a number of ranges of drive current. As the current is adjusted upwards from an initial operating point, the temperature of the gain chip increases, which in turn changes the round-trip phase of the cavity mode. This causes the center wavelength of the mode to increase. As the current is further increased, the lasing mode will shift far enough away from the center of the FBG’s reflection peak that single mode operation is no longer possible. At this point, the laser enters multimode operation. As the current is further increased, a new cavity mode will move into resonance with the FBG reflection peak, and the laser will once again move into single mode operation. This power vs. current (LI) behavior is shown in Figure 1. The single mode regions are consistent and stable as long as the device’s temperature is adequately controlled. The figure also plots the ULN’s LI behavior as the current is decreased. With decreasing current, the device is able to stay in single mode operation within each particular single mode range down to a lower current. This hysteresis is characteristic of the ULN.

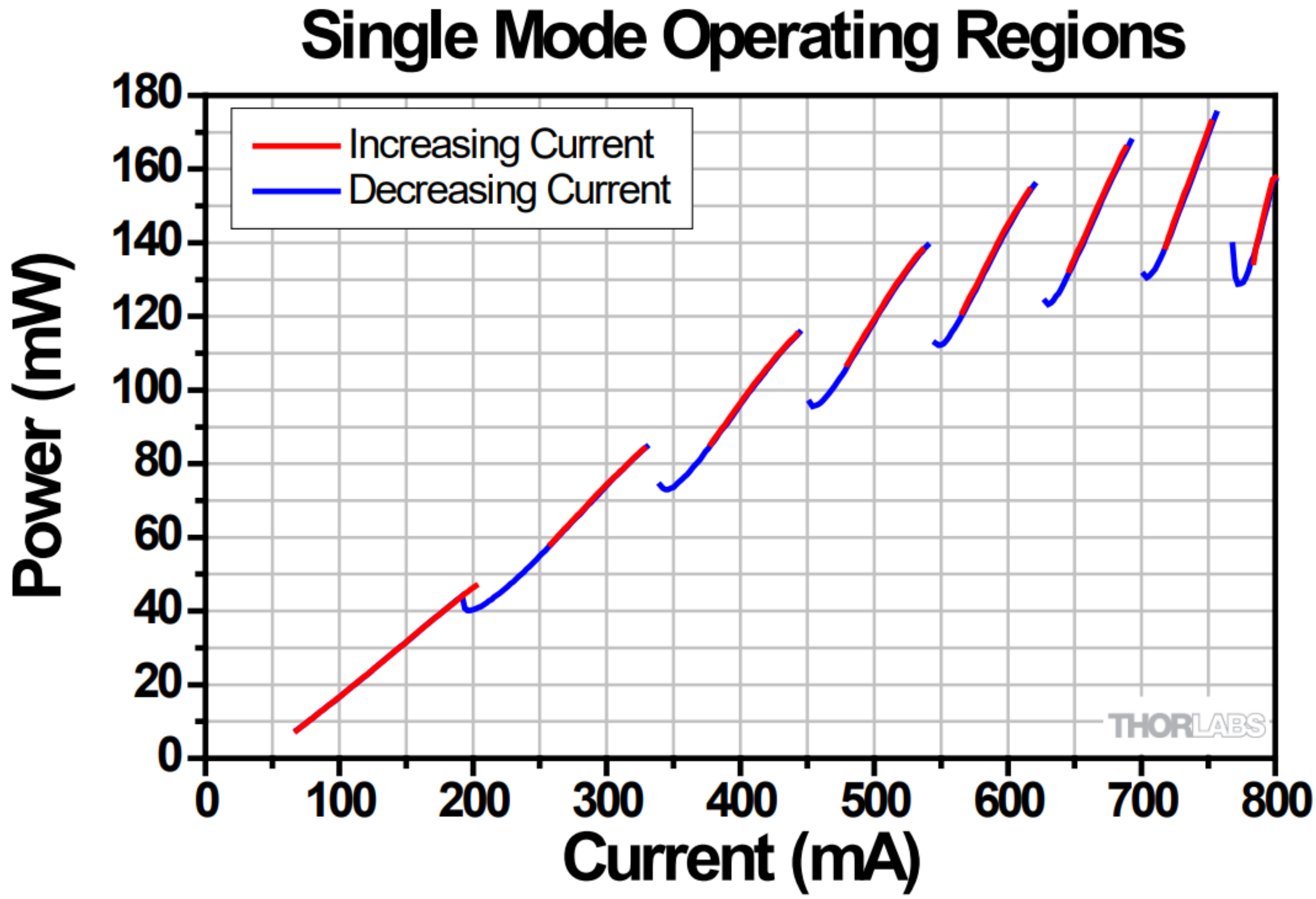


Figure 1 Typical power vs. current (LI) plot. Only single mode power is plotted. This is a currenttuning C configuration device operated at the optimal ΔT, which is the difference between TFBG and TCHIP.

The ULN laser's spectrum is much narrower than can be measured with a typical optical spectrum analyzer (20 pm resolution). However, side-mode suppression ratio (SMSR), center wavelength, and single mode behavior can all be measured with such a tool. A typical single mode spectrum is shown in Figure 2. The SMSR is well over 70 dB.

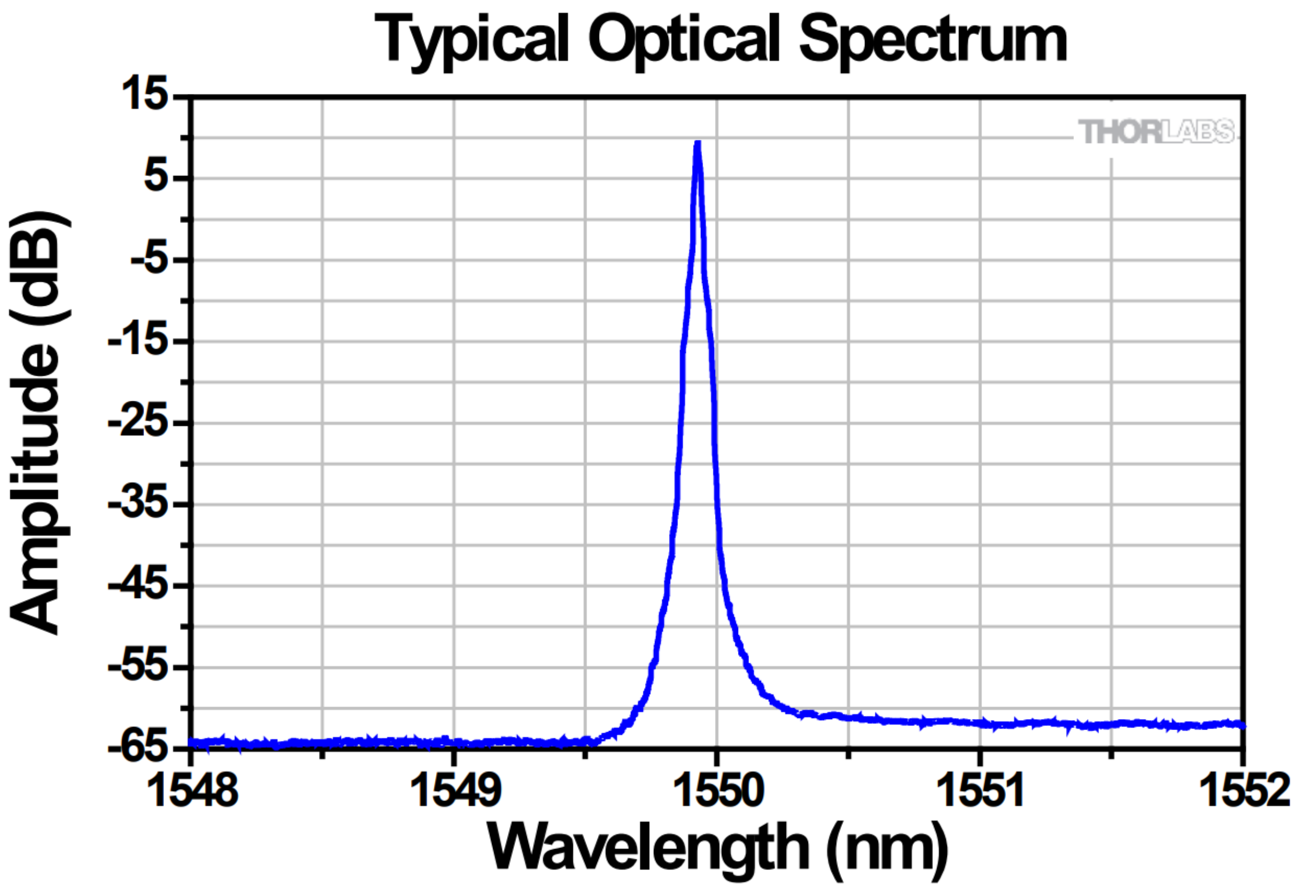


Figure 2 Typical ULN spectrum at single mode operation with an operating point above 100 mW. TCHIP and TFBG are 25 °C.

Current adjustment provides only a limited tuning range before the ULN laser hops to a new mode, as shown in Figure 3. The actual tuning is smoother than shown; these data are impacted by the 4 pm sampling resolution of this measurement. Longer-range tuning can only be achieved by adjustment of the FBG temperature. This changes the center wavelength of the FBG's resonant frequency.

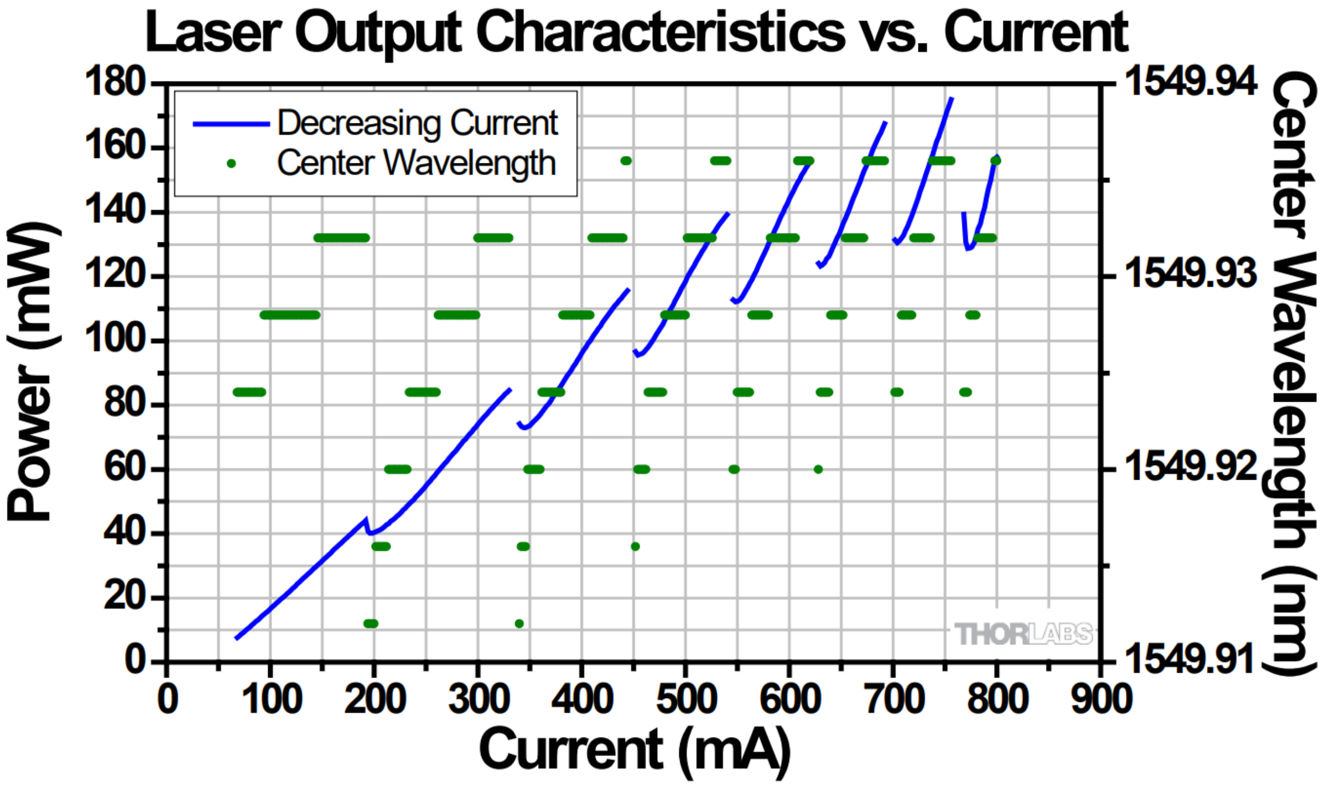


Figure 3 LI plot overlaid with current-tuning characteristics. Note that the optical spectrum analyzer used in this measurement was set to a sampling resolution of 4 pm; the actual tuning is smoother than shown here. This is a C-configuration device operated at the optimal ΔT, which is the difference between TFBG and TCHIP.

The ULN is available in two tuning configurations, each of which are optimized for a particular tuning method: Current (C) and Temperature (T). The configuration is set at the time of manufacture and can not be altered. It is indicated in the item number: “ULN15PC” is a C configuration device, while “ULN15PT” is a T configuration device.

“C” Configuration – Optimized for Mode-Hop-Free Current Tuning

The C configuration is optimized to provide the user with the widest possible range of currents at which the laser operates in a single mode. The mode-hop-free current tuning range is therefore maximized. In this configuration, it is not possible to independently adjust the temperature set points of a C configuration ULN’s gain chip and FBG without reducing the mode-hop free range. We report the optimal ΔT, which is the difference between the FBG temperature (TFBG) and chip temperature (TCHIP), for each device on its individual datasheet. Note that operation with TCHIP > 25 °C will reduce the device’s output power. Users wishing to thermally tune the device’s wavelength without impacting the output power should therefore select the T configuration.

The plots in Figure 1 and Figure 3 show a C-configuration device operated at the optimal ΔT. The multimode operation ranges are quite narrow, especially in the decreasing-current direction. Figure 4 shows the change in behavior of a C configuration ULN as the device is moved away from optimal ΔT. We see that the multimode gap between single mode regions increases away from the optimum. We also see that the start and end currents of the single mode regions move as TFBG is adjusted. This behavior is normal.

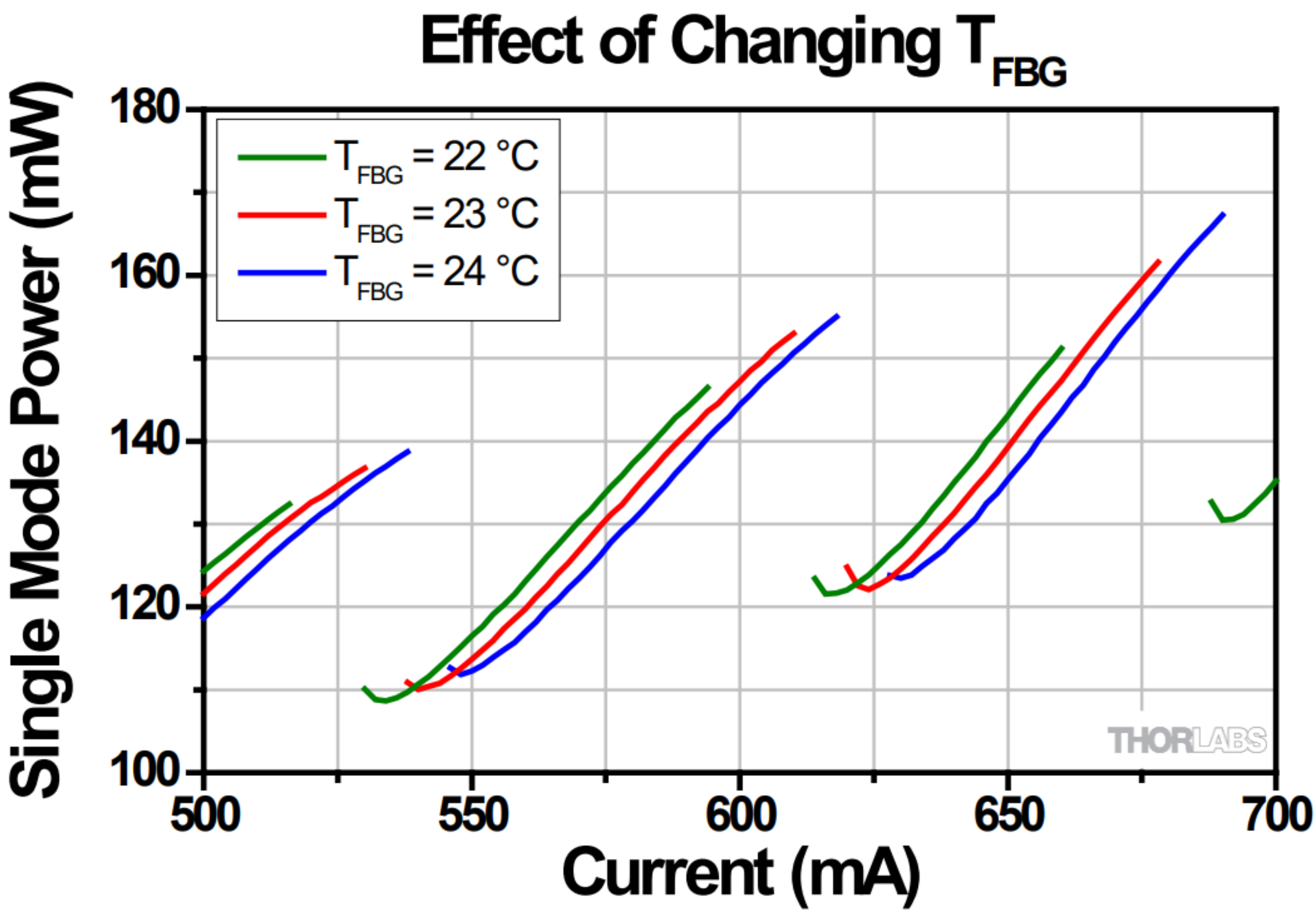


Figure 4 Change in single mode ranges as TFBG is changed for a C-configuration device. TCHIP is 25 °C for all measurements. -1 °C is the optimum ΔT for the specific device shown in this figure, corresponding to 24 °C for TFBG.

"T" Configuration – Optimized for Longer-Range Temperature Tuning

The T configuration allows for independent adjustment of TFBG without impacting the laser's output power. However, the current span of each mode-hop free range is considerably reduced in the T configuration. Users requiring the maximum possible mode-hop free tuning and/or current range should select the C configuration.

Figure 5 shows a typical LI curve for a T-configuration device. The reduction in the size of the single mode ranges can be seen when compared to the C-configuration device behavior shown in Figure 1. OSA measurements of the spectrum are shown at various TFBG in Figure 7. The tuning of the center wavelength is shown in Figure 8. It should be noted that the single mode regions do move as TFBG is adjusted, as shown in Figure 6; a ULN kept at a single current will therefore not operate single mode at all temper

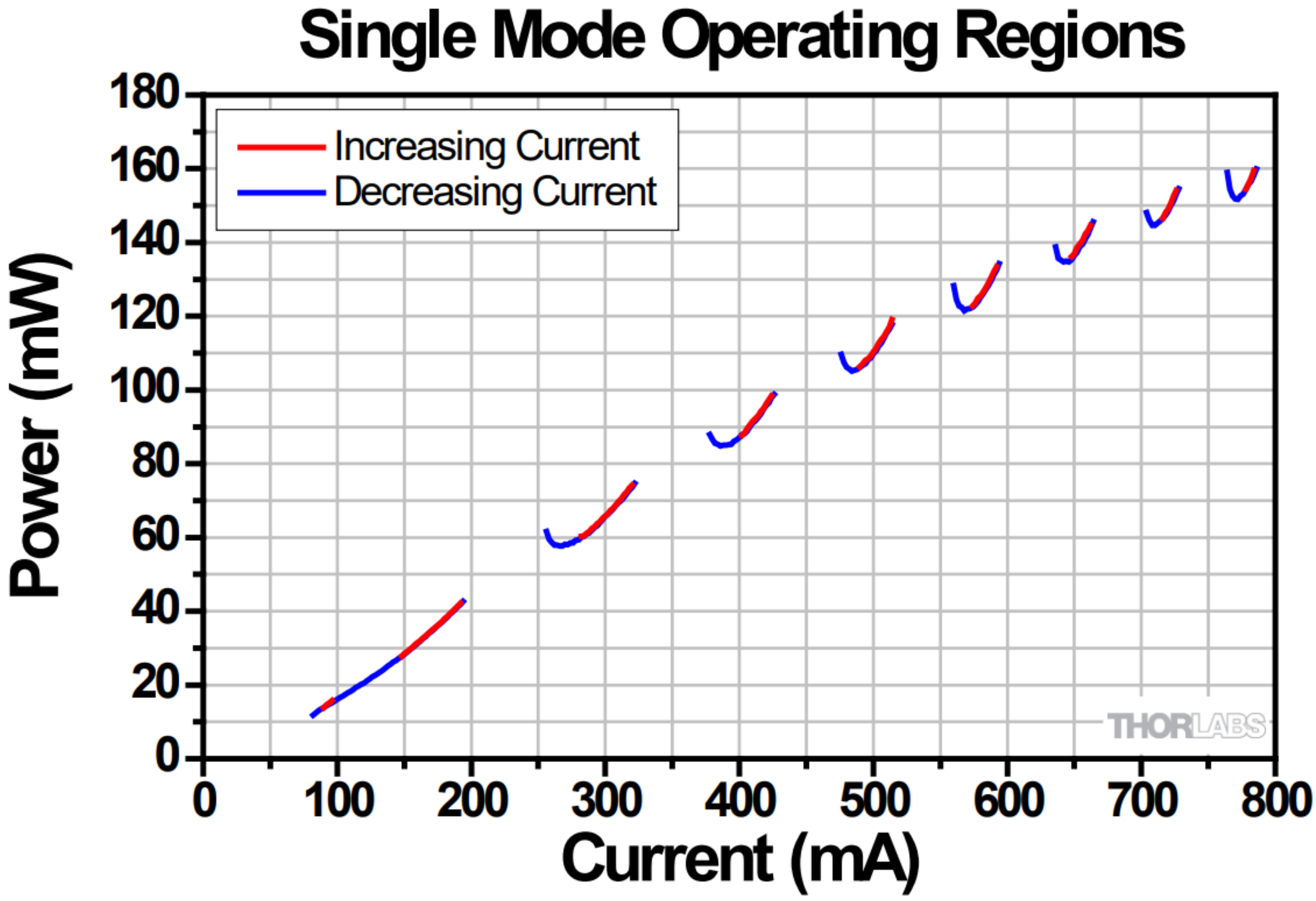


Figure 5 LI Measurement of a T-Configuration ULN at Constant TFBG

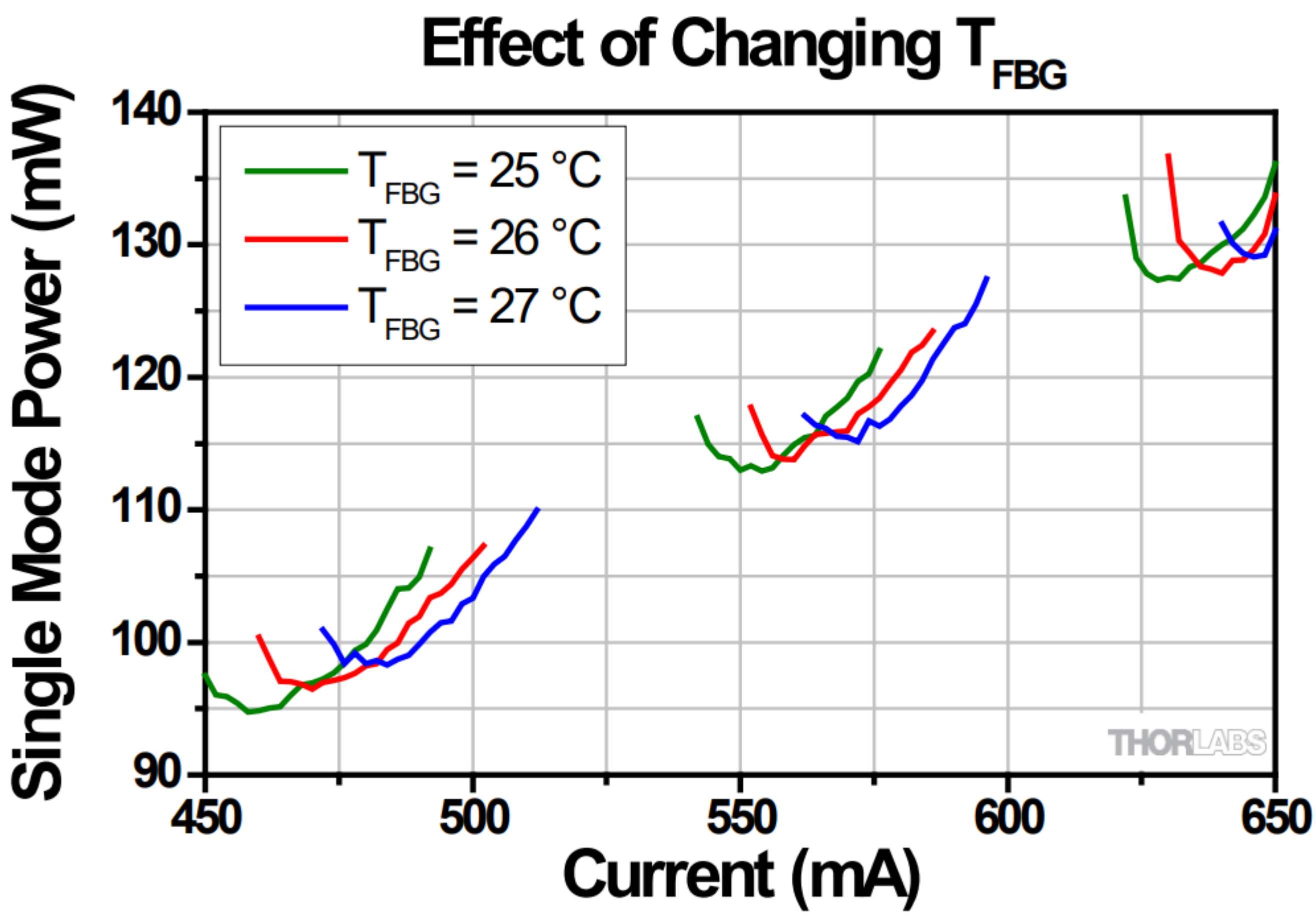


Figure 6 Change in single mode ranges as TFBG is changed for a T-configuration device. TCHIP is 25 °C for all measurements.

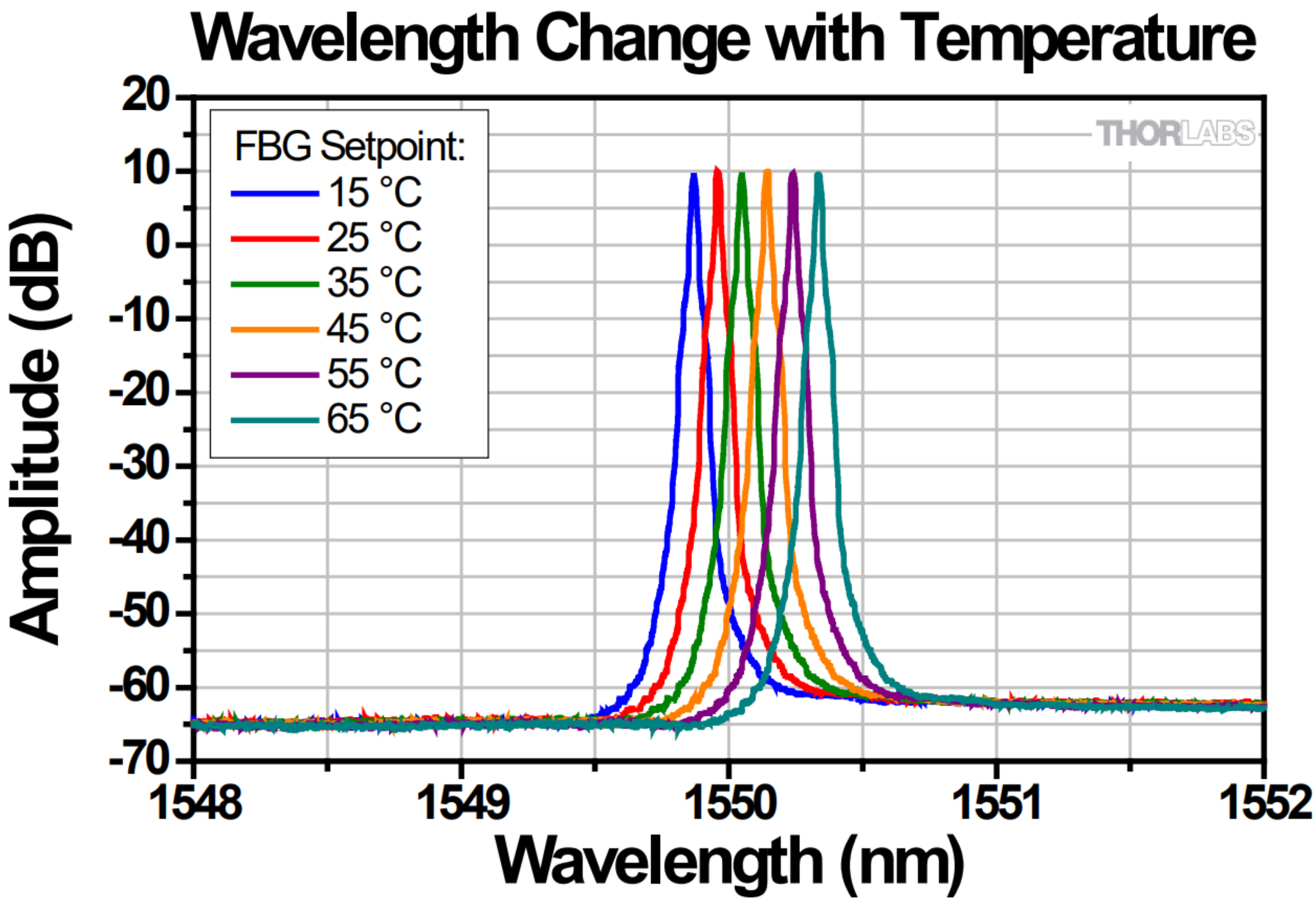


Figure 7 OSA trace of a T-configuration ULN spectrum at various TFBG with an operating point above 100 mW. Spectra are measured with a 20 pm resolution OSA.

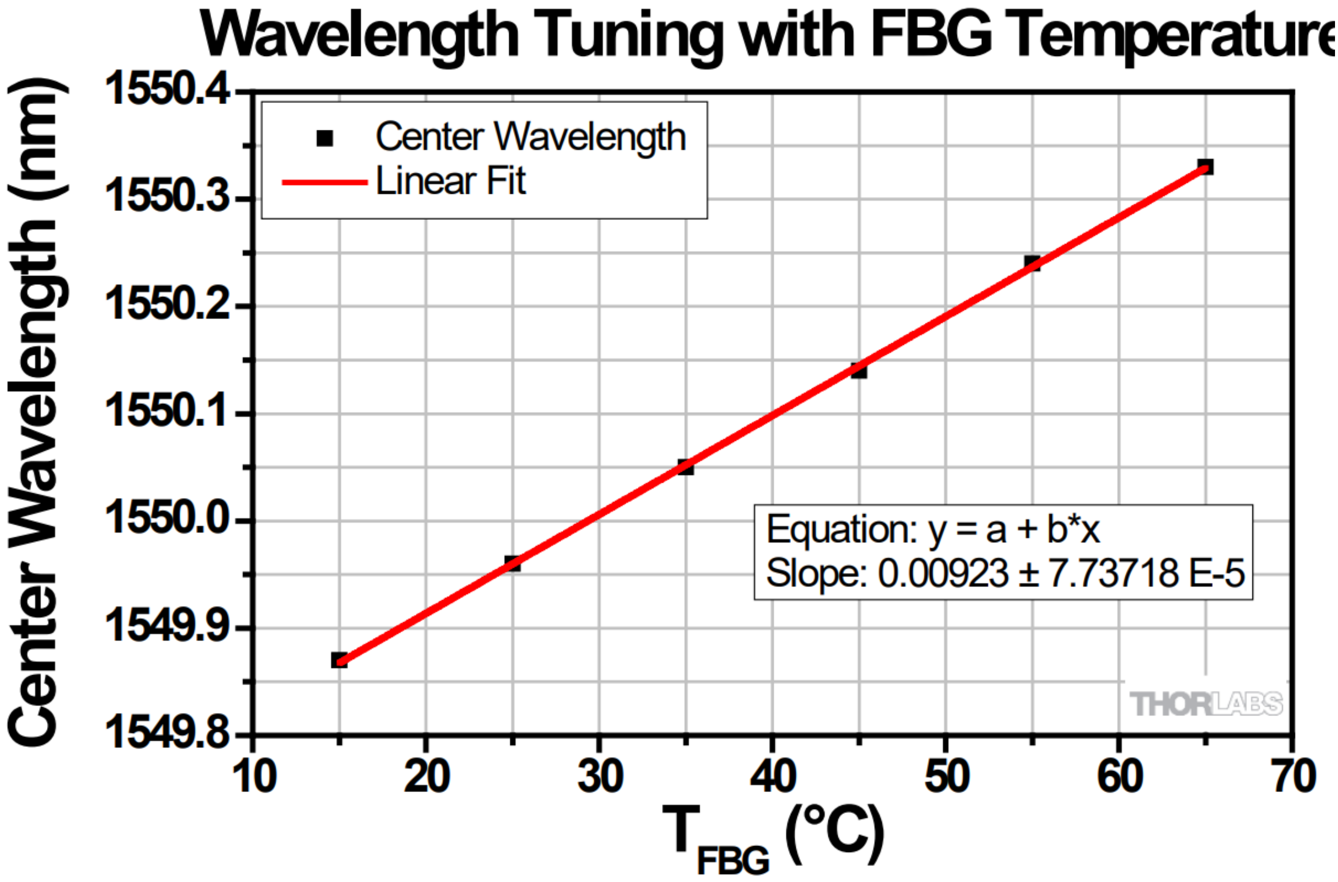


Figure 8 Tuning of center wavelength as TFBG is changed for a T-configuration ULN. The slope of the linear fit correlates to the device's temperature-tuning coefficient.

Frequency Noise Characteristics

The frequency noise spectral density of each ULN laser is measured before shipment. Typical performance is shown in Figure 10. As shown in the figure, the noise changes with current within a single-frequency zone. The frequency noise is always minimized at the high-current end of the zone; all lasers meet or exceed the specified linewidth under these conditions when combined with proper control electronics and minimal optical feedback (see Chapter 4).

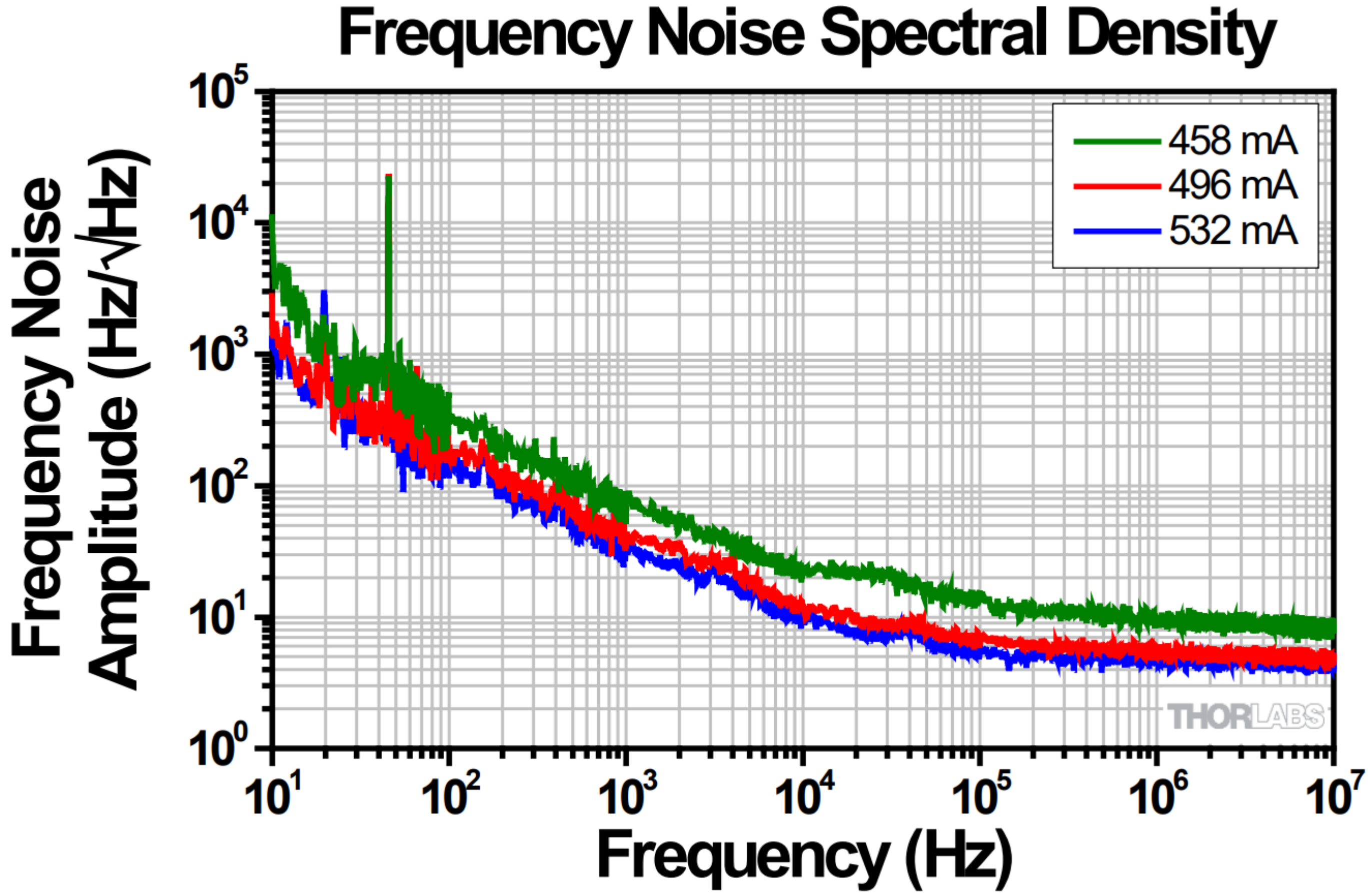


Figure 10 Frequency noise of a ULN at various currents within a single mode region. The peak in noise at 43 Hz is due to HVAC systems present in the testing facility.

The Lorentzian / instantaneous linewidth may be estimated from the high-frequency white noise level of the noise plot, according to:

Lorentzian linewidth = × (white noise level)2,

where the white noise level is measured in hertz/sqrt(hertz). The linewidth at longer integration times may be estimated using the method described in:

Gianni Di Domenico, Stéphane Schilt, and Pierre Thomann, “Simple approach to the relation between laser frequency and laser line shape”, Applied Optics, vol. 49, no. 25, pp. 4801 – 4807, 2010.

Intensity Noise Characteristics

The ULN has extremely low relative intensity noise (RIN). A typical low-frequency RIN measurement at operating power is shown in Figure 11. The RIN floor shown on the plot is the noise floor of the measurement system; the actual RIN is lower. A measurement of high-frequency RIN is shown in Figure 12; this data was taken on a different measurement system with a lower noise floor.

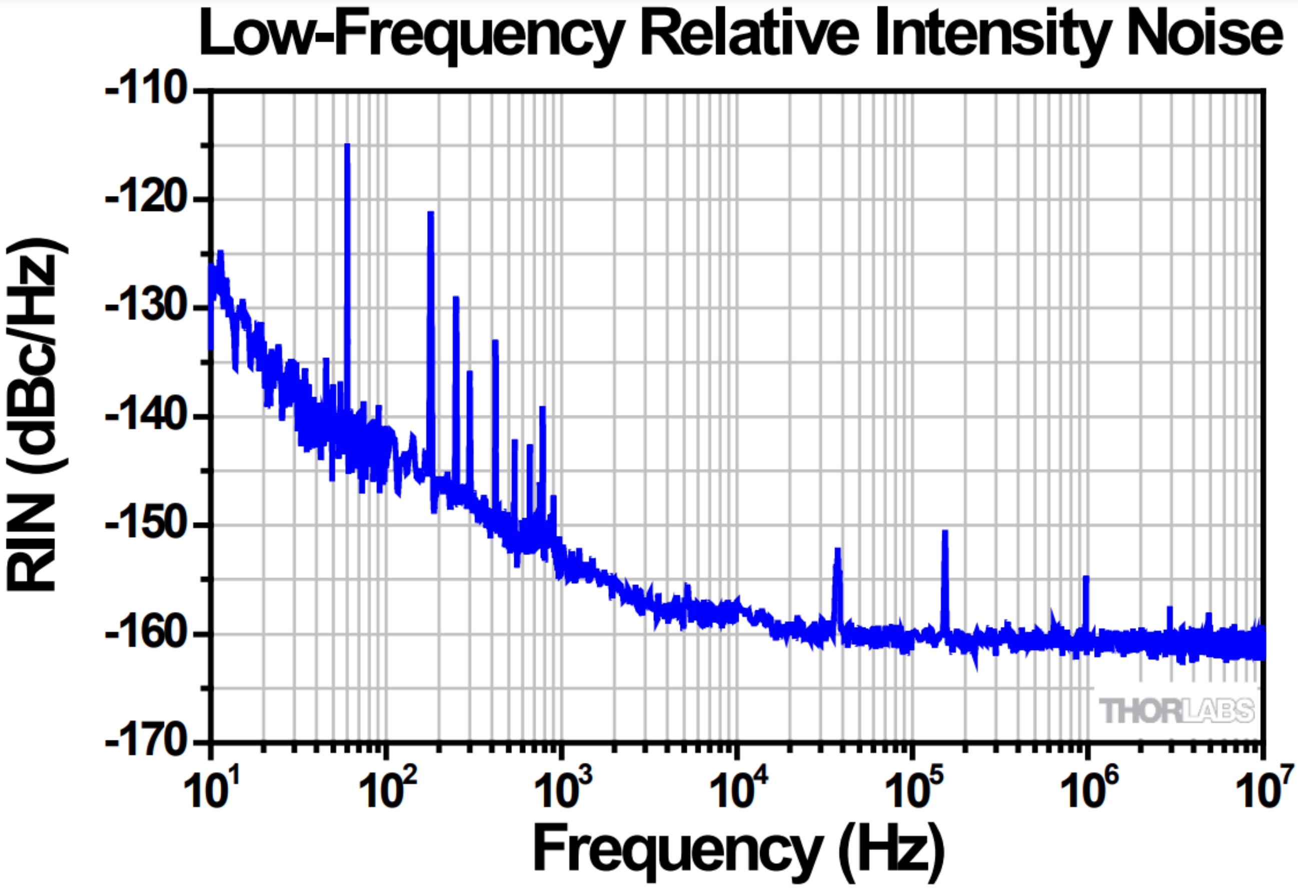


Figure 11 Low-Frequency RIN Measurement

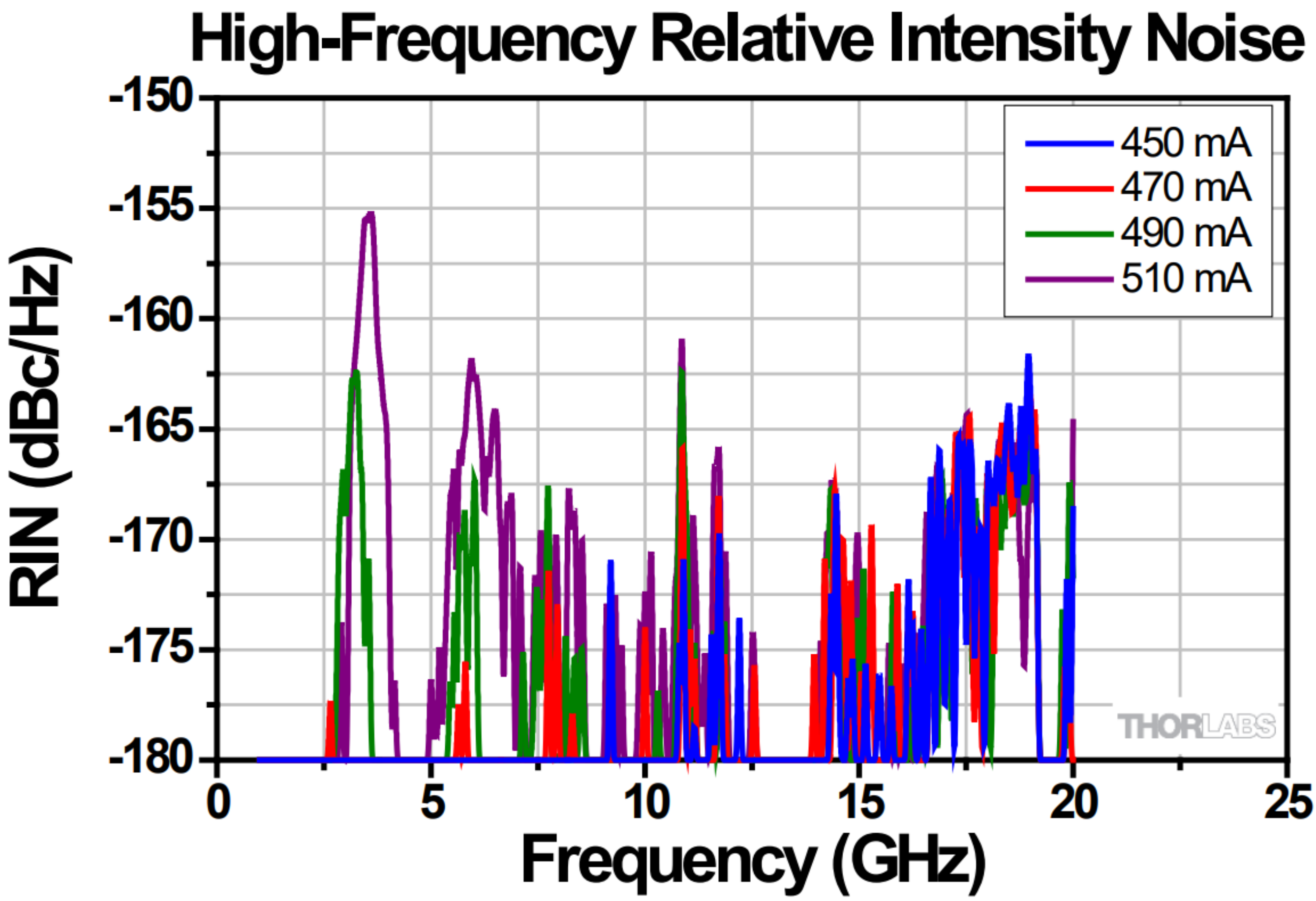


Figure 12 High-Frequency RIN Measurement. Data is typical and obtained from Morton and Morton (see

section 3.1 for detailed reference).

Chapter 4 Setup

Attention

Performance of the ULN laser is critically dependent on the stability of the laser drive and TEC drive electronics, as well as the absence of external optical feedback into the ULN. Please read the following section carefully pri or to integration of the ULN laser into a system or experimental setup.

To ensure stable operation, the user should place an optical isolator at the output of the ULN laser. A dual-stage isolator (>55 dB isolation) is recommended for best results.

Do not “hot swap” the ULN’s electrical or optical connections. Make sure the fiber connector tip is clean and undamaged before connecting it to other components.

The ULN laser must be placed on a suitable optoelectronic mount. Provision must be made for electronic contact with the device’s pins as well as adequate heat sinking. Use screws to secure the ULN to the mount (M2 or 2-56 are preferred). Do not exceed the mounting torque of 0.07 – 0.14 N•m (10 – 20 oz•in).

Control Electronics

The frequency/phase and intensity noise of any semiconductor laser is determined by at least two factors: the fundamental noise of the laser cavity and the noise of the control electronics.

The frequency noise spectral density shown in the previous chapter was acquired using low-noise control electronics, such that the fundamental noise of the laser cavity is the dominant contributor to the noise. The shape is characteristic of the frequency noise of semiconductor lasers. The white noise seen at high frequencies is largely determined by the fundamental Schawlow-Townes linewidth of the laser cavity. The 1/f noise at lower frequencies is largely driven by quantum fluctuations of charge carriers in the gain chip. This noise is largely determined by the design and fabrication of the chip. The peaks on and around 43 Hz are caused by acoustic contributions from the HVAC system in testing room.

If the laser current is provided by a driver that is noisy relative to the laser’s fundamental noise, then the current noise will increase the laser frequency noise above that fundamental level. A comparison is shown in Figure 13. Here we compare the frequency noise of a laser being driven to the same set points by two different controllers: a low-noise controller and a system based on Thorlabs ITC400x controllers. When driven by the ITC, the system exhibits excess noise in the 10 – 10 000 Hz range.

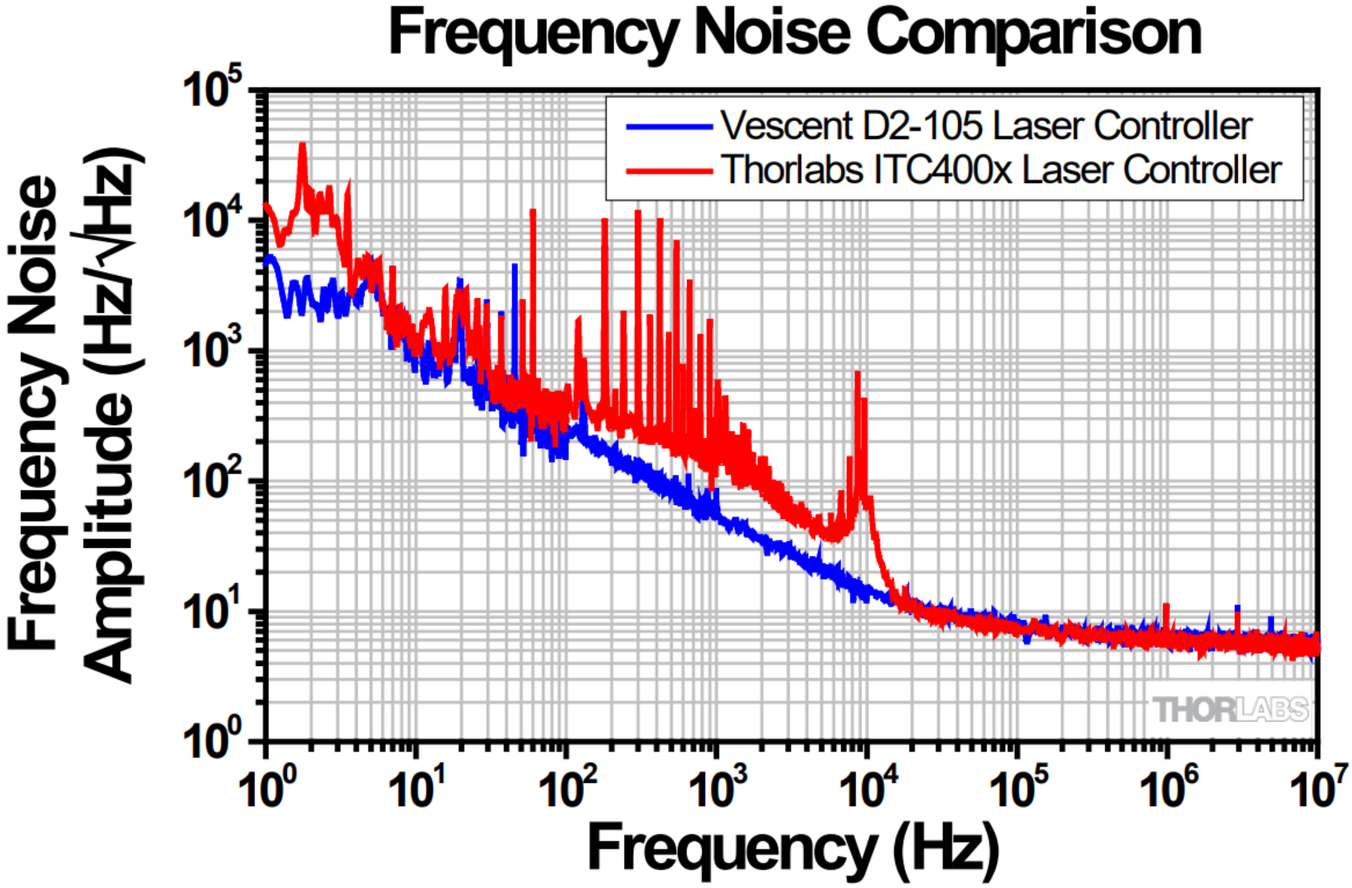


Figure 13 ULN frequency noise when driven by low-noise control electronics (Vescent D2-105) and by Thorlabs ITC400x controller.

Accessing the ULN laser's full potential therefore requires careful selection of an ultra-low noise current supply. The chosen current supply should be given adequate time to charge all internal electrical components such that the output current is stable before taking a measurement with the ULN laser. Thorlabs technical support can provide recommendations of suitable circuit designs and suppliers. Thorlabs current control instruments are generally not suitable for low-noise operation of the ULN.

Excess noise in the <10 Hz frequency range is typically caused by noisy or unstable temperature control. Thorlabs TED200C temperature controllers are suitable for low-noise operation of the ULN, however, users should carefully optimize the PID controls for both the chip and FBG temperature controllers to obtain optimal performance.

Chapter 5 Operation

The laser performance is sensitive to the temperature of both control loops and to the drive current. Small differences exist in calibration between instruments. While the plots on the datasheet suggest recommended operating points, we advise all users to verify that the ULN is in single mode operation at the desired setpoint using an OSA. Small adjustments may be needed to obtain the required performance.

The ambient temperature has an influence on ULN performance. In most laboratory environments, single frequency operation will remain unchanged from the test datasheet. If the case temperature deviates greatly from 25°C, it may be necessary to reset the laser current and/or TFBG to find single-frequency operation.

The ULN is sensitive to both seismic and acoustic vibration. Users should take precaution to decouple any sources of vibration from the laser. Acoustic damping may be required to obtain optimal performance in acoustically noisy environments.

Chapter 6 Trouble Shooting

The ULN laser contains no user-serviceable parts. If the laser's performance does not match the information provided on the serialized data sheet, check to be sure that the following conditions are met:

- Laser is properly mounted on a suitable heat sink.
- A 55 dB or greater optical isolator is connected to the laser output.
- An ultra-low noise current control is used.
- The output fiber connector is undamaged and clean.

If these conditions are all met and the laser performance is still unacceptable, please contact technical support for further assistance.

Specifications

All specifications are measured at TCHIP = 25 °C, TCASE = 25 °C, TFBG set as directed on serialized datasheet.

General Specifications	
Absolute Max Current	800 mA
Absolute Max Power	200 mW
Operating Case Temperature	-5 to 70°C
Storage Temperature	-40 to 85°C
Gain Chip TEC Max Current	3 A
Gain Chip TEC Max Voltage	4.6 V
FBG TEC Max Current	3 A
FBG TEC Max Voltage	3.2 V
Steinhart-Hart A Coefficient (All Thermistors)	1.1291×10^{-3}
Steinhart-Hart B Coefficient (All Thermistors)	2.3412×10^{-4}
Steinhart-Hart C Coefficient (All Thermistors)	8.7674×10^{-8}
PD Responsivity	0.95 A/W (Typ.)
PD Max Reverse Voltage	15 V

ULN15 Series[a]	Value		
Specification	**Min**	**Typical**	**Max**
Center Wavelength	1530 nm	1550 nm	1565 nm
Lorentzian Linewidth[a]	–	100 Hz	250 Hz
Output Power CW @ I_{CW}	100 mW	140 mW	–
Operating Current CW	–	650 mA	800 mA
Threshold Current	–	50 mA	–
Forward Voltage @ I_{CW}	–	3.0 V	4.0 V
Side Mode Suppression Ratio @ I_{CW}	60 dB	70 dB	–
Relative Intensity Noise[b]	–	-165 dBc/Hz	–
Polarization Extinction Ratio	–	20 dB	–

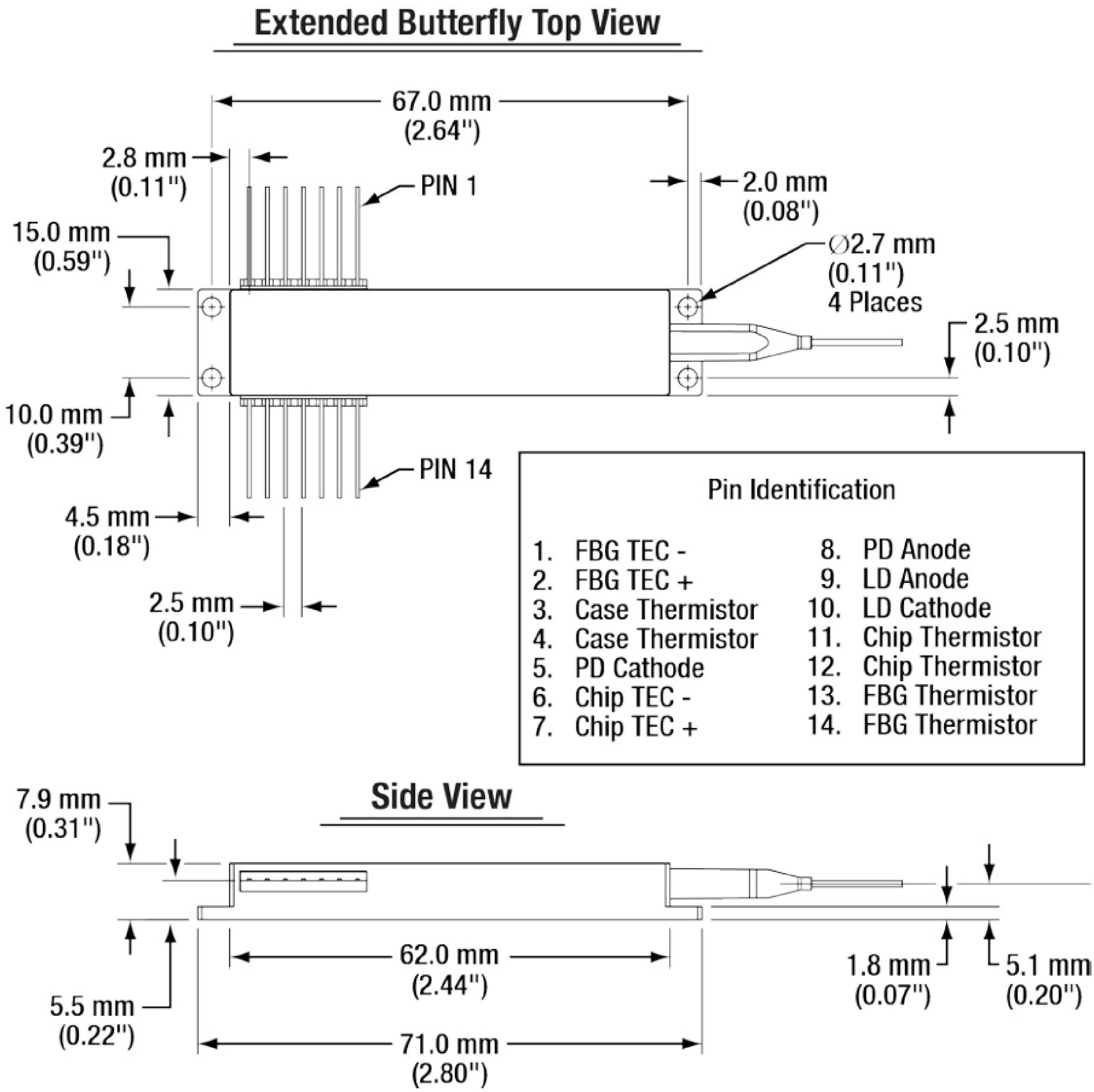
a. At High-Current End of Single Mode Range
b. At Low-Current End of Single Mode Range and Measured Above 1 GHz

Tuning Characteristics	Value		
T-Configuration	**Min**	**Typical**	**Max**
FBG Temperature Range	10 °C	–	70 °C
FBG Temperature Tuning Coefficient	–	9 pm/K	–
FBG Temperature Tuning Range	–	500 pm	–
C-Configuration	**Min**	**Typical**	**Max**
Current Tuning Coefficent	–	0.25 pm/mA	–
Mode-Hop-Free Tuning Range, Current Tuning @ I_{CW}	–	20 pm	–

Fiber Specifications[a]	
Fiber Type	Corning® PM15-U25D
Wavelength	1550 nm
Numerical Aperture	–
Cutoff Wavelength	1300 nm – 1440 nm
Mode Field Diameter @ 1550 nm	10.5 µm ± 0.5 µm
Maximum Attenuation @ 1550 nm	0.5 dB/km
Fiber Length	1 m
Connector	FC/APC, 2.0 mm Narrow Key[a]

a. Slow Axis Aligned Parallel to Key

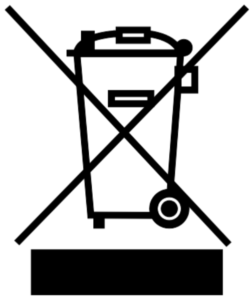
Chapter 8 Mechanical Drawing



Chapter 9 Regulatory

As required by the WEEE (Waste Electrical and Electronic Equipment Directive) of the European Community and the corresponding national laws, Thorlabs offers all end users in the EC the possibility to return “end of life” units without incurring disposal charges.

- This offer is valid for Thorlabs electrical and electronic equipment:
- Sold after August 13, 2005
- Marked correspondingly with the crossed out “wheelie bin” logo (see right)
- Sold to a company or institute within the EC
- Currently owned by a company or institute within the EC
- Still complete, not disassembled and not contaminated



As the WEEE directive applies to self-contained operational electrical and electronic products, this end of life take back service does not refer to other Thorlabs products, such as:

- Pure OEM products, that means assemblies to be built into a unit by the user (e. g. OEM laser driver cards)
- Components
- Mechanics and optics
- Left over parts of units disassembled by the user (PCB's, housings etc.).

If you wish to return a Thorlabs unit for waste recovery, please contact Thorlabs or your nearest dealer for further information.

Waste Treatment is Your Own Responsibility
If you do not return an "end of life" unit to Thorlabs, you must hand it to a company specialized in waste recovery. Do not dispose of the unit in a litter bin or at a public waste disposal site.

Ecological Background
It is well known that WEEE pollutes the environment by releasing toxic products during decomposition. The aim of the European RoHS directive is to reduce the content of toxic substances in electronic products in the future.

The intent of the WEEE directive is to enforce the recycling of WEEE. A controlled recycling of end of life products will thereby avoid negative impacts on the environment.

Chapter 10 Thorlabs Worldwide Contacts

For technical support or sales inquiries, please visit us at **www.thorlabs.com/contact** for our most up-to-date contact information.

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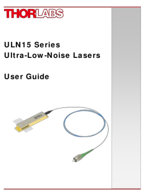
Documents / Resources

	THORLABS ULN15 Series Ultra-Low-Noise Lasers [pdf] User Guide ULN15 Series Ultra-Low-Noise Lasers, ULN15 Series, ULN15 Series Lasers, Ultra-Low-Noise Lasers, Lasers

References

- Thorlabs, Inc. - Your Source for Fiber Optics, Laser Diodes, Optical Instrumentation and Polarization Measurement & Control
- Thorlabs, Inc. - Your Source for Fiber Optics, Laser Diodes, Optical Instrumentation and Polarization Measurement & Control