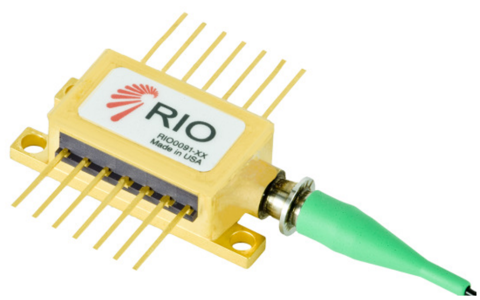
RIO
REDFERN INTEGRATED OPTICS INC.

RIO009x Series - 1550nm PLANEX™ Laser

For Fiber Optic Sensing Applications

Application Note

November 2011
Rev 1.6



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RIO

Table of Contents

RIO

1 Revision History

Revision	Date	Change Description
1.0	April 2008	Initial Release
1.1	May 2008	Added Table 1, Laser bias current source noise limits.
1.2	August 2009	Change Table 1, Laser bias current source noise limits.
1.3	September 2009	Added Steinhart-Hart coefficient.
1.4	October 2009	Added bias current ramping rate on laser turn-on procedure.
1.5	February 2010	Added current noise spec for Grade 4. Updated current noise spec.
1.6	November 2011	Added PLANEX pin-out information (Sec. 8.1)

WARNINGS

- **<u>ESD:</u>** The RIO 009x PLANEX lasers are ESD sensitive devices. Observe standard precautions for handling ESD sensitive devices.

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2 Purpose

The purpose of this document is to describe the recommended test set-ups for the RIO009x series of PLANEX semiconductor lasers. It also outlines recommended laser drivers and TEC controllers to achieve optimal performance.

3 RIO PLANEX ECL Overview

The RIO009x PLANEX is a high-performance cost effective Planar External Cavity Laser (ECL). The design is based on RIO's proprietary planar technology (PLANEX) and consists of a high-speed gain chip and a Planar Lightwave Circuit (PLC) with integrated Bragg grating, forming a laser cavity. The outline of the RIO ECL is presented in Figure 1.

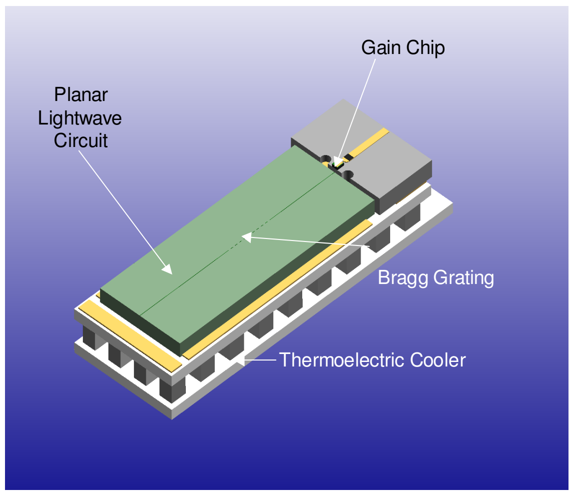


Figure 1. Simplified RIO ECL internal layout

The PLANEX ECL has significant performance advantages compared to competing technologies such semiconductor DFB lasers and fiber lasers:

- Narrow linewidth
- Low frequency and phase noise
- Low relative intensity noise (RIN)
- Low wavelength sensitivity to temperature & bias current
- Small form factor, 14pin butterfly
- Low power dissipation

The device is designed in an industry standard 14-pin Butterfly sealed package.

Figure 2. RIO ECL 009x laser in 14-pin Butterfly package

4 Specifics of PLANEX Setup and Operation

The RIO PLANEX laser requirements for laser bias drivers, TEC temperature management and control loops are similar to commercially available DFB lasers. However, setup, tuning, and testing have some differences. Please review this application note, the RIO ECL datasheet, and the sample test report (one is included in the Appendix) before setting up and testing the ECL. Each RIO laser has a recommended TEC temperature (Ts) set point. This temperature and corresponding thermistor resistance are indicated in the test report supplied with each ECL. It is necessary to maintain the recommended Ts to provide optimal power and noise performance.

Typical power and wavelength vs. TEC temperature characteristics are presented in Figure 3.

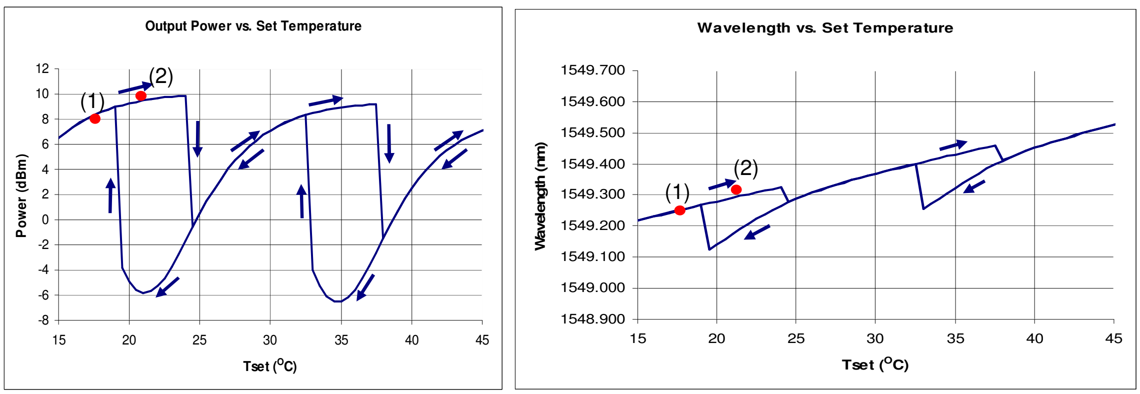


Figure 3. Typical power and wavelength vs. TEC temperature characteristics with operating points outside (1) and inside (2) the hysteresis region. When tuning the temperature up or down, the highlighted curves are followed.

Figure 3 shows the hysteresis in the power vs. laser temperature and wavelength vs. laser temperature characteristics. Those properties of ECL are well understood and stable over the lifetime of the product. During initial ECL temperature setting you may observe spectral distortions – this is an indication that the ECL temperature is outside of the recommended range or operating on the lower arm of the hysteresis. As soon as you tune the temperature to the recommended value, Ts, and then apply the bias current, you will observe a single longitudinal mode spectrum.

The recommended Ts may be below (1) or within (2) the hysteresis region (see Figure 3). Either operating point will give stable laser operation. If the recommended temperature is within the hysteresis region, it will always refer to the upper arm of the hysteresis curve.

When the recommended laser tuning procedure is followed, stable laser operation is guaranteed, with the laser operating as per the published datasheet, over the life of the laser.

Tuning the TEC temperature outside the recommended set point region will not damage the ECL and will not lead to any permanent performance degradation. With the ECL temperature adjusted to Ts and operating in the upper arm of the hysteresis (if that is where the recommended Ts set-point is), the ECL will provide the expected spectral and power performance.

The recommended laser temperature set-point will always be sufficiently below the mode-hop point to ensure stable operation over time. However, care must be taken in ensuring the temperature control loop does not allow the temperature to drift so far from the recommended set-point that a mode-hop event could occur.

Note: The ECL wavelength vs. temperature tuning coefficient is typically ~15 pm/°C, which is significantly smaller than for DBF lasers (typically 90-100 pm/°C).

5 RIO ECL Electrical, Optical and Thermal Specifications

RIO ECL electrical and optical specifications are as per the RIO datasheet. Refer to the most recent datasheet for the PLANEX laser under test.

6 Reading a RIO 009x ECL test report

A typical RIO 009x laser test report is included in Appendix A. The marked Sections are explained below.

Table (A) gives the serial number and part number of the laser along with the test date and test operator.

Table (B) lists the proper laser operating conditions and measured performance:

Operating temperature (Tset) – is the recommended operating temperature of the ECL for optimal performance. Conformance to the values listed in the test report as well as the product datasheet is only guaranteed within ±0.5°C of Tset. Each laser comes with its own recommended Tset.

Operating bias current (Ibias) – is the recommended optimal laser DC bias current. Listed wavelength and output power is at Ibias.

Maximum bias current (Imax) - is the recommended maximum laser DC bias current. Setting the laser above Imax will only degrade laser performance from optimal. Setting the Ibias above Imax (but below the Absolute Maximum Laser Bias) will not damage the laser but it may cause the laser to mode hop; forcing the user to re-tune the laser temperature to move the laser back to the optimal operating point.

Threshold Current – Laser threshold current at Tset.

Center Wavelength at TEC temperature at Tset, and Ibias – Laser peak wavelength when operated under the recommended conditions.

ITU Channel – When the laser is operating at Tset and Ibias, this is the corresponding ITU-T grid frequency number.

Channel offset – Laser peak wavelength offset from the center of the ITU channel when the laser is operating at Tset and Ibias.

Output power at TEC temperature at Tset, and Ibias – Total laser output power when the laser is operating at Tset and Ibias.

Side Mode Suppression Ratio at Tset, and Ibias – Laser SMSR when operated under the recommended conditions.

Polarization Extinction Ratio (room temperature) – With the Polarization Maintaining Fiber option, this is the ratio of the launched power in the main (slow) polarization axis to power in the other polarization axis.

Note (C) lists the measured thermistor resistance when the laser is being operated at the recommended temperature set point. This value can be useful in testing when the TEC controller being employed does not list calculated temperature but only measured thermistor resistance.

Graph (D) shows the wavelength vs. set temperature characteristic for this laser. The recommended operating point may or may not be within the hysteresis of a mode hop. Make sure laser is set up to operate in the correct arm of the hysteresis loop.

Graph (E) shows the output power vs. set temperature characteristic for this laser. The recommended operating point may or may not be within the hysteresis of a mode hop. Make sure laser is set up to operate in the correct arm of the hysteresis loop.

Graph (F) shows the time-averaged spectrum, measured with an optical spectrum analyzer, of the laser when operating at its recommended settings.

Graph (G) shows the output power and monitor current of the laser when operating at its recommended temperature set point.

Graph (H) is a plot of the measured and averaged phase noise of the laser when operating at its recommended settings. The phase noise is normalized to 1m optical path difference.

7 Low noise operation and Test of the ECL

In Section 4 the basic CW behavior of the RIO ECL was explained. This Section will give the guidelines that should be followed to arrive at the optimum performance with respect to phase noise and linewidth.

7.1 Current drivers and noise filtering

The drive current used to pump the gain chip should exhibit "low noise", because any fluctuation in the current will cause fluctuations in the laser cavity carrier density, the refractive index and ultimately the wavelength of the light. Fluctuations in wavelength are nothing less than frequency noise, which, in an Interferometric sensing application amounts to phase noise, hence the importance to keep the current noise density of the driver to a minimum.

A recommended commercial laser bias current driver is the ILX Lightwave LDX-3620 with battery option.

Figure 4. ILX Lightwave laser bias current driver

The current noise can and should be further reduced by using an electrical passive filter on the driver cable (if used in a laboratory set up) or by integrating a similar filter on the PCB. The laboratory filter recommended is the ILX Lightwave LNF-320.

Figure 5. In-line cable noise and current spike filter.

Another way of decreasing noise is by using a battery-operated driver if possible. Still, the power output stage of such a driver will generate noise and the design should be verified by measuring the resulting optical phase noise.

If using a non-commercial laser bias current source to measure the phase noise of the RIO 009x laser, the current noise density must be lower than the values given in Table 1 below. Maximum values for the 4 available grades of PLANEX laser are given across frequency.

	Current Driver Noise Spec		nA/Sqrt(Hz)	
Frequency, Hz	**Grade 1**	**Grade 2**	**Grade 3**	**Grade 4**
5	51.32	34.60	16.88	8.44
10	36.23	24.07	12.10	6.02
100	10.80	6.84	3.79	1.86
200	7.89	4.92	2.82	1.37
1000	3.67	2.22	1.36	0.65
10000	1.86	1.07	0.72	0.34

Table 1. Maximum laser bias current noise limits.

If a laser bias current source with a current noise density which is higher than the maximum limits is used, the measured phase noise will limited by noise of the current source and not of the laser.

7.2 Thermoelectric cooler and thermal control loop

The TEC temperature of the laser must be set precisely in order to achieve optimal power and center wavelength. Drift and low-frequency noise in the TEC current will create frequency noise in the laser output which can interfere with sensing applications. Care must be taken to ensure the TEC current controller circuit is stable and has very low noise. A recommended commercial laser temperature controller is the Newport Model 6000. Gain setting 0.2 (slow) is recommended.

Figure 6. Newport laser temperature controller.

The internal thermistor should be used in a control loop to stabilize the temperature of the ECL sub-assembly mounted on the thermoelectric cooler. The thermistor employed by RIO has a value of 10.0 kΩ at 25.0 °C with 1) a thermistor constant, β of 3950 (for "beta" formula approximation), or 2) thermal coefficients, C_1 = 1.2146 X 10^{-3}, C_2 = 2.1922 X 10^{-4}, and C_3 = 1.5244 X 10^{-7} (for Steinhart-Hart equation). Note that the 'beta' formula approximation is only good at narrow temperature ranges (+/-1 °C from reference temperature) in general. If the TEC temperature controller being employed does not give a value of temperature, but rather thermistor resistance, the table below lists the thermistor values versus temperature for the thermistor used in the RIO009x PLANEX laser.

Temp (^{O}C)	Rmin, Ohm	Rtyp Ohm	Rmax Ohm
10	19430	19760	20100
11	18550	18860	19170
12	17710	18000	18290
13	16910	17180	17450
14	16160	16400	16650
15	15440	15670	15900
16	14750	14960	15180
17	14100	14300	14490
18	13480	13660	13840
19	12890	13060	13220
20	12330	12480	12640
21	11800	11940	12080
22	11290	11420	11550
23	10800	10920	11040
24	10340	10450	10560
25	9900	10000	10100
26	9473	9573	9673
27	9066	9166	9266
28	8679	8778	8878
29	8310	8409	8508
30	7959	8057	8156

Temp (^{O}C)	Rmin, Ohm	Rtyp Ohm	Rmax Ohm
31	7625	7722	7819
32	7306	7402	7499
33	7002	7097	7193
34	6712	6806	6901
35	6436	6529	6622
36	6172	6264	6356
37	5921	6011	6102
38	5681	5770	5860
39	5452	5539	5628
40	5233	5319	5407
41	5024	5109	5195
42	4825	4908	4993
43	4634	4716	4800
44	4452	4533	4615
45	4278	4357	4438
46	4112	4190	4269
47	3953	4029	4107
48	3801	3876	3952
49	3655	3729	3803
50	3516	3588	3661

Table 2. Thermistor resistance values as a function of temperature.

7.3 Physical mount for the 14-pin butterfly package

To hold the laser in place and make proper electrical contact with the pins, a laser test fixture such as the ILX Lightwave LDM-4984 is recommended. Another option is a Newport 744 laser diode mount.

Figure 7. ILX Lightwave laser mount

8 Installation

The standard package consists of the butterfly laser with fiber pigtail sealed in a shipping container accompanied by datasheets.

Before operating the Laser Module:

- Inspect the laser module for any signs of damage
- Read the mounting instructions thoroughly, and become familiar with all safety symbols and instructions to ensure that the laser module is operated and maintained safely.

Caution:

• Any semiconductor laser is sensitive to electrostatic discharge (ESD). Exposure to ESD can cause permanent damage to the laser, which may affect immediate performance or result in reduced life time. The laser is tested to MIL 883 standard method 3015 (500 V Human Body Model), which means that there is some immunity against ESD, but care must be exercised to avoid ESD.

1. Always use ESD safe working environment
2. Short the anode and cathode of laser and monitor PD when the module is disconnected with the clamps provided.
3. Use ESD wrist straps and grounded work benches at all times when handling the laser module.
4. Ground all equipment, such as power supplies and soldering irons.

• Power supply surges can cause failure of the laser similar to ESD.

1. Always turn down the current before connecting or disconnecting the laser.
2. Never disconnect power supply or turn off equipment while the laser is on.
3. Make electrical connections by soldering or using reliable connectors. It is advised not to use clip leads, such as alligator clips.

• Although the fiber can withstand bending radii smaller than 30 mm, the use of such radii is not advised, and there is a risk of breakage. Be especially careful when unpacking the device before installation, when possible loops and twists in the pigtail should be unraveled.

• Bending the electrical leads too far or too often can cause breakage of the leads. Excessive force on the leads or the ceramic can lead to cracks in the ceramic and loss of hermiticity.

• Be careful not to drop the laser. The shock that acts upon the device when falling from a table to the ground can easily exceed the maximum guaranteed shock resistance.

• The maximum laser module temperature is 85 °C. The module is not suitable for reflow soldering in an oven.

8.1 RIO ECL Pin-Out

Figure 8 shows the pin assignment of RIO ECL laser, and the detailed description of each pin is provided in the table below. Prior to mounting the RIO ECL laser into any laser mounts, check and route the pins of the laser mount properly to match with the RIO ECL pin configurations.

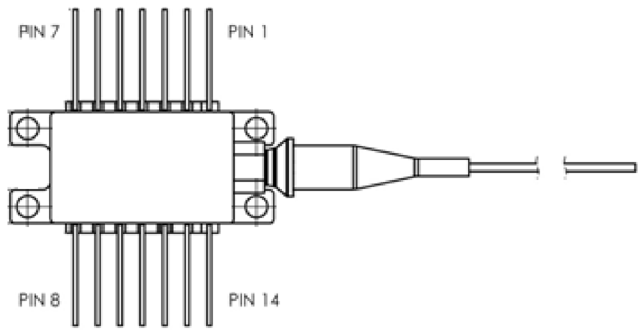


Figure 8. RIO ECL pin assignment

Pin No.	Description	Pin No.	Description
1	Thermistor +	8	Not connected
2	Thermistor -	9	Package
3	Laser cathode DC Bias Current (-)	10	Package
4	PD Anode (-)	11	Laser Anode (+)
5	PD Cathode (+)	12	Cathode (RF input), Input impedance: 25 Ω
6	TEC +	13	Laser Anode (+)
7	TEC -	14	Package

8.2 Mounting the laser

Under operating conditions, especially at high ambient temperature, the Thermo-electric cooler will generate a considerable amount of heat. The maximum TEC power dissipation is given in the specifications, and can be in the order of 2 to 3 Watt. To remove this heat from the package, the bottom of the butterfly must be mounted to a heatsink using the 4 screw holes in the base plate..

To install the laser on the heat sink:

1. Make sure that no hard grainy particles are present on the heatsinking area
2. Place the thermally conductive material (cut to the size of the butterfly base) onto the heatsink. Recommended thermal material: Bergquist Gap Pad VO Ultra Soft (thickness 0.04”).
3. Using a torque-limited screwdriver, attach the laser to the heat sink by fastening two screws diagonally across from each other. Do not fasten the screws to the final torque yet.
4. Fasten the remaining two screws in the same way.
5. Tighten all four screws to the final torque value. Recommended torque:

- <3 N.cm using Bergquist Gap Ultra Soft is the best to minimize phase noise sensitivity to external vibration and acoustic noise. Use epoxy to secure the screws (recommended thread lock: Loctite 222MS) in this case.
- Torque should be <20 Ncm in any cases, like mounting laser to the hard surface and/or using different thermally conductive materials.

Soldering the Laser to a PCB

To solder the leads to the electrical connections on a PCB:

1. Use common soldering equipment. Pre-tinning is not necessary.

Do not exceed the maximum pre-scribed soldering heat of 350 °C for less than 10 sec.

Handling Fibers

The fiber pigtail can be standard SMF or PMF. When guiding the pigtail and securing it in place, avoid bending radii <35 mm because this will decrease the output power due to bending losses.

8.3 Optimum Set Point

The operating point of the laser must be properly chosen to guarantee its performance over the lifetime of the device. Each unit comes with a test report with the optimum set point in current and temperature as has been determined by RIO in the extensive final test program for each individual butterfly laser. In determining the optimum set point the trade-off between optical power, phase noise and ITU channel offset is taken into account. This guarantees the best performance of each device over the full lifetime within the specifications. **Therefore it is not recommended to deviate from this preferred setting.**

To get the optimum set point for the laser from the test report, refer to Section 6, Reading a RIO009x ECL test report.

8.4 Switching the laser on

Once the laser is mounted on the PCB with its drivers and control loops, it can be switched on and it will be ready for use.

To ensure the laser is operating at its correct operating point in the top arm of the hysteresis curve:

Always activate the thermal control loop first, and let the internal temperature stabilize, before applying the operating current. Reversing this sequence may result in the PLANEX operating in the lower branch of the hysteresis loop, leading to low power, the wrong wavelength and poor phase noise performance.

Following this procedure of letting the temperature stabilize first, then applying the laser bias (bias current ramping rate ~ 10 mA/sec.), will always result in operating at the correct operating point.

If for some reason it is necessary to apply both the bias current and TEC current simultaneously, the way to guarantee operation at the correct operating point is to tune the laser to several degrees below the recommended temperature set-point first into hysteresis-free area, and then slowly increase the TEC temperature to the final set-point. This will also ensure operation at the correct operating point on the hysteresis curve.

8.5 Verifying correct operation

Once the laser has stabilized to its correct Tset and Ibias, measure the wavelength and output power. If both of these values match the ones given in the laser test report; then the laser is operating properly at the correct operating point.

8.6 Troubleshooting

If diminished power or no power is present at fiber connector:

- Ensure laser bias is on and set to the correct value
- Ensure laser temperature is set to correct value via the TEC controller. If uncertain that the temperature being displayed is correct, monitor the thermistor resistance and compare to the value given in the test report.
- Ensure laser is operating at the correct point on the hysteresis curve. Follow the guidelines given in Section 8.3 on setting up the laser operating point.
- Check that the optical connector is clean and free of scratches.

If light present but the wavelength is incorrect:

- Ensure laser is operating at the correct point on the hysteresis curve. Follow the guidelines given in Section 8.3 on setting up the laser operating point.
- Ensure laser temperature is set to correct value via the TEC controller. If uncertain that the temperature being displayed is correct, monitor the thermistor resistance and compare to the value given in the test report.
- Ensure laser bias is on and set to the correct value. The magnitude of the bias current will have an effect on wavelength.

RIO

Appendix A: RIO009x Test Report

Test Report
RIO External Cavity Laser

(A)

Part Number	RIO0095-3-35-2
Serial Number	100165
Test Date	2/22/2008
Operator	WL
QA	SL

(B)

Parameter	**Value**	**Units**
Operating temperature (Tset) (Note 1)	22.0	°C
Operating bias current (Ibias)	80	mA
Maximum operating bias current (Imax)	95	mA
Threshold Current	5.0	mA
Center Wavelength at Tset, and Ibias	1549.303	nm
ITU Channel	35	-
Channel offset	-17	pm
Output Power at Tset, and Ibias	11.0	mW
Side Mode Suppression Ratio	43	dB
Polarization Extinction Ratio	>26	dB

(C)

- Thermistor resistance: 11.42 kΩ at Tset

Note 1: Temperature should be stable before switching on the operating bias current.

(D)

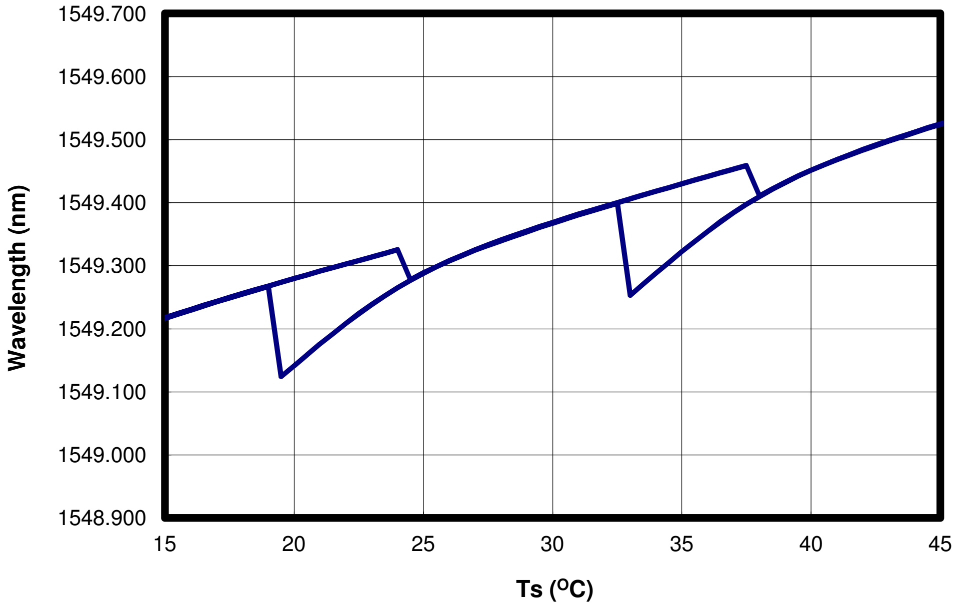


Fig. 1: Wavelength Vs. TEC Temperature (@Ibias)

(E)

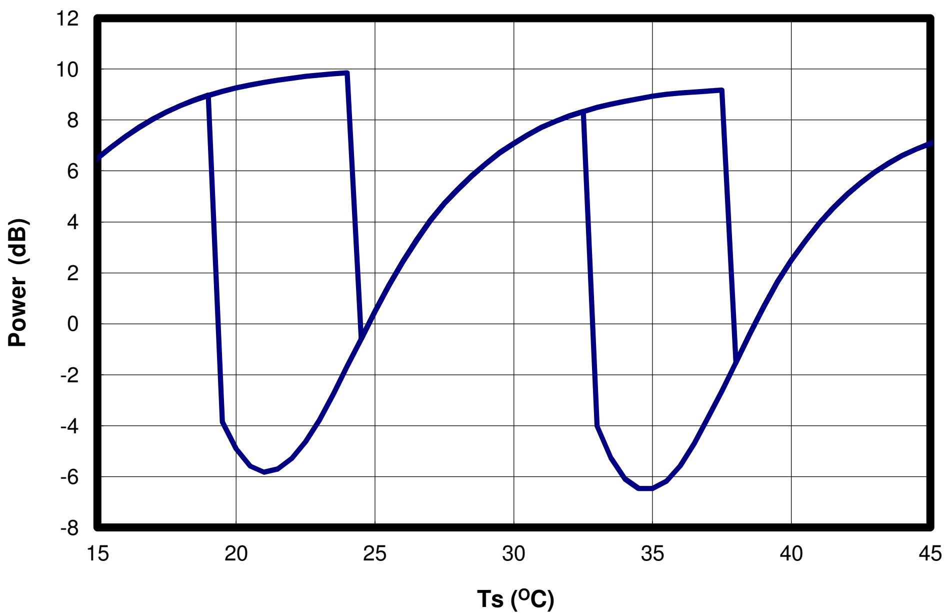


Fig. 2: Fiber Coupled Power Vs. TEC Temperature (@Ibias)

(F)

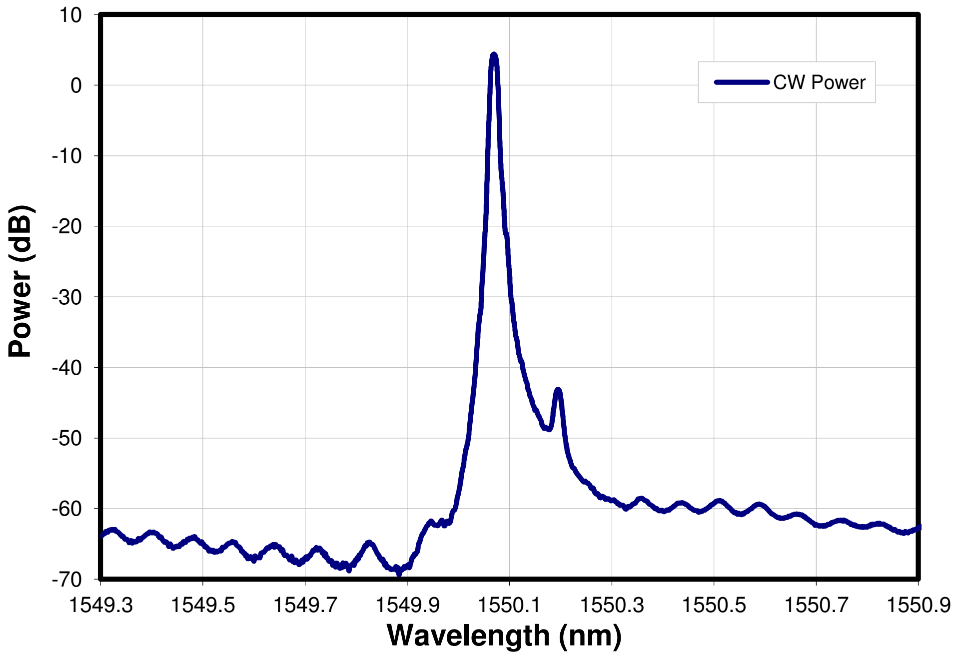


Fig. 3: Spectrum (CW, Tset, Ibias)

(G)

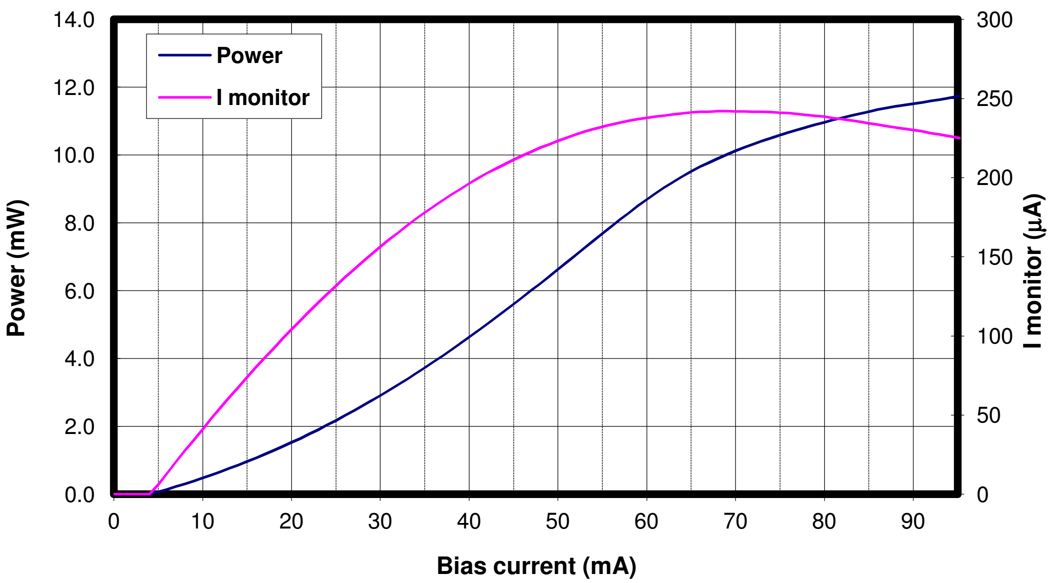


Fig. 4: Fiber Coupled Power and Imonitor vs. Bias Current at Tset

(H)

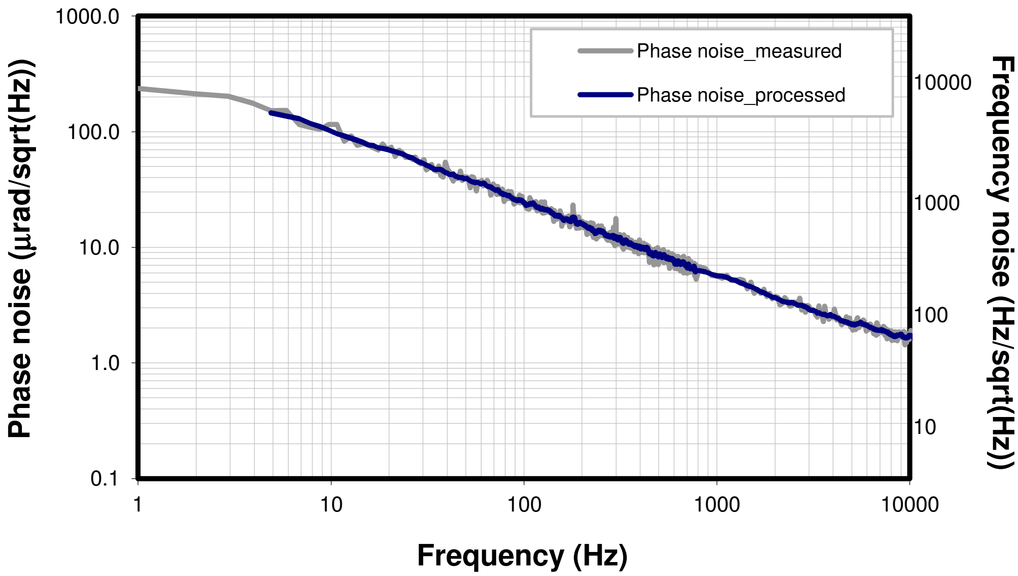
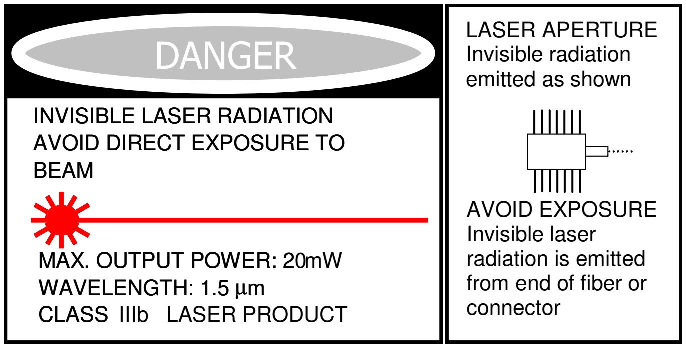


Fig. 5: Phase Noise at Tset, Ibias, normalized to 1 m OPD
Measured with external TEC controller and external bias current source

Laser Safety Information

Laser Modules are classified as FDA/CDRH Class IIIb laser products per CDRH, 21 CFR 1040 laser safety requirements.



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