Warranty

Calmar Optcom Inc. warrants this product to be free from defects in material and workmanship for a period of two years from the date of shipment. If it is found to be defective during the warranty period, the product will be either repaired or replaced at Calmar Optcom's option.

To exercise this warranty, write or call Calmar Optcom Inc. You will be given prompt assistance and return instructions. Send the instrument, transportation prepaid, to the indicated service facility. Repaired products are warranted for the balance of the original warranty period, or at least 90 days.

Limitation of Warranty

This warranty does not apply to defects resulting from the modification or the misuse of any product or part. Calmar Optcom Inc. shall not be liable for any indirect, special, or consequential damage.

Part No. Man-PSL-10-30411

Table of Contents

Safety Symbols and Terms

The following safety terms are used in this manual:

- The **Warning** heading in this manual explains dangers that could result in personal injury or death.
- The **Caution** heading in this manual explains hazards that could damage the instrument.
- The **Note** heading provides information that may be beneficial in the use of this instrument.

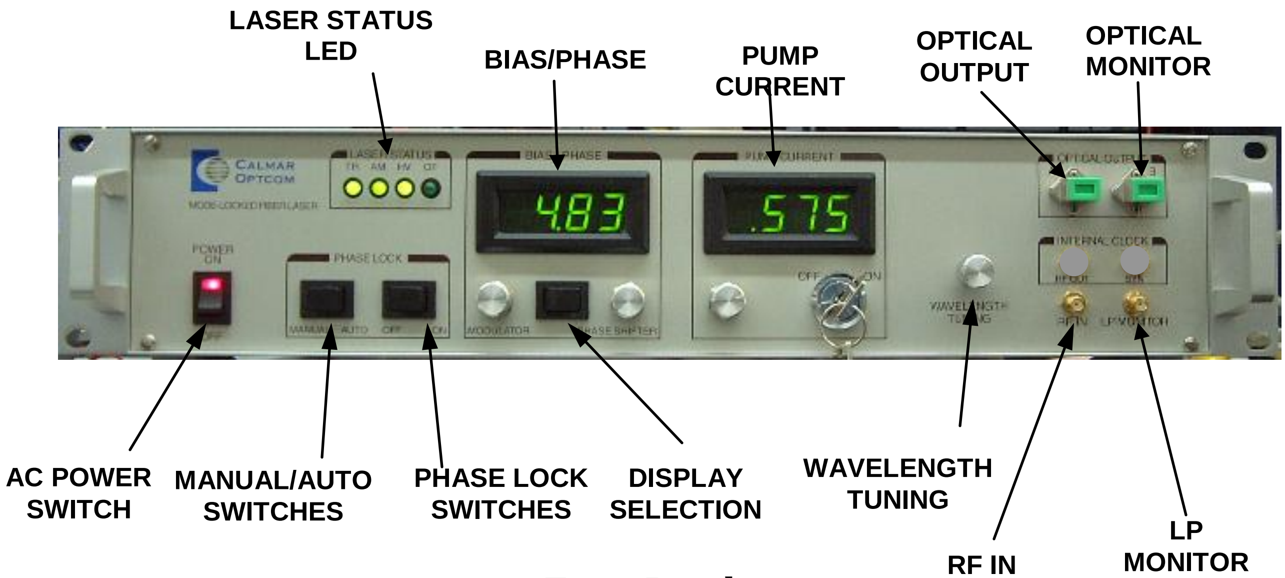
Notes for a Safe Operation

- **Warning**: The product generates an output peak power of 100 Watts (1550 nm laser with average power less than 120 mW) that may cause permanent eye damage or skin burns.
- The product has been designed for an AC power of 85 – 250V, 47 – 63 Hz. Before switching the product on, make sure that it has the proper AC power supply.
- **Warning**: The product encloses a class III laser (1480 nm laser diode with power less than 300 mW) that may cause permanent eye damage or skin burns. Under normal operating conditions, the laser light is contained in the optical fiber within the product. Any disassembly of the product may expose the laser, and is strongly discouraged. Keep the AC power supply disconnected if disassembling the product.
- Fiber connectors (FC/PC) are very sensitive to contamination. All fiber connectors should be cleaned before being connected to the output of the product. Any contamination may severely reduce the output power.
- Avoid mechanical shock to the unit. Excess force may cause misalignment of the unit.
- Unauthorized opening of the PSL unit is strongly discouraged. The unit contains fragile fiber-optic components, which can be damaged if the unit is opened. This unit does not contain any parts that need service by an end user. Warranty will be voided if any unauthorized opening causes damage to the unit.
- An electrical shock hazard exists inside the product. The product encloses up to 1000 Volts high voltage. Disconnect AC power supply before disassembling the product.

Specifications

(PSL-10-3-22-TA-S-C, Serial #2010230411)

OPTICAL CHARACTERISTICS	
Pulse Width	1.0 ps – 2.0 ps
Peak Wavelength	1545 nm – 1560 nm
Repetition Rate	9.0 – 11 GHz
Maximum Output Power	> 10 mW
Spectral Width	2 nm typical
OPTICAL COMPONENTS	
Gain Medium	Er-doped fiber
Pump Source	1480 nm diode laser
Connectors	FC/PC PM fiber connector
OPERATING REQUIREMENTS	
Operating Voltage	85-250 V/AC 47 – 63 Hz, 300 Watts
RF Drive Frequency	9.0 – 11 GHz
RF Drive Level	-4 dBm to 0 dBm
Operating Temperature	15 to 35 degrees C
PHYSICAL CHARACTERISTICS	
Size	48 cm x 42 cm x 9 cm
Weight	20 lbs



Front Panel

Rear Panel

Figure 1   Panel illustrations

Section 1 – Principle of Operation

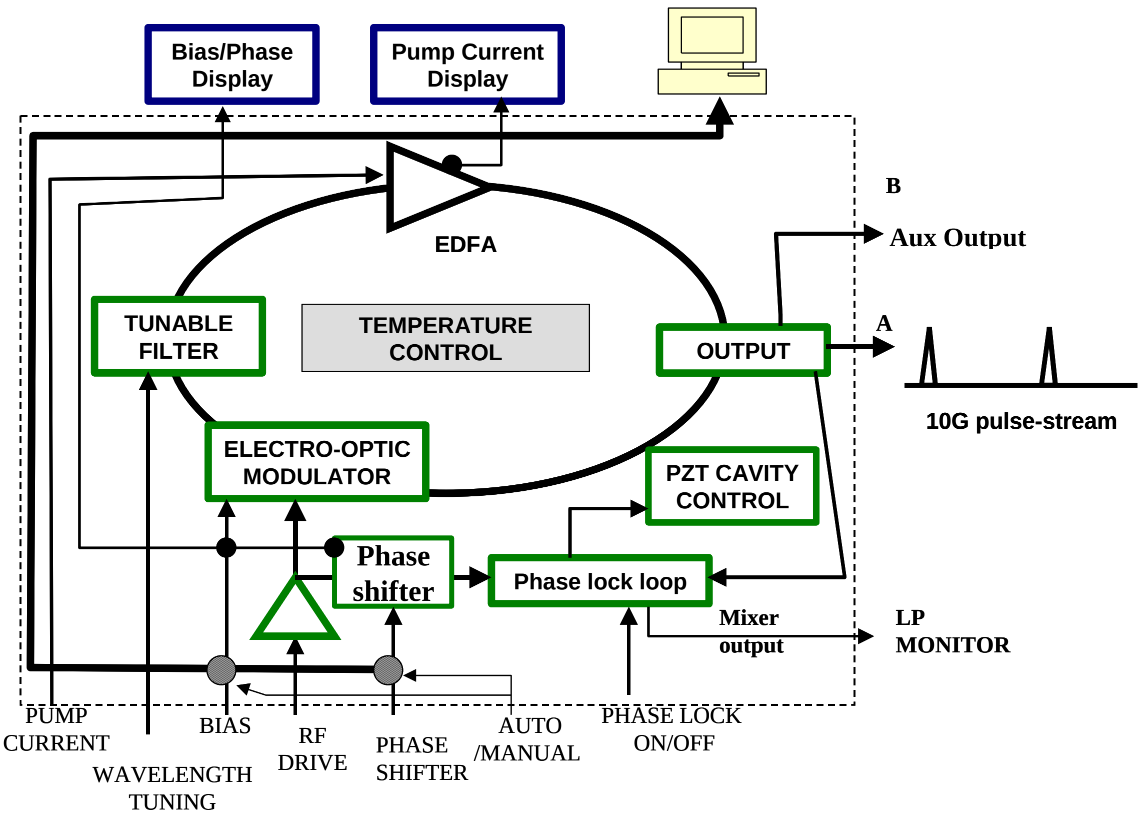


Figure 2. Functional diagram of PSL

The PSL is an optical pulse source. It produces an optical pulse train at repetition rates of 9 – 11 Gb/s. The optical pulse train has pulse widths in the range of 1 – 10 ps depending on the model number. The optical pulse has wavelengths in the range of 1535 nm to 1560 nm.

The PSL laser is based on an actively mode-locked fiber laser. The laser cavity consists of **EDFA**, **OUTPUT** coupler, **ELECTRO-OPTICS MODULATOR**, **TUNABLE FILTER** and fiber that connect these devices together. The **PZT CAVITY CONTROL** adjusts the cavity length to achieve stable mode-locking. The base rate of the PSL is a 10 GHz pulse source.

WAVELENGTH TUNING controls the center wavelength of the tunable filter. **WAVELENGTH TUNING** determines the laser output wavelength.

The gain medium in the **EDFA** is Erbium-doped fiber. The pump laser in the **EDFA** provides optical pump to excite the gain medium. The pump laser is a 1480 nm diode laser. The diode laser is driven by an electrical current source. The current is displayed in the front panel and can be adjusted by tuning the **PUMP CURRENT** control knob. Adjustment of the pump laser current changes the output power.

The **ELECTRO-OPTIC MODULATOR** modulates the loss in the laser cavity to support the active mode-locking. The user supplied **RF DRIVE** is first amplified by an internal RF amplifier, and then drives the **ELECTRO-OPTIC MODULATOR**. The laser repetition rate equals the **RF DRIVE** frequency. The **ELECTRO-OPTIC MODULATOR** is also controlled by externally supplied bias voltage. The modulator bias (**MOD BIAS**) voltage needs to be adjusted to a proper DC value to ensure proper mode-locking. Since the modulator bias point can drift over time, the modulator bias voltage may need to be adjusted from time to time.

The **PHASE LOCK LOOP** circuit provides a control voltage to **PZT CAVITY CONTROL**. The **PZT CAVITY CONTROL** fine-tunes the laser cavity length to ensure stable operation. The laser cavity has a round trip frequency of f_R ($f_R \sim 2$ MHz) that depends on the cavity length. To satisfy the condition of stable mode-locking, f_R of the laser multiplied by an integer M (M ~ 5,000) must be matched by the RF drive frequency AUTO **mode** ($f_D \sim 10$GHz) precisely.

$$f_D = M \times f_R \text{ (M is an integer)}$$

The laser repetition rate equals f_D. The laser can have multiple repetition rates according to the above formula, since M can be an arbitrary integer.

Since the laser cavity optical length may change according to temperature changes, **TEMPERATURE CONTROL** is used to ensure constant laser cavity length. The cavity length changes about 1.09E-5 per degree C. The temperature control gives a coarse tuning of f_R.

$$\Delta f_D = -1.09e\text{-}5\ \Delta T\ f_D\ (\Delta T = T - To)$$
$$\Delta f_R = -1.09e\text{-}5\ \Delta T\ f_R$$

At a constant temperature, stable mode-locking can be achieved over a set of discrete microwave driving frequency points (f_D). These discrete points are separated by f_R (~ 2.0 MHz). Varying the operating temperature can change the f_D. An ~ 18 degree C change of the temperature can lead to 2.0 MHz variations near 10 GHz which will enable the laser to operate at any frequency point.

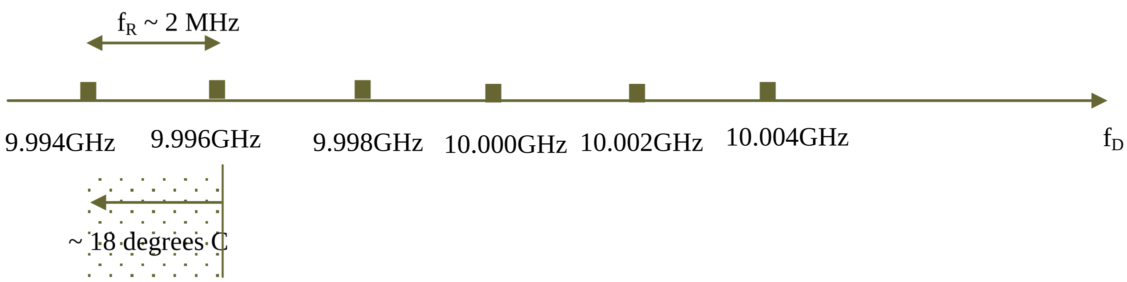


Figure 3. Illustration of discrete repetition rate points for which the fiber laser can produce stable output at a certain temperature. The spacing between discrete points is about 2 MHz. By varying temperature in the range of 18 degree C, the discrete frequency points will shift by 2 MHz, thereby covering all the frequencies.

PZT CAVITY CONTROL gives a fine-tuned f_R all the time. The range of PZT control is about several hundred kilohertz.

PHASE SHIFTER controls the phase of the **RF DRIVE** signal into the **PHASE LOCK LOOP.** The **PHASE SHIFTER** must be adjusted precisely so that the **PHASE LOCK LOOP** can function properly. There is a mixer inside the **PHASE LOCK LOOP**. The mixer output voltage should be close to zero when the PSL is mode-locked properly. The **LP MONITOR** produces the mixer output.

Section 2 – System Operation

2.1 - Front and Rear Panels

Operation controls are on the front panel. Power supply inlet, temperature control and computer control input/output are on the rear panel.

Table 1 - Front Panel

Labels		Description	Function
POWER ON/OFF		Rocker switch	Turn AC power on and off to control AC power supply to the whole system
PUMP CURRENT		ON/OFF key switch	Enable/Disable pump laser
		10-turn potentiometer	Set current of pump laser when in **MANUAL** mode
		Digital panel meter	Display current of pump laser in Amperes
LASER STATUS	**TR**	Laser temperature status	On: indicates laser temperature in normal working range (around 36.6 degrees C for 9.95328 GHz)
	AM	Laser auto lock status, default ON	In **AUTO** mode: ON indicates lock successful; FLASHING lock failure; OFF lock initializing. In **MANUAL** mode: always ON.
	HV	PZT voltage status	On: indicates PZT voltage in normal range.
	OT	System temperature status	On: indicates over temperature. PSL needs to be shut down quickly.
PHASE LOCK	**MANUAL /AUTO**	Rocker switch	**MANUAL**: pump current, modulator bias and phase shifter are controlled by the front panel knobs. **AUTO**: pump current, modulator bias and phase shifter are computer-controlled through internal computer or remote computer.
	ON/OFF	Rocker switch	ON: enables phase lock loop to supply control voltage to PZT cavity control OFF: disables phase lock loop

(continued on next page)

(continued)

BIAS/PHASE		Rocker switch	Switch Display to BIAS or PHASE
		Digital panel meter	Displays bias voltage or phase shifter voltage
		MODULATOR knob	Adjusts bias voltage in **MANUAL** mode, disabled in **AUTO** mode
		PHASE SHIFTER knob	Adjusts phase voltage in **MANUAL** mode, disabled in **AUTO** mode
OPTICAL OUTPUT	A	FC/PC PM fiber receptacle	Optical pulse output; PM fiber; key to the slow mode axis
	B	FC/PC SM fiber receptacle	Auxiliary optical pulse output; SM fiber
WAVELENGTH TUNING		Knob	Tunes wavelength
RF OUT		Major internal clock output; SMA F connector	Used to drive the PSL. ~9.95328GHz, ~0dBm.
SYN		Secondary internal clock output; SMA F connector	Used to trigger the equipment. ~1dBm
RF IN		SMA F connector	RF drive signal, 9 – 11 GHz (refer to Page 10 for exact setting)
LP MONITOR		SMA F connector	Monitors phase lock loop mixer output level

Table 2 - Rear Panel

Labels	Description	Function
POWER	AC power inlet	Connect to AC power supply 85 – 250 VAC
TEMPERATURE CONTROLLER	Temperature controller	Adjusts laser temperature
FUSE	Fuse holder	3 A fuse
10/100 MBPS PORT	Ethernet connector	Provides the remote control function of the PSL
FAN	Fan blocks	Cools the PSL for appropriate operation

2.2 – Operating Parameters

There are seven operating parameters that need to be set in order to obtain the desired optical pulses from the PSL laser. Two of the parameters are for the external RF drive source that has to be set by the user. The other five parameters can be set by the PSL front panel adjustments in the **MANUAL** mode. In the **AUTO** mode, three of the five parameters can be controlled by a computer.

Table 3 – Operating Parameters

Parameters	Location	Adjustment Method	Comments
RF DRIVE FREQUENCY f_D	External	Manual	Range: 9 GHz to 11GHz
RF DRIVE POWER LEVEL	External	Manual	Range: - 4 dBm to 0 dBm
LASER TEMPERATURE	PSL Back Panel	Manual temperature controller adjustment	Range: 30 – 55 degrees C, needs to be set to match the RF drive frequency (see Table 5, and Page 7 for $\mathbf{f_D}$ calculation)
WAVELENGTH	PSL Front Panel	Manual wavelength tuning knob	Range: 1545 nm – 1561 nm
MODULATOR BIAS	PSL Front Panel	Manual / Auto	Need to be optimized to achieve low noise operation
PHASE SHIFTER	PSL Front Panel	Manual / Auto	Need to be optimized to achieve low noise operation
PUMP CURRENT	PSL Front Panel	Manual / Auto	Control output power, need to be in a stable range for stable operation

From **Section 1 – Principle of Operation,** assuming the laser cavity has a round trip frequency of f_R and the RF driving frequency to satisfy the condition of stable mode-locking is f_D, we have:

$$f_D = f_T \pm N \times f_R \text{ (N is a integer, 0, 1, 2, …)}$$

$\mathbf{f_R}$**:** laser cavity round trip frequency

$\mathbf{f_D}$**:** RF frequency satisfying the condition of stable mode-locking

$\mathbf{f_T}$**:** test point frequency

Table 4 - Operating Driving Frequency

Name	Range		Initial Test Frequency	Notes
f_D	max	11 GHz	9.95328 GHz	Optimal value may change depending on the above formula. At each frequency point, the tolerance is 2E-5 or 200 kHz. Laser temperature is set at 36.6 degrees C.
	min	9.0 GHz		
f_R	N/A		2.62MHz	

The laser temperature must be set to match the RF drive frequency f_D. Table 5 provides information for one special frequency.

Table 5 - Operating Driving Frequency and Laser Temperature

	Drive Frequency (GHz)	Laser Temperature (C)	Note
1	9.95328	36.6	Initial temperature setting. This value changes for different RF drive frequency. This value may drift over time. Refer to Section 2.5 for calibration.

Table 6 - Operating Parameters when RF Drive Frequency is 9.95328 GHz

Name	Range		Initial Optimum Value	Note
RF DRIVE FREQUENCY			9.95328 GHz	
RF DRIVE POWER			-2.0 dBm	Occasionally varying RF power by +/- 2 dB may help to achieve low noise
LASER TEMPERATURE			36.6 degree C	Relates to RF drive frequency. May need calibration periodically.
WAVELENGTH			1559 nm	
PUMP CURRENT	Max	950 mA	800 mA	Pump current influences output power, output pulse width, and output stability.
	Min	400 mA		
MODULATOR BIAS	Max	8.9 V	6.7 V	Modulator bias voltage influences stability. Optimal bias voltage usually drifts quickly during initial operation.
	Min	0 V		
PHASE SHIFTER	Max	19 V	4.9 V	The phase shifter voltage influences the stability of the laser. The optimal phase shifter value strongly depends on the RF drive frequency.
	Min	0		

2.3 – PSL Initialization

INITIAL STATE

Before turning on the **POWER** switch, the **PUMP CURRENT ON/OFF** switch should be in the **OFF** position. The **PUMP CURRENT** control knob should be set to minimum (turned counter-clockwise all the way).

Turn the **POWER** switch on. After about 15 minutes, the **LASER STATUS TR** LED should light. The laser can now be operated.

For **AUTO** mode operation, the **PHASE LOCK MANUAL/AUTO** switch should be on **AUTO**. The **PHASE LOCK ON/OFF** switch should be in the **ON** position. For more details see the section **PSL Locking in AUTO Mode.** If the RF signal frequency and power level satisfy the requirements of the PSL, the laser will automatically set its optimized operating conditions.

For **MANUAL** mode operation, the **PHASE LOCK MANUAL/AUTO** switch should be on **MANUAL**. The **PHASE LOCK ON/OFF** switch should be in the **OFF** position. After the **LASER STATUS TR** LED lights, turn the **PUMP CURRENT ON/OFF** switch in the **ON** position. For more details see the section **PSL Locking in MANUAL Mode.**

WARM UP

The laser cavity is in a temperature-controlled chamber. After **POWER** switch is turned on, it usually takes about 15 minutes to warm up the laser cavity to its operating temperature. For the default temperature setting of 36.6 degrees C, the **LASER STATUS TR** LED should light when the laser cavity reaches its operating temperature. For other temperature setting, please ignore the **LASER STATUS TR.** The temperature will achieve its stable condition in another 15 minutes to one hour. The laser can operate after it reaches its operating temperature; however, the laser will be most stable when the laser cavity temperature reaches its stable condition.

The operating temperature needs to be set to a certain value depending on the RF drive frequency. Refer to Table 5 for special temperature settings for two RF drive frequencies of 10.70922 GHz and 9.95328 GHz. For other frequencies, it is recommended adjusting the temperature in the range of 30 - 48 degree C. The temperature coefficient of the laser drive frequency is –1.09E-5 per degree C. Please refer to Section 1 for appropriate temperature and repetition rate settings.

Note: The room temperature needs to be 5 degrees C or more below the laser temperature. Otherwise the laser temperature may not reach the set temperature.

It is recommended that when the laser is not in use temporarily, the power switch should be left **ON** to keep the laser cavity temperature stable for quick startup operation.

EXTERNAL RF SOURCE SETUP

The following is the minimum equipment needed to be able to adjust the PSL to its operating state:

(1) **RF SOURCE**, around 10 GHz with frequency tuning resolution better than 10 KHz, maximum output power more than 0 dBm, and low phase noise.

(2) High speed digital sampling scope (bandwidth > 20 GHz) with optical input, trigger frequency range > 10 GHz. A high-speed (< 20 ps) photodetector can be used as the optical front end with the digital sampling scope.

The setup is as shown in Figure 4a. The **RF SOURCE** output is split into two parts. One part goes to the PSL **RF IN**. The other part goes to the **DCA** (digital high speed sampling scope) trigger input. The **OUTPUT A** of the PSL should be attenuated to below 1 mW and then fed through the optical input of the plug-in module of the **DCA**.

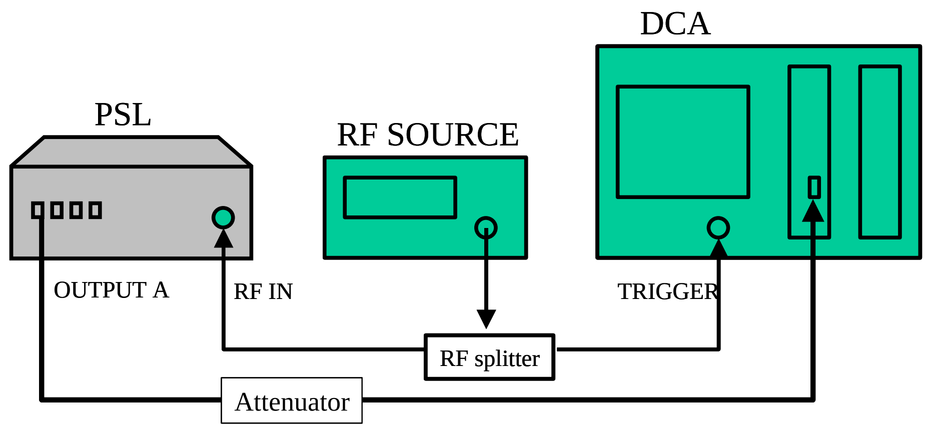


Figure 4a. Setup for initializing the PSL driven by an external RF SOURCE

Set the **RF SOURCE** output level such that the PSL has **–4 dBm** to **0 dBm** input and the high speed **DCA** has and adequate trigger input. Set the **RF SOURCE** frequency to a point as stated in Table 3.

Set the **DCA** to *20 ps/div* and short persistence mode. Make sure the **DCA** is well triggered and its vertical scale and offset are set for optimal display.

- **Caution: Most high-speed optical detection systems are highly vulnerable to high power damage. It is recommended to attenuate the optical power to below 1 mW before feeding it into any high-speed optical detection setup.**
- **Caution: Clean the fiber connector tip before connecting it to the OPTICAL OUTPUT. A dirty connector tip will increase connection loss significantly.**
- **Note: OUTPUT A has high optical output power around 30 mW. The fiber connector connection lifetime is usually short. It is very important to clean the fiber tip before any**

use. It is also highly recommended that any fiber connection should be done only when PUMP CURRENT is switched off.

WAVELENGTH SETUP

Turn the **PUMP CURRENT ON/OFF** key switch to the **ON** position. Turn the **PUMP CURRENT** knob clockwise to set the **PUMP CURRENT** to ***0.800 A***.

Use an optical spectrum analyzer to monitor the output of the PSL unit. Adjust WAVELENGTH to a desired wavelength. The wavelength measurement will be more accurate after the PSL is locked to its optimized condition.

2.4 – PSL Locking in Manual Mode

According to Table 7 on page 22, set **MODULATOR BIAS** and **PHASE SHIFTER** to the value close to the desired wavelength.

LASER LOCKING

1) First, the PSL **PHASE LOCK ON/OFF** switch should be in the **OFF** position.

2) After setting the frequency of the **RF SOURCE** to f_T, fine-tune the frequency around the initial f_T to find the clear 10 GHz pulse train display on the **DCA**. A typical trace is shown in Figure 5a. It is normal at this moment for the trace on the **DCA** to be clear only for a short period of time and then drift away.

Note: A. If the laser temperature and RF drive frequency are not matched, one cannot find a stable trace.

B. If the PSL is driven by the **INTERNAL CLOCK**, the RF frequency is not tunable. At this step it is possible that the trace on the **DCA** triggered by an external RF SOURCE is clearer than the one triggered by the **INTERNAL CLOCK**.

3) Set the **PHASE LOCK ON/OFF** switch to the **ON** position. The trace on the **DCA** should now stop drifting.

4) Fine-tune **PHASE SHIFTER** and **MODULATOR BIAS** around their initial set value to achieve a stable low noise trace on the **DCA**. It would be helpful sometimes to fine-tune the **WAVELENGTH TUNING**. A typical trace is shown in Figure 5b.

NOTE: A. If the trace keeps drifting, refer to TROUBLE SHOOT.

B. **MODULATOR BIAS** can drift over a range of several volts, and usually drifts fast at the beginning of laser operation, and drifts slowly over time. The range for optimal **MODULATOR BIAS** is about 0.3 volts to 0.5 volts.

C. The stability of the laser is sensitive to the **PHASE SHIFTER** setting. The **PHASE SHIFTER** drifts slowly. The optimal **PHASE SHIFTER** range is usually less than 0.2 volts.

D. If the PSL is driven by the **INTERNAL CLOCK**, the performance of PSL will be very sensitive to the **PHASE SHIFTER** setting.

TROUBLE SHOOT

Problem: During the above stated process, **PHASE LOCK ON/OFF** switch is set to **ON,** but trace fails to stabilize and then **LASER STATUS HV** LED is off.

Answer: One should repeat the above process from 1) to 4). If it fails after several tries, it means the initial **MODULATOR BIAS** and/or **PHASE SHIFTER** is too far away from the optimal points. Now the **PHASE LOCK ON/OFF** switch should be set to the **OFF** position. One should find optimal **MODULATOR BIAS** and **PHASE SHIFTER** points, and repeat the above process 1) to 4).

FINDING OPTIMAL MODULATOR BIAS: The optimal **MODULATOR BIAS** point is about 0.2 Volts above the modulator bias null point. The **RF SOURCE** frequency should be fine-tuned to show a clear trace near 10GHz. One can find the modulator bias null point by varying **MODULATOR BIAS** while observing the **DCA** display. When the **DCA** indicates that the laser produces an output pulse train at 20 GHz, **MODULATOR BIAS** is close to the null point. Record this **MODULATOR BIAS** voltage as modulator null point. The optimal **MODULATOR BIAS** voltage is 0.2 volts above the null point.

FINDING OPTIMUM PHASE SHIFTER: At the optimal **PHASE SHIFTER** value, the mixer output DC level is close to 0 volt and the slope of variation is negative. The **RF SOURCE** frequency should be fine-tuned so that the **DCA** shows nearly clear 10 GHz traces. One can observe the mixer output **LP MONITOR** on a 100 MHz scope (1 ms/div, 100mV/div) with DC input. By varying the **PHASE SHIFTER** knob, one can find the optimal **PHASE SHIFTER** value.

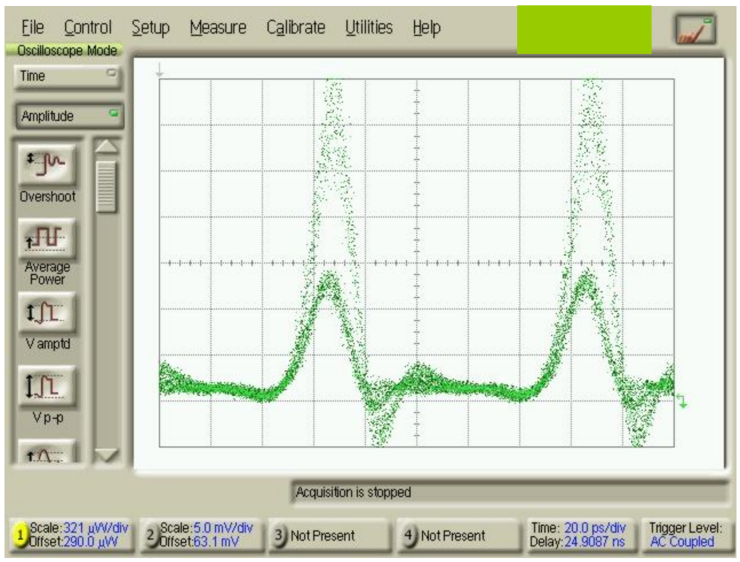


Figure 5a. A typical fast scope trace on a DCA when the RF SOURCE frequency is close to a stable mode-locked frequency point. The phase lock switch is off.

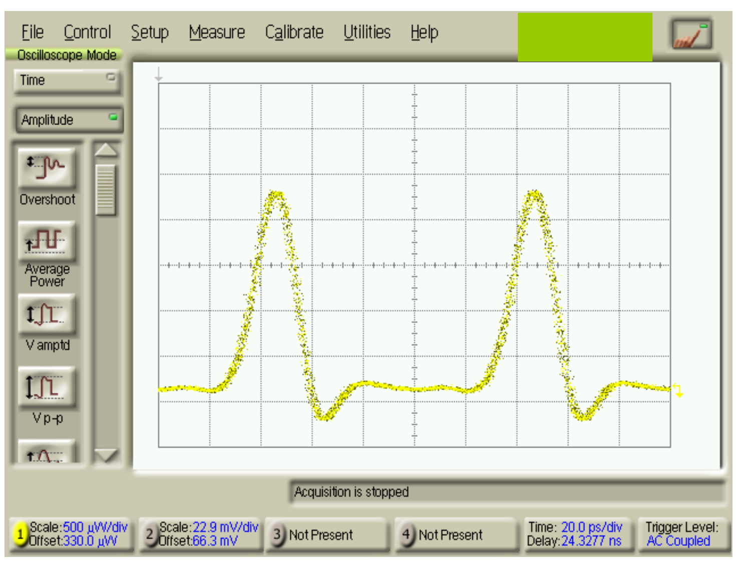


Figure 5b. A typical fast scope trace on a DCA when the laser is phase-locked to the RF SOURCE with phase and bias optimized.

2.5 - Calibration of Laser Temperature

When user needs to do the laser temperature calibration?

Under following conditions, user needs to do laser temperature calibration
1). User needs to operate the laser at a new repetition rate not supplied by the manual.
2). After laser operating for certain time, the laser is not working well at original temperature setting.

Factory suggests user to do the temperature calibration every month.

Step-by-step calibration of the laser temperature.

Refer to section 1 for the principle behind the calibration process. The aim of the calibration to set laser temperature so that cavity length matches the driving frequency within the PZT control range.

Assume that a repetition rate **fa** is the repetition rate you wish the laser to lock. (For the example **fa**=9.95328G).

1.Find a repetition rate fb near the repetition fa which laser can lock

First, the PSL is initialized according to section 2.3. Make sure laser is stabilized at set temperature and wavelength tuning knob is set in the range of 1545 nm –1560 nm. Then set PSL **PHASE LOCK ON/OFF** switch at **OFF** position.

After setting the frequency of the **RF SOURCE** to **fa** (9.95328G for this example), use 100 Hz increment to fine-tune RF source frequency around the initial **fa**. Find the clear pulse train display on **DCA** such as what are shown in Figure 5a or Figure 5b. Record the frequency shown in RF SOURCE as **fb** (at the example **fb**=9.95306G)

Note: User can find at least two **fb**, one **fb** > **fa**, the other **fb** < **fa**. The two **fb** have frequency difference of 2.62 MHz which is the fundamental cavity frequency of the laser. User therefore has option to increase the laser temperature or decrease laser temperature depends on which **fb** is chosen.

2. Read current laser working temperature set point T1.
You can get laser working temperature set point **T1** on the rear panel of the PSL. The yellow number in the display of the temperature controller is the laser working temperature set point **T1**. (At the example **T1**=38.0)

3. Calculate the temperature calibration ΔT
ΔT =-(fa-fb) * 1 Degree/0.109MHz
For this example, **ΔT= -(9953.28M-9953.06M)* 1. Degree/0.109 M= -2.0 Degree**

4. Change laser work temperature set-point to T2
After get **ΔT, you need change** laser working temperature to **T2=T1+ ΔT**
For the example **T2**=38.0+(-2.0)= 36.0 C

Note: If T2 is out of range of 30 – 55 degree, choose another fb in step 1 and find the T2 in the range of 30 – 55 degree.

After you got **T2**, push the temperature controller **up** or **down** button to change the temperature set point to **T2**.

Wait the laser work temperature stable again, then try to manually locked the laser at fa. If it is successful ,**Calibration is done.**

Section 3 – Output Characterization

3.1 – Output Characteristics

The characteristics of the PSL output (serial number S/N 2010230411) are shown in Table 7. The pulse width of the laser was measured by using a 2-meter PM fiber patch cord connecting the **OPTICAL OUTPUT** to an autocorrelator. The measurements were made on Auto Mode.

Table 7. Characteristics of the PSL output (RF f = 9.95328 GHz, T = 36.6 degrees C)

Wavelength (nm)	1545.7	1548.6	1549.6	1553	1554.5	1556	1556.8	1557.9	1559	1560.6
Pulse Width (ps)	1.2	1.6	1.3	1.36	1.1	1.5	1.6	1.6	1.15	1.6
Output Power (mW)	20	12	16	16	23.1	21	12	12	21	12
Pump Current (mA)	740	450	600	600	900	800	450	450	800	450
Phase Shifter	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9
MOD BIAS	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7

3.2 – Pulse Width Characterization

The pulse width of the PSL output was measured using an autocorrelator. Figure 11 shows the autocorrelation trace in a linear scale. Figure 12 shows the autocorrelation trace in a log scale.

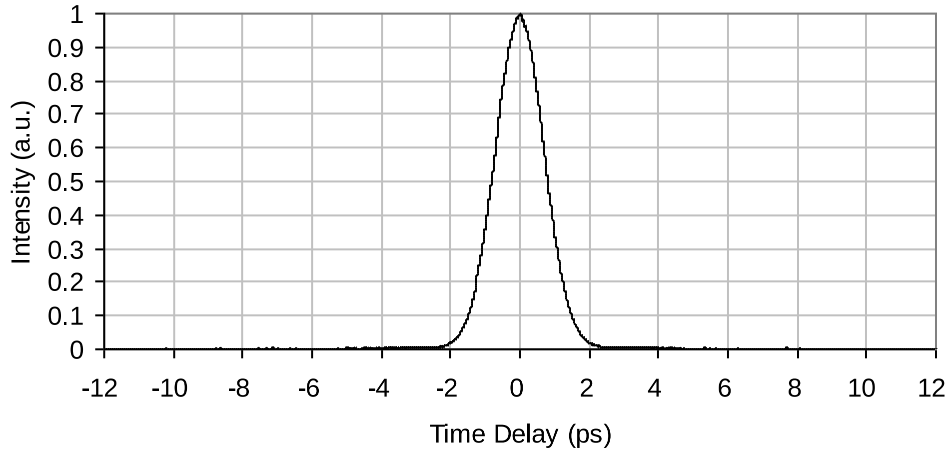


Figure 11. Autocorrelation trace in linear scale

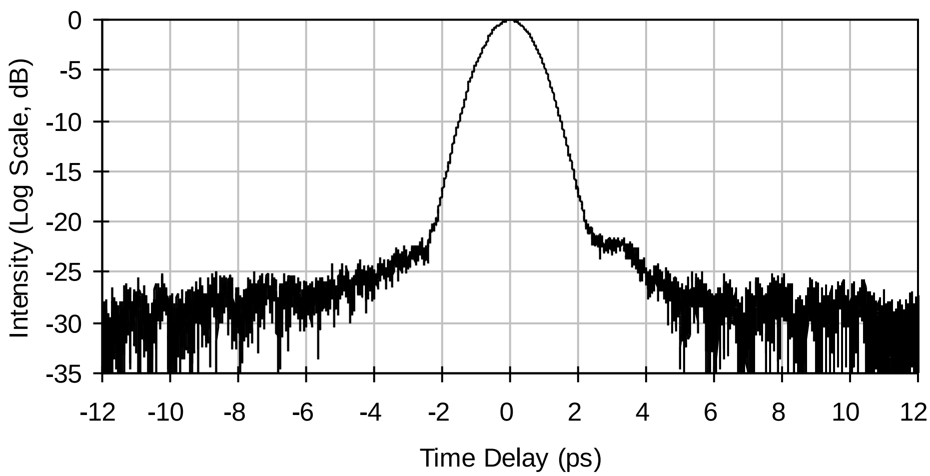


Figure 12. Autocorrelation trace in log scale

3.3 – Optical Spectral Characterization

Figure 13 shows an optical spectrum of the PSL output when stable mode-locking is achieved. The resolution is set at 0.02 nm. When the laser is stable, the 0.08 nm (10 GHz) modulation is clearly visible and the depth of modulation is usually larger than 15 dB.

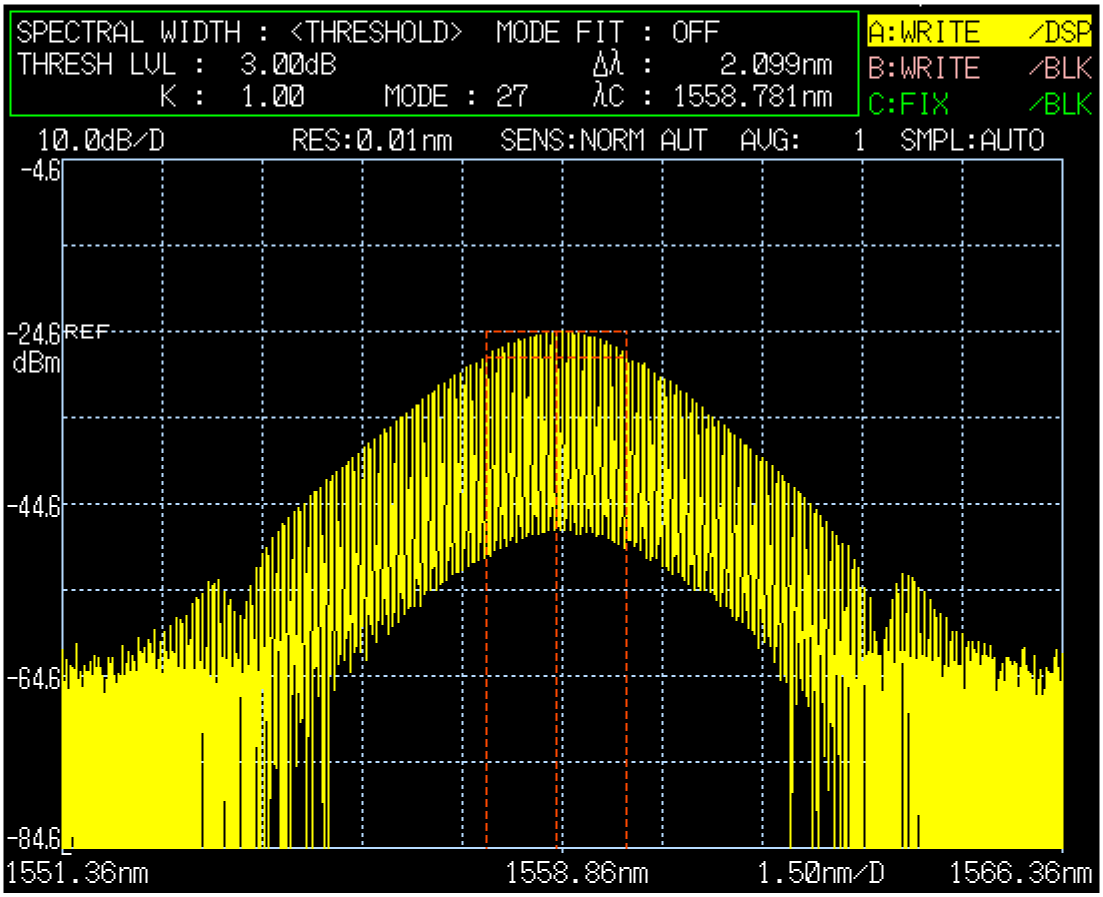


Figure 13. Optical spectrum of a 10 GHz output when the laser is in a stable mode-locking state

3.4 – Pulse Train Characterization

Using a setup as in Figure 4, one can characterize the pulse. Figure 14 shows the output of the 10 GHz pulse trains.

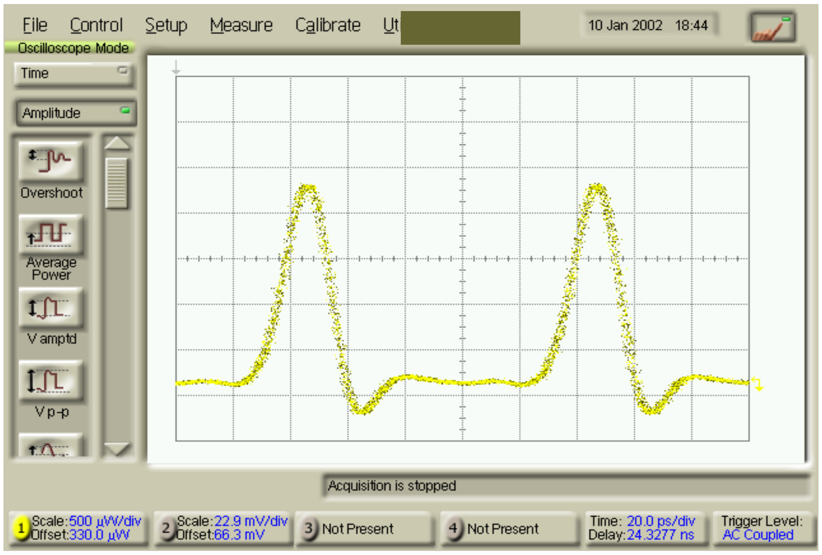


Figure 14. The scope trace of 10 GHz output of the PSL

3.5 – RF Spectrum Characterization

The PSL output is characterized by means of a high-speed photodetector (> 10GHz) followed by a RF spectrum analyzer. The RF spectrum around the modulation frequency (10 GHz) gives a good indication of laser stability. The lower the side mode, the better the stability of the laser. The PSL can achieve a side mode-suppression ratio better than 65 dB.

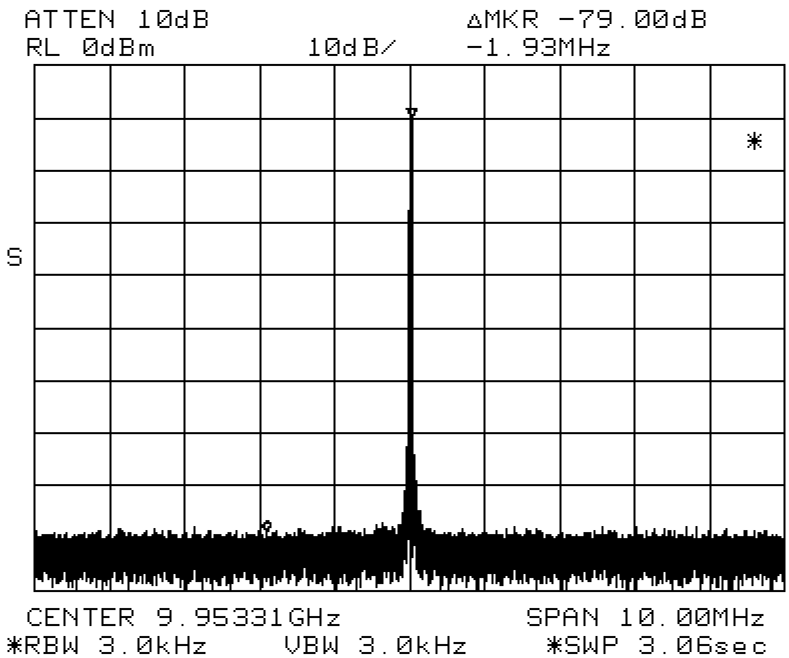


Figure 15. The RF spectrum of 10 GHz output of PSL