THORLABS

LLD1530
Frequency-Locked Laser

User Guide

Table of Contents

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

WARNING

Wavelength ~1.53 µm
Maximum Output Power < 10 mW
Beam Divergence ~ 0.2 rad

The classification of this laser follows the European Standard IEC 60825-1:2014.

Viewing the laser output with telescopic optical instruments (for example, telescopes and binoculars) close to the aperture may pose an eye hazard! Using the instrument in combination with collimating optics may have an impact on the assigned laser classification. The safety of any system incorporating the equipment is the responsibility of the assembler of the system.

Use of controls or adjustments or performance of procedures other than those specified herein may result in hazardous radiation exposure. There are no user-serviceable parts inside the instrument – never remove the red cover from the instrument.

WARNING

Do not open the instrument. Risk of electric shock. Please use the instrument only in combination with the included power chord and make sure that a connection to earth ground is given.

WARNING

If the equipment is used in a manner not specified by the manufacturer,
the protection provided by the equipment may be impaired. Do not load the top of the instrument with weight.

The instrument contains less than 10 ml of C_2H_2 at a pressure of 2 Torr.

WARNING

Do not cover the fan grill on the back of the instrument.

CAUTION

This instrument should be kept clear of environments where liquid spills or condensing moisture are likely. The LLD1530 frequency-locked laser is not water resistant. To avoid damage to the instrument, do not expose it to spray, liquids, or solvents.

Chapter 3 Specifications

3.1. Specification Tables

Performance Specifications					
Parameter	**Min**	**Typ.**	**Max**	**Unit**	**Notes**
Center Vacuum Wavelength		1532.8323		nm	
Stability (Long Term)	-	< ±10	±25	MHz	After Warm Up[1]
	-	< ±0.08	±0.2	pm	
	-	< ±0.00033	±0.00085	cm^{-1}	
Accuracy (at Start Up)	-	< ±15	±25	MHz	
	-	< ±0.12	±0.2	pm	
	-	< ±0.00050	±0.00085	cm^{-1}	
Precision (at StartUp)	-	< 1	--	MHz	After Warm Up and for Constant Environmental Conditions
	-	< 0.008	-	pm	
	-	< 0.00003	-	cm^{-1}	
Laser Linewidth (FWHM)	-	<3	-	MHz	Found by measuring the beat note between two locked LLD1530 lasers over a 10 µs duration.
Side Mode Suppression Ratio (SMSR)	35	-	-	dB	
Relative Intensity Noise (RIN)	-	100	-	dBc/Hz	20 MHz Measurement Bandwidth, 200 ms Signal Acquisition
Optical Power Stability	-	1.1	-	%	30 minute Duration
Optical Output Power	-	-	10	mW	IEC 60825-1:2014
Max Change in Ambient Temperature before Frequency Re-Lock Needed[2]	$\Delta T = \pm 3.5$ °C				
Ambient Temperature Change Triggering Frequency Re-Lock[3]	$\Delta T = \pm(0.9)*3.5$ °C				AUTO Mode Only
Laser Class[4]	Class 1				
Optical Fiber Type	SMF-28 Ultra				

[1] Variations in the instrument's temperature are the main source of wavelength drift. Maintaining operation within specifications requires re-locking the laser wavelength after a temperature change of 3.5 °C. Re-locking events are triggered automatically when operating in AUTO mode, and an LED on the front panel indicates the need to re-lock when operating in MANUAL mode.

[2] When operating in MANUAL Mode, the LOCKED staus LED will be extinguished when the temperature change exceeds these limits. The performance specifications given above will not apply if the LOCKED status LED is not illuminated. When operating in AUTO mode, the instrument's frequency will be automatically re-locked before these limits are reached.

[3] In MANUAL mode, the RELOCK NEEDED status LED illuminates when these limits are exceeded. If the RELOCK NEEDED status LED is illuminated, the performance specification given above will not apply. In AUTO mode, external disturbances that cause loss of frequency locking also trigger a re-lock procedure.

[4] Collimation optics are not recommended for use with this laser, as their use may result in the emission limit for Class 1 laser products being exceeded.

Connectors	
Parameter	**Value**
Optical Fiber Connector	FC/APC
Digital control interface	D-Sub 9 pin Female

Environmental and Power Specifications	
Parameter	**Value**
Operating Temperature Range[5]	10 °C - 40 °C
Storage Temperature Range	0 °C - 60 °C
Power requirements	100 - 240 VAC, 0.3 A, 50 - 60 Hz
Fuse	0.5 A, 250 V, Type T, 5 x 20 mm
Maximum Operating Altitude	2000 m Above Sea Level

[5] *Non Condensing*

3.2. Graphs

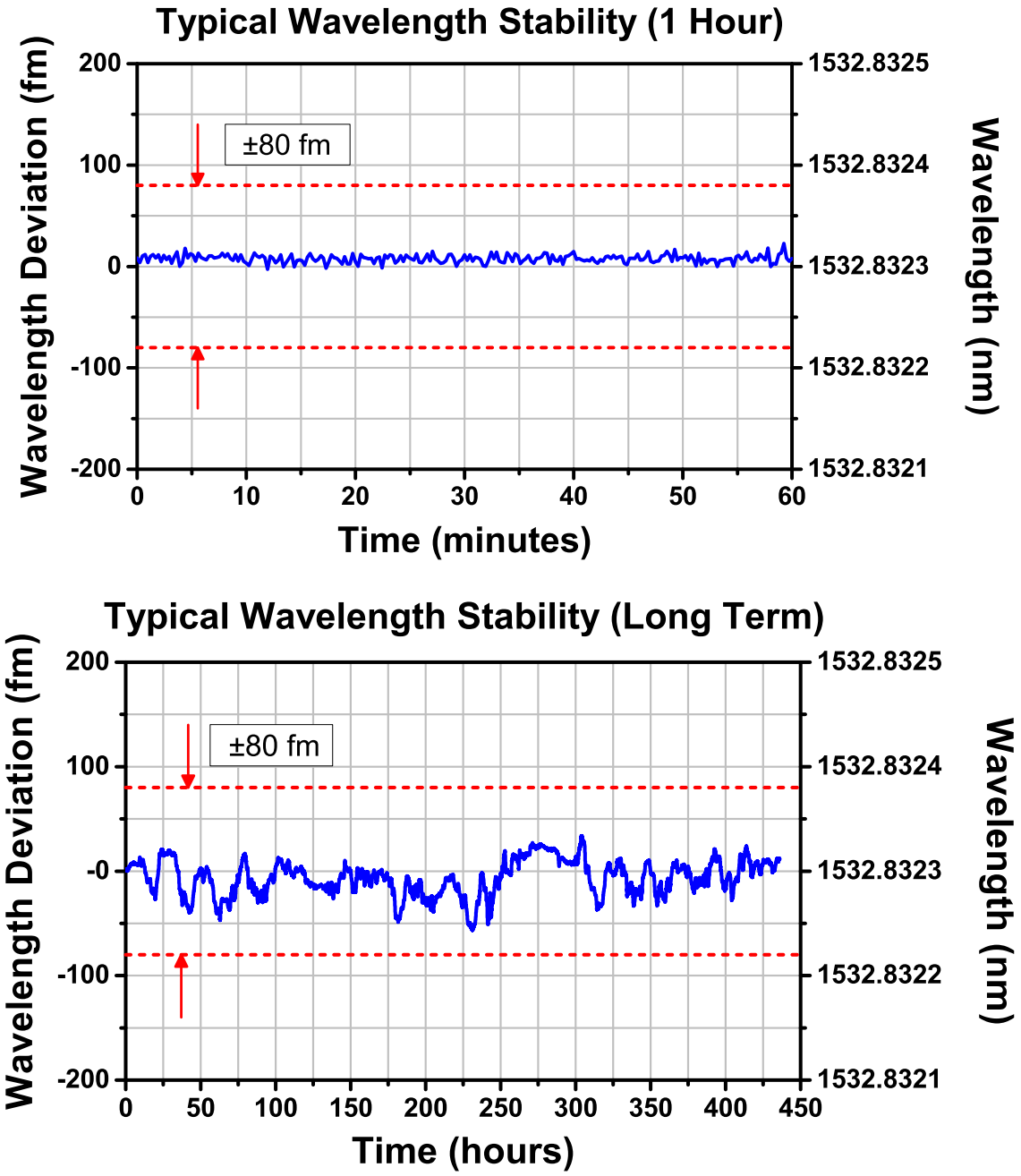


Figure 1 The top plot shows the typical variation in the LLD1530's vacuum emission wavelength over one hour. Frequency stability data were measured using two LLD1530 lasers and a beat note approach; one LLD1530 was intentionally operated with a slightly detuned optical frequency to generate the beat note. The frequency measurements were converted to wavelength for the plot. The data in the bottom plot were measured using Thorlabs' OSA205C and show the typical long-term vacuum wavelength stability of the LLD1530. All data were acquired while the lasers operated in MANUAL Mode under ambient conditions. No re-locking procedures were performed during data acquisition.

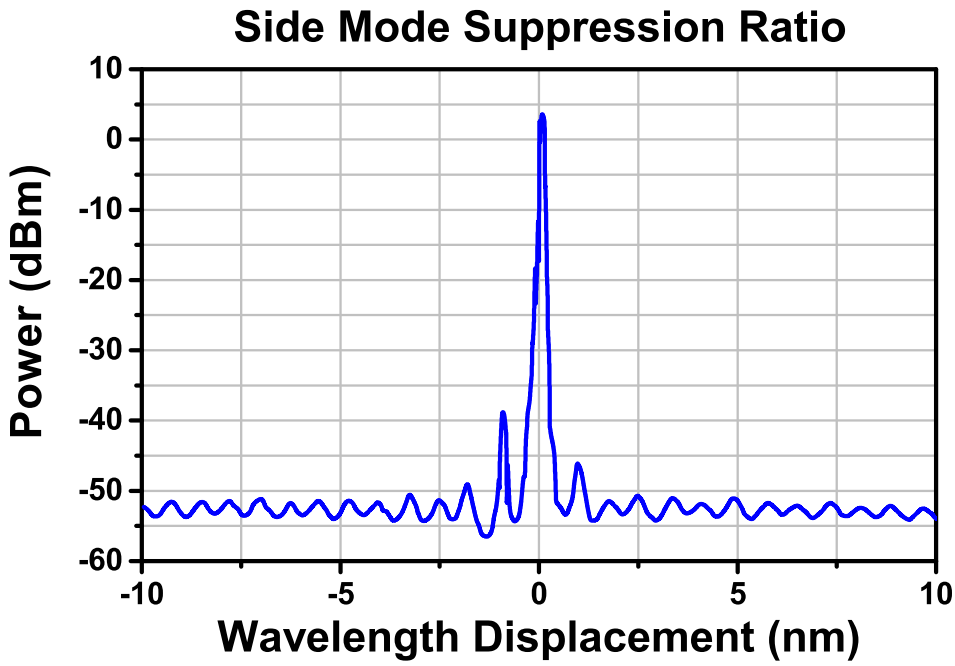


Figure 2 Plot showing a typical side mode suppression ratio (SMSR) of the DFB laser integrated into the LLD1530 laser reference system.

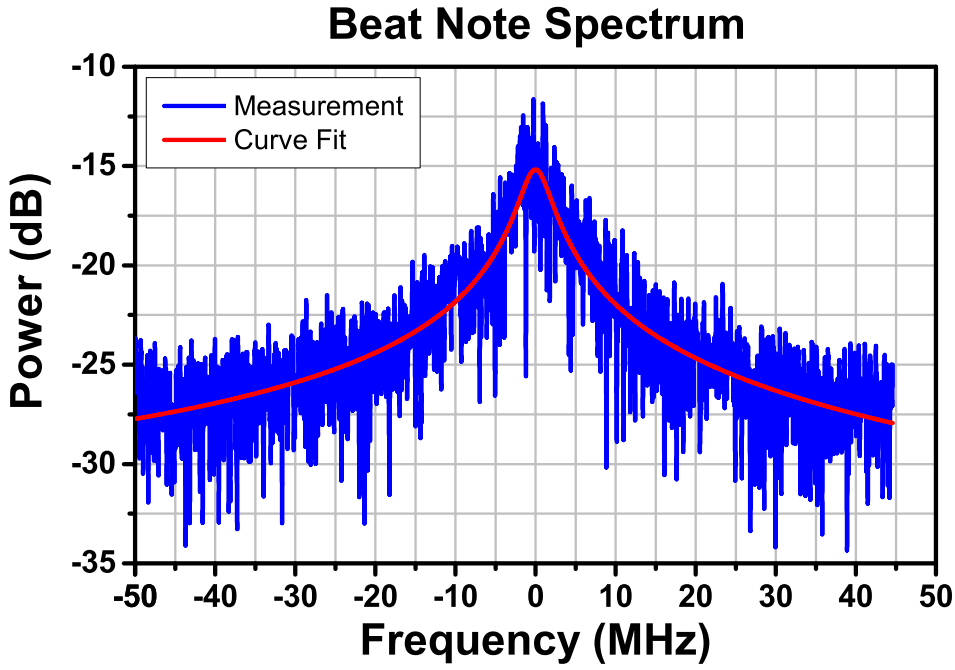


Figure 3 Typical beat note spectrum between two LLD1530 frequency-locked laser sources (blue curve), plotted with a Lorentzian curve fit (red curve). The beat note was recorded over 10 µs using a 150 MHz detector. A 2.5 MHz FWHM linewidth was derived from the measurement data and the 3.6 MHz FWHM of the curve fit.

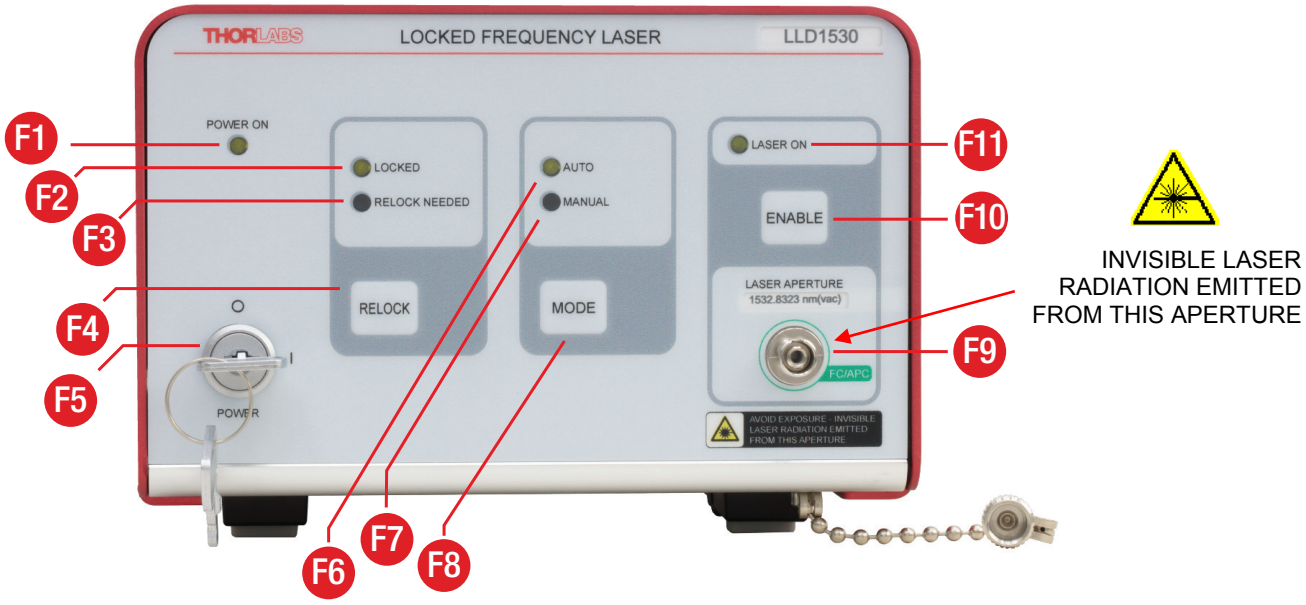
Chapter 4 Controls and User Interface

The front and back panels of the instrument include instrument status indicators, controls, optical output ports and a digital I/O interface. The locations and functionality of these features are described in the following.

WARNING

Caution – Use of controls or adjustments or performance of procedures other than those specified within this manual may result in hazardous radiation exposure!

4.1. Front Panel Features



Label	Function
F1	LED Indicates Power is Supplied to Unit
F2	LED Indicates Laser Frequency is Locked within ±25 MHz Range
F3	LED Indicates Laser Frequency is Near the Edge of the ±25 MHz Range
F4	Button to Trigger Laser Re-Lock Procedure (Enabled in Manual Mode Only)
F5	Key Switch Provides Power to the Unit
F6	LED Indicates Operation in Automatic Mode
F7	LED Indicates Operation in Manal Mode
F8	Button to Switch between Automatic and Manual Modes
F9	Laser Emission Output Aperture, FC/APC Connector
F10	Button to Enable Laser Emission
F11	LED Indicating Laser is On and Laser Emission Present

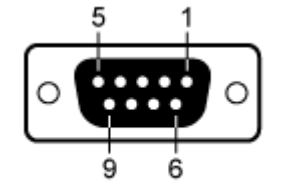
4.2. Back Panel Features

Label	Function
B1	Laser Interlock Jack
B2	Digital I/O Interface, Female DB9 Connector
B3	AC Power Cord Connector

4.3. Digital I/O

The D-Sub 9 Pin female DIGITAL I/O interface on the rear panel can be used to operate and receive operating status information from the LLD1530. Interfacing with the instrument via this digital I/O port requires the LLD1530 to be powered on. This is done by connecting the instrument to mains power and turning the key in the key switch to position I. When the instrument is powered, the POWER ON LED is illuminated.

The pin configuration is described in the table below. The interface inputs can be activated by setting pin 1 to low (GND). **As long as the signal on pin 1 is LOW, all buttons on the front panel are disabled,** and the instrument can be controlled solely by the digital inputs on the rear panel. All LEDs on the front panel; however, continue to indicate the current state of the instrument. Pins 4 through 6 on the rear panel also provide status information.



Female 9 Pin Connector

Pin	Function	State		Type
		LOW (GND)	HIGH (5V)	
1	Enable Laser	ENABLED	DISABLED	Input
2[6]	Trigger Relock	RELOCK	--	Input
3	Select Operating Mode	MANUAL	AUTO	Input
4	System Status Indicator		RELOCK NEEDED	Output
5	System Status Indicator		LOCKED	Output
6	System Status Indicator		LASER ON	Output
7	Not Connected			
8	Not Connected			
9	GND			

[6] *To initiate the relocking procedure, set this pin Low for at least 100 ms, but not longer than 1 s. Otherwise, keep this pin high.*

Chapter 5 Operation

CAUTION

This instrument should be kept clear of environments where liquid spills or condensing moisture are likely. The LLD1530 locked frequency laser is not water resistant. To avoid damage to the instrument, do not expose it to spray, liquids, or solvents.

5.1. Description

Thorlabs' LLD1530 Frequency Locked Reference Laser is a laser-diode-based, turnkey system with a vacuum emission wavelength of 1532.8323 nm. The distributed feedback (DFB) laser at the heart of the LLD1530 has a <3 MHz linewidth and a high side mode suppression ratio (SMSR) of at least 35 dB. The laser frequency is actively stabilized to a National Institute of Standards and Technology (NIST)-traceable molecular transition of acetylene (C_2H_2). The LLD1530 provides a laser emission frequency at start-up within ±25 MHz of the target operating frequency, regardless of where within its 30 °C temperature operating range the instrument is powered on and frequency locked. This is accomplished by Thorlabs' sophisticated start-up algorithm and the design of the gas cell parameters, which were chosen to ensure the low influence of temperature fluctuations on the output frequency. The emission frequency immediately after start-up is then maintained with a ±25 MHz stability, providing an overall frequency accuracy of ±50 MHz. The LLD1530 is a convenient and high-performance source for demanding FTIR system, instrument calibration, gas sensing, and coherent telecommunications instrumentation.

Re-locking procedures may be required, not because of any gas cell behavior, but because other components in the LLD1530 exhibit modest temperature-dependent optical properties. The re-locking procedure, which in AUTO mode is automatically triggered when needed, easily compensates for these. When operating in MANUAL mode, the LLD1530 will prompt the user to trigger the re-locking procedure but will not perform them automatically.

We recommend operating in AUTO mode, in which the laser emission frequency is stabilized to within ±25 MHz of the laser emission frequency immediately following the most recent frequency locking procedure. In AUTO mode, the system automatically triggers a frequency re-locking procedure when the laser emission frequency drifts by an amount close to, but less than, 25 MHz. For more information about the threshold that triggers the frequency re-lock, see Chapter 3 and Section 5.3. The RELOCK button is not enabled in AUTO mode.

MANUAL mode is intended to be used when a task is intolerant of the variations in the intensity and wavelength that occur during the re-locking procedure. The user may toggle between AUTO and MANUAL modes using a button on the front panel. When operating in MANUAL mode, the red RELOCK NEEDED LED illuminates at the threshold that would trigger a frequency re-locking procedure in AUTO mode. When the emission frequency drifts more than 25 MHz from the frequency of the laser emission immediately following the most recent frequency locking procedure, the "LOCKED" LED is extinguished. The LLD1530 will continue to operate, but the specified frequency accuracy cannot be guaranteed when the RELOCK NEEDED LED is illuminated. When the laser operates in MANUAL mode, the user may initiate the frequency re-locking procedure at any time by pressing the RELOCK button.

The system provides the optical output via an FC/APC connector on the front panel. The female DB9 connector on the back panel offers a digital I/O interface that enables the user to select the operating mode and trigger the frequency re-locking procedure, as well as obtain operating status information.

5.2. Start-Up Procedure

The LLD1530 is powered up in the following way. Please reference the labeled front panel features in Section 4.1:

1. Turn on the system by turning the POWER key (F5); the POWER-ON LED (F1) will indicate that the system is powered. Turning on the system does not enable laser emission.

2. Press the ENABLE button (F10) to turn on the laser. After approximately 2 s, the laser turns on and the LASER-ON LED (F11) illuminates to indicate that light is being emitted from the LASER APERTURE (F9).

The system will automatically lock the laser frequency to that of a molecular transition in C_2H_2, which takes around 15 seconds in most cases[7]. The LOCKED LED (F2) will indicate when the procedure is finished and the system is ready to use.

5.3. Automatic and Manual Modes of Operation

Care has been taken to minimize temperature-related drifts of the LLD1530 output wavelength. However, changing environmental conditions, for example due to an increase in system temperature resulting from extended period of operation, may cause the frequency to drift outside of the specified ±25 MHz frequency range. The relationship between laser frequency and temperature has been well characterized, and changes in the ambient temperature are monitored to determine when it is necessary to execute a frequency re-locking procedure in order to maintain operation within specifications. When the ambient temperature changes ±3.5 °C from the temperature at which the laser was last frequency locked, the laser frequency has drifted up to ±25 MHz. This is the boundary of the specified range around the target frequency.

The LLD1530 allows the user to choose how the instrument should respond when the frequency nears the edge of the specified frequency range by offering two operational modes, AUTO and MANUAL. The preferred mode of operation can be selected by pressing the MODE switch button (F10). The LEDs (F6 and F7) above the mode switch button indicate the current mode of operation. The mode may be changed whenever desired, including any time after the laser has been enabled.

While the instrument operates in **automatic mode,** the frequency re-locking procedure is triggered after the temperature of the instrument has changed by 90% of ±3.5 °C, or after an external disturbance causes the frequency locking to be lost. The RELOCK control (F4) is disabled during operation in automatic mode. The re-locking procedure typically completes in 15 seconds.

When the instrument operates in **manual mode,** the RELOCK NEEDED LED (F3) will illuminate after the temperature of the instrument has changed by 90% of ±3.5 °C. This LED indicates the temperature has changed by enough since the last locking event that the frequency is close to exiting the specified range, and that re-locking the laser frequency is necessary to maintain operation within specifications. Pressing the RELOCK button (F4) will trigger the re-locking procedure. If the temperature changes by ±3.5 °C, the LOCKED LED is extinguished.

Operation in the manual mode can benefit experiments in which it would be detrimental for the laser emission to be interrupted, or when the application is intolerant of the “wavelength steps” that occur during the re-locking process. However, if the RELOCK NEEDED LED (F3) is illuminated, the specified frequency accuracy cannot be guaranteed.

Regardless of the mode of operation, the LOCKED (F2) LED is extinguished while the re-locking procedure executes. The LOCKED LED will illuminate again after the re-locking procedure completes and the output wavelength is stable. Please refer to Section 5.5 for more information on the stability of the instrument.

WARNING

Note that invisible laser radiation is emitted even during a re-lock event!

[7] *In rare cases when the LLD1530 is disturbed by mechanical or thermal influences the lock procedure can take up to around a minute or until the system is undisturbed again.*

5.4. Disabling the Laser

After the laser has been powered and enabled, it can be disabled at any time by pressing the ENABLE button (F10). When the laser is disabled, the DFB laser inside the LLD1530 is turned off and hence the frequency lock will be lost. When the laser is enabled again, by pressing the ENABLE button, the lock of the laser frequency to the molecular transition has to be re-established (as described in Section 5.2). At all times, the LASER ON (F11) and LOCKED (F2) LEDs indicate the current status of the instrument.

5.5. Warm Up and Stability

For best output wavelength stability please allow the LLD1530 to warm up for approximately 20 minutes with the laser enabled. This helps to stabilize the temperature inside the instrument. We recommend you then perform a re-lock of the instrument's frequency. This is done by pressing the RELOCK button (F4) if operating in MANUAL mode, or by disabling and enabling the laser using the ENABLE button (F10) if operating in AUTO mode. In both cases, the laser will execute a re-locking procedure that will ensure the it is operating with the start-up accuracy specified in Section 3.1. Whenever you need the most accurate wavelength reading in your experiment, we recommend you to re-lock the instrument for best accuracy.

However, please note that if the RELOCK-NEEDED LED (F3) is extinguished, the instrument operates with the accuracy specified in Section 3.1. This is true even immediately after the system is powered on.

5.6. Laser Safety Interlock

The laser is equipped with a phono-type interlock jack located on the back panel. To enable the laser source, a short circuit (< 430 Ω) must be applied across the terminals of the interlock connector. The shorting device (interlock pin) installed in all units shipped from Thorlabs performs this function. Leave the shorting device installed unless using an external safety circuit or other type of remotely controlled switch to enable laser output.

Making use of the Interlock feature requires the appropriate 2.5 mm phono-type plug, which is diagrammed in the figure below and is readily available through most electronics retailers. The plug should be wired to the external safety circuit or switch and then plugged into the back panel's interlock jack in place of the shorting device. The electrical specifications of the interlock jack are listed in the following table.

Interlock specifications	
Interlock Switch requirements	Must be Normally Open Dry Contacts. Apply no External Voltages to the Interlock Input.
Type of Mating Connector	2.5 mm Mono Phono Jack
Open Circuit Voltage	5 VDC
Short circuit current (typical)	0.5 mA

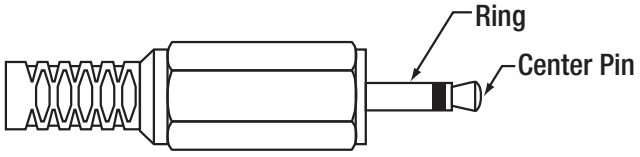


Diagram of a Phono-Type Plug

Chapter 6 General remarks

6.1. Use of the Equipment

This frequency reference laser source is designed and intended for indoor laboratory use.

6.2. Maintenance and Repair

WARNING

There are no user-serviceable parts inside the instrument – never remove the red cover from the instrument.

The instrument should not need regular maintenance by the user. If necessary the display, housing, and front panel can be cleaned using a soft cloth moistened with normal, mild glass cleaner. Do not use any chemical solvents or harsh cleaners on the display. Do not spray any cleaning solutions directly onto any part of the unit.

The instrument does not contain any modules that can be repaired by the user. If a malfunction occurs, please contact Thorlabs Technical Support and arrangements will be made to investigate the problem. Do not remove the cover. There are no user serviceable components inside.

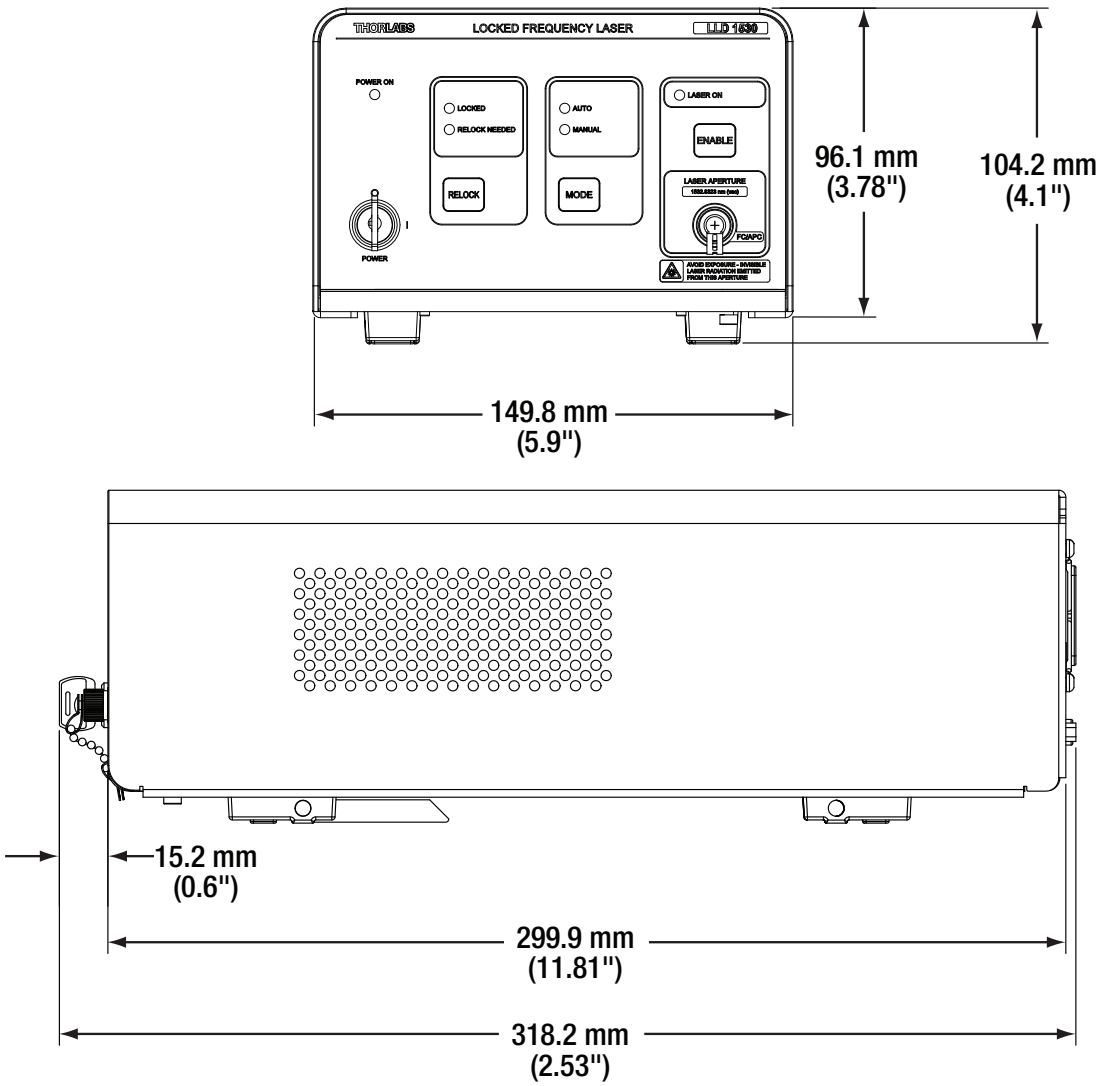
Optical patch cords used to connect to the front panel of the instrument should have their end faces cleaned every time a new connection is made. The end faces of the internal fiber connectors can easily be damaged by the use of dirty fiber ends. If damage occurs, the instrument will need to be sent back for repair. We suggest using a fiber end-face cleaning product such as the Thorlabs FCC-7020 shown below. Alternatively, a lint-free cloth moistened with isopropyl alcohol or methanol can be used. Never use acetone.

Figure 4 Thorlabs FCC-7020 Fiber Endface Cleaner for Patch Cables

The optical connectors on the front panel may be cleaned using a 2.5 mm bulkhead cleaner such as the Thorlabs FBC1. This allows the user to clean the fiber end-face without removing it from the internal bulkhead adapter.

Figure 5 Thorlabs FBC1 Fiber Endface Cleaner for Bulkheads

Chapter 7 Mechanical Drawing



Chapter 8 Troubleshooting

Consulting the following may provide assistance if you experience difficulties with the LLD1530. If you have any questions, please contact your local Thorlabs Technical Support office.

If the unit does not appear to turn on correctly, please check the following items:

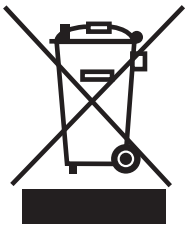
- Ensure that the main AC receptacle is powered
- Ensure that main power cable is fully seated at both ends
- Ensure that the key switch is in the "I" position
- Check the main power fuse (see Maintenance and Repair Section)

Observation	Explanation / Solution
The ENABLE button does not work / the LASER ON LED does not illuminate when the ENABLE button is pressed.	The LLD1530 has a built-in 2 second slow-start circuit for ESD protection. Pressing the ENABLE button will activate the circuit, but light will not be immediately emitted. Light will be emitted after the 2 second delay, and light emission is indicated by an illuminated LASER ON LED.
The LOCKED LED has not illuminated after the laser has been enabled for at least one minute.	The most common reason for this is that the system has been disturbed after the ENABLE button has been pressed, e.g. by mechanical or electronic disturbances. Another common reason for this is that the laser has been disabled during a lock procedure. A lock procedure will be triggered automatically whenever the laser is enabled by pressing the ENABLE button. If the laser then is disabled before the LOCKED LED is illuminated (either by pressing the ENABLE button or by opening the interlock connection), the lock procedure recognizes this and halts. The lock procedure will continue after the laser is enabled again. In both cases, if the LOCKED LED is still not illuminated after approximately one minute, turn the system off with the key switch and turn it on again; enable the laser by once pressing the ENABLE button and wait; the LOCKED LED should illuminate after ~15 seconds.

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



Wheelie Bin Logo

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

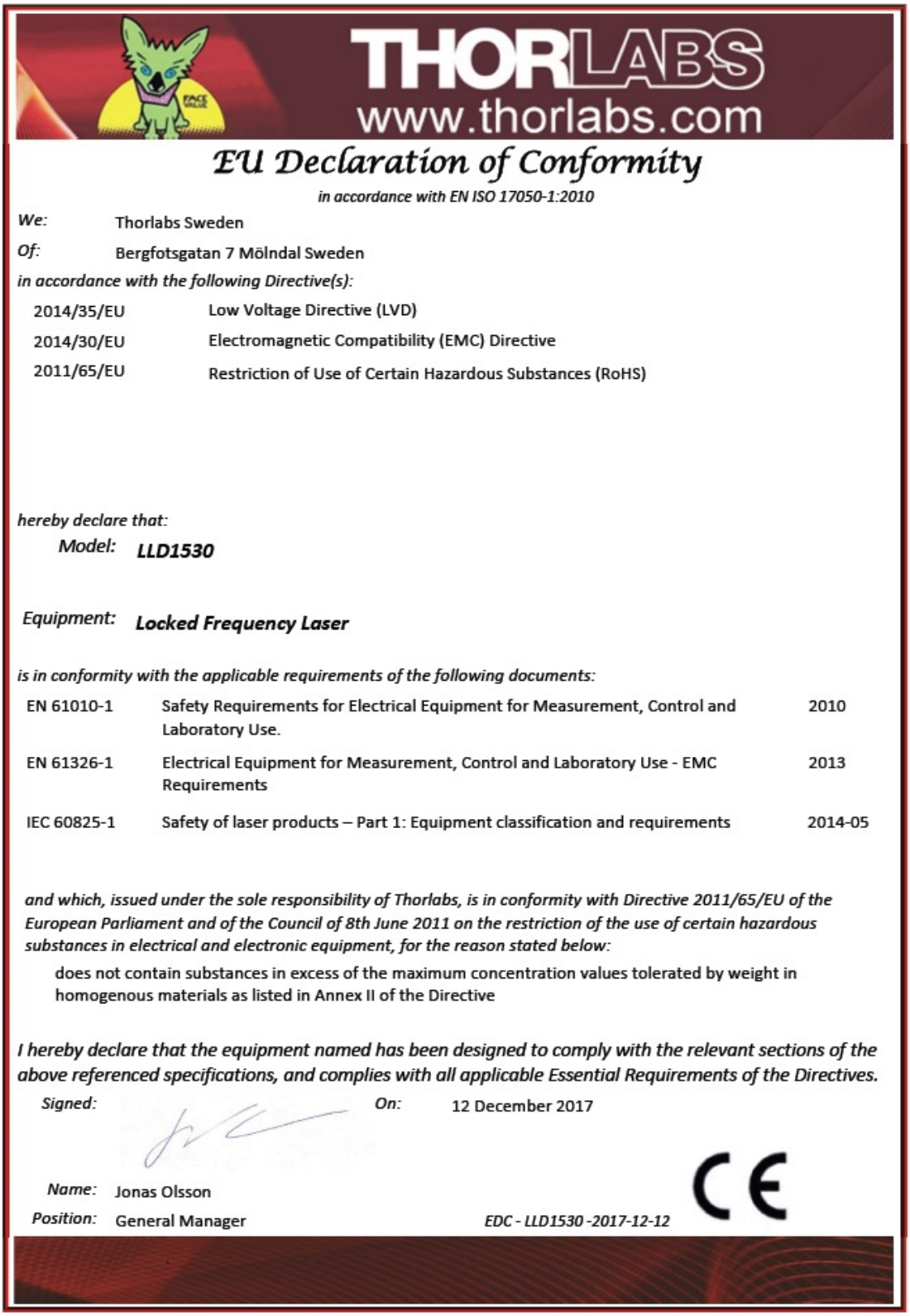
If you do not return an “end of life” unit to Thorlabs, you must hand it to a company specialized in waste recovery. Do not dispose of the unit in a litter bin or at a public waste disposal site.

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 Declaration of Conformity



THORLABS
www.thorlabs.com

EU Declaration of Conformity

in accordance with EN ISO 17050-1:2010

We: Thorlabs Sweden

Of: Bergfotsgatan 7 Mölndal Sweden

in accordance with the following Directive(s):

2014/35/EU	Low Voltage Directive (LVD)
2014/30/EU	Electromagnetic Compatibility (EMC) Directive
2011/65/EU	Restriction of Use of Certain Hazardous Substances (RoHS)

hereby declare that:

Model: ***LLD1530***

Equipment: ***Locked Frequency Laser***

is in conformity with the applicable requirements of the following documents:

EN 61010-1	Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use.	2010
EN 61326-1	Electrical Equipment for Measurement, Control and Laboratory Use - EMC Requirements	2013
IEC 60825-1	Safety of laser products – Part 1: Equipment classification and requirements	2014-05

and which, issued under the sole responsibility of Thorlabs, is in conformity with Directive 2011/65/EU of the European Parliament and of the Council of 8th June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment, for the reason stated below:

does not contain substances in excess of the maximum concentration values tolerated by weight in homogenous materials as listed in Annex II of the Directive

I hereby declare that the equipment named has been designed to comply with the relevant sections of the above referenced specifications, and complies with all applicable Essential Requirements of the Directives.

Signed: *On:* 12 December 2017

Name: Jonas Olsson

Position: General Manager

EDC - LLD1530 -2017-12-12

CE

Chapter 11 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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UNLEASHED