THORLABS

TL-T

INTUN Tunable Laser

Manual

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Part 1. Handling the INTUN TL-T

1.1. Safety Requirements

The INTUN TL-T is a sensitive product and should be handled accordingly. To avoid damage to the INTUN TL-T or personnel handling the laser, the following precautions should be followed:

- Read this manual carefully before powering up the INTUN TL-T or connecting the INTUN TL-T to any other equipment.
- Do not under any circumstances look into the optical output when the device is operating. The laser radiation is not visible to the human eye, but it can seriously damage your eyesight.
- Protect the equipment from external shock and excessive vibrations.
- To avoid harmful shock, do not operate the INTUN TL-T if there are any signs of damage to any part of the outer enclosure (covers, panels, etc.).
- Do not expose the equipment to rapid temperature fluctuations.
- The INTUN TL-T is not designed for outdoor use.
- Do not expose the equipment to dust, dusty air, condensation, or high humidity.
- Always store and use the INTUN TL-T in a vertical position (as further described in the manual).
- Handle with care when unpacking the INTUN TL-T.
- The original transport case supplied by Thorlabs should always be used when shipping the INTUN TL-T to Thorlabs for service.
- Use an ESD wrist strap when handling the INTUN TL-T.
- Do not use solvents on or near the equipment as they may damage the INTUN TL-T.
- Handle all connectors, both electrical and optical, with care. Do not use unnecessary force as this may damage the connectors.
- Depending on the model, the laser will be a class 3R or 3B laser product and proper safety precautions should be taken.

1.2. ESD Precautions

All types of electronic components, particularly integrated circuits, are sensitive to electrostatic discharge (ESD), a common cause of electronic equipment failure. Equipment failure due to ESD can be reduced by always wearing an ESD wrist strap whenever handling boards or units.

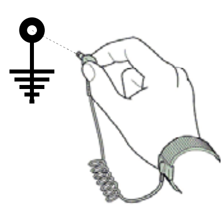


Figure 1: The ESD wrist strap is connected to ground to minimize ESD failure.

Part 2. Introduction

This manual describes how to interface and control the INTUN TL-T continuously tunable laser source (TLS), a flexible OEM module that is designed and manufactured by Thorlabs and is intended for integration into a variety of fiber optic test and measurement equipment, sensors, and spectroscopy systems. It can be used in step or sweep mode, and the wavelength and optical power are controlled by a simple analog interface.

This manual will sometimes refers to other documents (e.g., product specification, packing instructions), all of which can be obtained from Thorlabs.

2.1. Features and Options

The INTUN Lasers manufactured by Thorlabs combine broad wavelength tunability with quick tuning speed, linearity in sweep, high absolute accuracy, and repeatability. Some of the main features are highlighted below:

- High absolute accuracy eliminates the need for frequent calibrations.
- Good repeatability results in consistent measurements.
- Truly continuous, smooth tuning (i.e., small tuning speed variations, no backward movements, and no mode hops) is important for many applications such as interferometry and fiber sensing.
- The narrow linewidth is a prerequisite for high-resolution interferometric, heterodyne, and spectroscopic measurements.
- Wide tuning range covers one or two bands, leading to a flexible laser source that eliminates the need for multiple sources.
- High tuning speed results in fast measurements, saving time and money.
- Compact size and easy-to-integrate interface leads to a cost-effective system that provides maximum flexibility and rapid implementation.

Acronyms and Abbreviations

The first time an abbreviation appears in the manual, the expanded form is shown, followed by the abbreviation in parentheses [e.g., Electrostatic Discharge (ESD)]. Thereafter, the abbreviated form is used.

Important Messages

Red highlighted text is used throughout this manual to alert the user to important messages and warning messages. Both types of messages are illustrated below. These directions are meant to highlight information, which if neglected can result in permanent damage to the product, serious injury to the user, or fatality.

Attention/Warning!
This is an example of an attention or warning message.

Part 3. System Description and Interfaces

This chapter is intended as an aid for designing a system that contains an INTUN TL-T. In order to ensure that the INTUN TL-T will operate correctly and meet the stated specifications, requirements regarding handling and operation stated within this manual must be met.

3.1. What is a Tunable Laser Source (TLS)?

A Tunable Laser Source (TLS) is a laser whose output wavelength can be swept (continuous or random access) over a certain wavelength range. The INTUN TL-T laser's tuning range typically varies from 3-150 nm, depending on the model chosen. The TLS can be thought of as an optical equivalent to the conventional electrical sweep oscillator. Although the acronym TLS is sometimes used interchangeably with ECL (External Cavity Laser), ECL actually refers to the technical design of the laser itself. Therefore, TLS encompasses a larger number of products than ECL since an ECL is not necessarily tunable.

TLS's are frequently used in various measurement applications to record some quantity (e.g., intensity) as a function of wavelength. Each application requires detailed knowledge of some or all of the parameters that characterize a TLS (e.g., wavelength range, side mode levels, spontaneous noise levels, line width, sweep characteristics).

3.2. Brief System Overview

As shown in Figure 2, the INTUN TL-T is a TLS based on a semiconductor laser mounted in a Littrow external cavity laser geometry. This tuning arrangement allows for high output power while maintaining a large mode-hop-free tuning range.

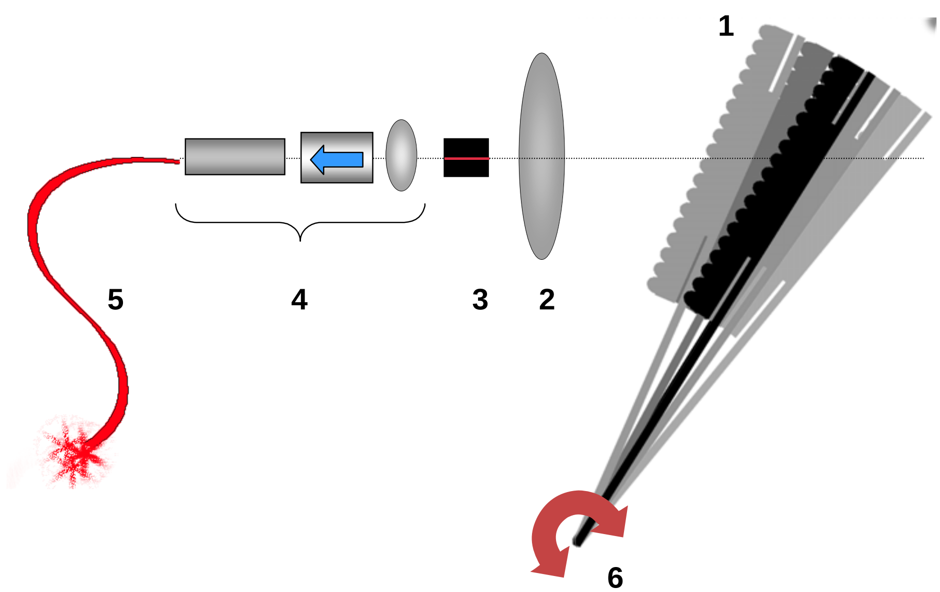


Figure 2: Schematic of the INTUN TL-T

The INTUN is based on a Littrow resonator: 1) diffraction grating, 2) intra-cavity collimating hybrid (i.e., refractive and diffractive combination) achromatic lens, 3) laser diode, 4) output coupling optics including an isolator, 5) optical fiber, and 6) motor.

The interface between the INTUN TL-T and the user is analog. Analog voltages are used to set the output wavelength and output optical power; however, a stable voltage source is necessary for supplying these analog control signals. By applying an analog voltage to the interface, the wavelength can be either tuned randomly to any wavelength or continuously tuned (i.e., swept) between any two wavelengths within the specified operational wavelength range for that model. The tuning is truly continuous due to the construction of the tuning arrangement (i.e., no stepper motor drive).

The INTUN TL-T is fully controlled by its electronic control system and the user-supplied analog signals for setting output wavelength and optical output power. Furthermore, the INTUN TL-T requires an external DC power supply to be operational.

3.3. Basic Operation

The INTUN TL-T is based on a patented, low source, spontaneous emission (SSE), Littrow-style external cavity laser geometry. The intra-cavity lens collimates the light emitted from the laser diode before the beam impinges on the diffraction grating. Wavelength selectivity is achieved by tilting the diffraction grating. The amount of tilt is controlled by a patented moving coil ("motor") arrangement and is chosen such that the reflected beam is directed back towards the laser diode. Thus, the laser resonator cavity is formed between the diffraction grating and the left-hand side of the laser diode as shown in Figure 2 above. The output beam is collimated and sent through an optical isolator before the beam is launched into the optical fiber.

Due to the analog interface, the INTUN TL-T is easy to integrate into any system configuration. The user supplies an analog signal to tune (sweep) the laser between the minimum and maximum wavelengths defining the tuning range. The tuning of the INTUN TL-T is truly continuous. The output wavelength of the laser will follow the applied analog signal. Furthermore, by applying a constant voltage to the tuning input, the laser will lase at a fixed wavelength. Therefore, the laser can randomly access any fixed wavelength within its tuning range.

The control system continuously monitors the angular position and the angular speed of the mechanical arm onto which the grating is mounted. The outputs are fed to the internal control circuitry. The wavelength control system is designed to do the following:

- Follow a ramp (i.e., wavelength vs. time signal) without errors and with short settling times.
- Keep the laser at a fixed wavelength (i.e., a fixed angular position of the grating arm) without errors.
- Obtain fast step response with short settling times when moving between fixed wavelengths ("random access" tuning).
- Minimize errors in position due to external forces such as vibrations or magnetic fields.

The control system also monitors the optical output power, which can be set by the user using an analog control port; once set, the system will maintain that input power over the entire tuning-range of the INTUN TL-T.

The laser chip and the laser cavity are kept at a constant temperature using a closed-loop thermoelectric cooler.

The inner metal casing functions as a body for the attachment of the different modules, such as fiber coupling, laser unit, and sensor mechanics. The outer casing is made of metal and a layer of thermal isolating material. In addition, a magnetic shield, constructed from a high permeability material, prevents external magnetic fields from interfering with the motor coils.

All lasers, and especially lasers having resonator cavities defined by mechanical tolerances, are delicate precision instruments, and they must be handled accordingly. The INTUN TL-T is designed to withstand normal transport and operating conditions.

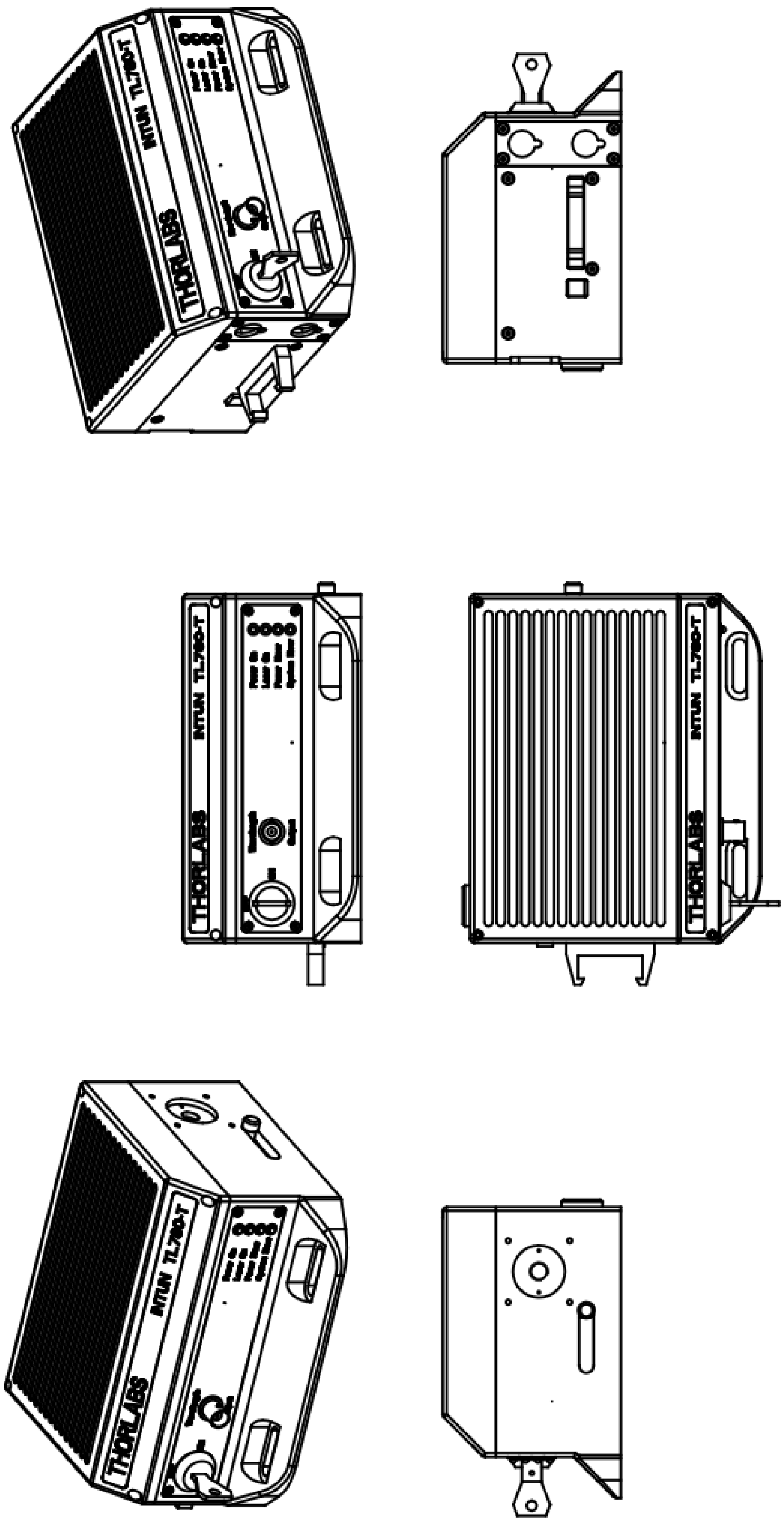


Figure 3: The INTUN TL780-T case

3.4. Mechanical Interface

Measuring 49 x 93 x 260 mm (W x H x L) (49 x 93 x 274.1 mm if the locking mechanism belonging to the signal connector is included), the INTUN TL-T provides a powerful laser source in a small footprint. The front and side views of the INTUN TL-T are shown in Figures 4 and Figure 5, respectively.

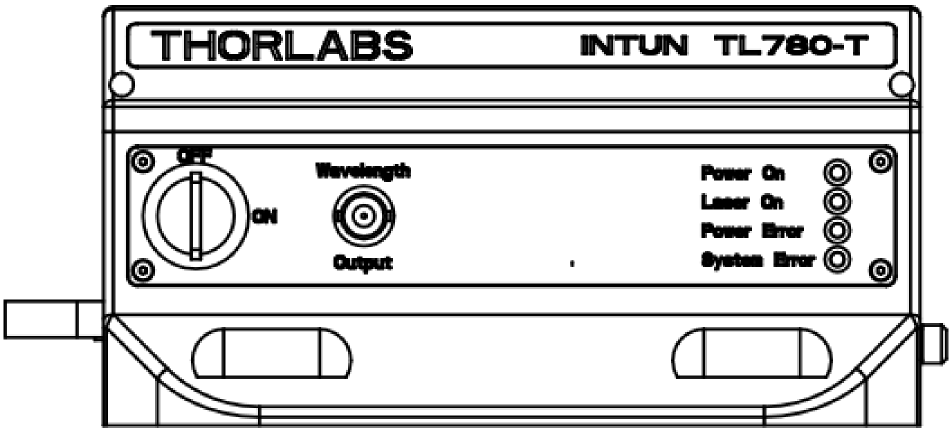


Figure 4: Front view of the INTUN TL780-T.

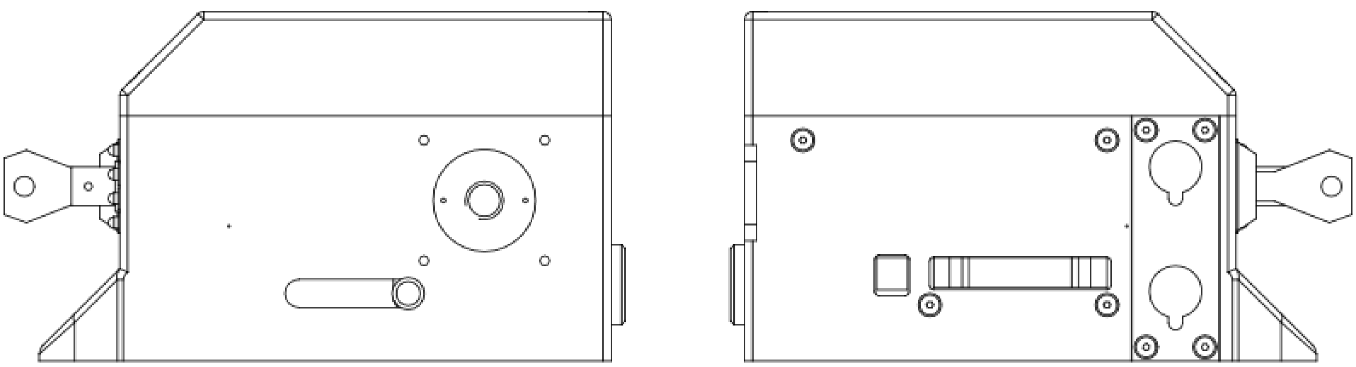


Figure 5: Side views of the INTUN TL-T.

Mounting the INTUN TL-T

The orientation of INTUN TL-T must be horizontal during operation. There are two mounting slots (M6 or 1/4") on the front of the INTUN TL-T as shown in Figure 4. The laser should be secured using both mounting slots.

Figure 6: The INTUN with control unit

Environmental Conditions

Warning!
Sudden changes in temperature should be avoided as they may cause condensation to form on the optical equipment, leading to a negative influence on the device's performance.

In order to ensure specified performance, the unit is designed to withstand the following ETSI (European Telecommunications Standards Institute) standards with the exceptions given below.

Storage and Transport

ETS 300 019-1-1.1 (Storage in partially temperature-controlled locations)

ETS 300 019-1-2.2 (Careful transport)

Applicable EMC standards

EMC testing is done according to EN 61326-1 Annex A "Immunity test requirement for equipment intended for use in industrial locations"

Emission according to EN 55022 class B

Immunity against radiation according to EN 61000-4-2, 4-3, 4-4, 4-5, 4-6, and 4-8

Immunity against radiation according to ENV 50204

Safety Standards

Safety requirements for electrical equipment for measurement, control, and laboratory use as outlined in the EN 61010-1 standard

UL 3101-1 standards for electrical equipment for laboratory use

According to IEC 60825-1 edition 1.2 2001-08 (laser safety), the INTUN TL-T is classified as 3B or 3R depending on model. Refer to the label on the laser itself for classification.

Laser safety classifications as outlined in IEC 825

Exceptions and Extensions to Standards Compliance

Operating temperature range: 15 to 30 °C

Dew point: <26 °C noncondensing environment (RH 85%) @ 30 °C

External vibration will gradually degrade the performance.

External magnetic field at the surface: < 6 µT at 30 – 200 Hz (5 A/m)

3.5. Electrical Interfaces

IMPORTANT!
Read this chapter carefully before connecting the INTUN TL-T to any voltage source.

The INTUN TL-T is fully controlled and monitored by a set of analog and digital control[1] and status[2] signals as shown in Figure 7.

[1] A control signal is defined as an input signal to the INTUN TL780-T (written to INTUN TL780-T). The control signals can be either analog or digital.
[2] A status signal is defined as an output signal from the INTUN TL780-T (read from the INTUN TL780-T).

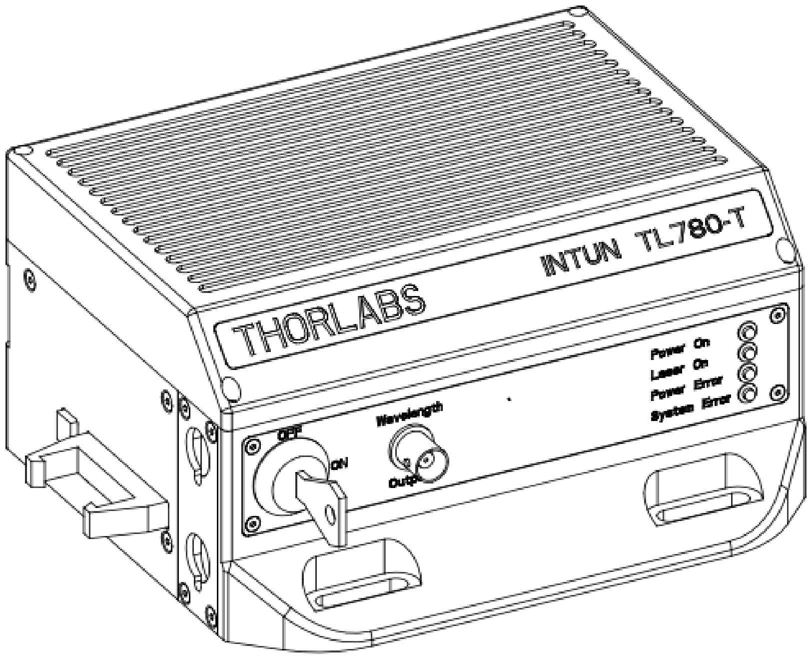


Figure 7: The INTUN TL780-T control and monitor controls and status signals.

The user needs to provide the following electrical connections:

- DC power +5 V and ± 15 V (see page 14)
- DC voltage, low noise, [-10 V, 10 V] for setting the output wavelength (see page 25)
- DC voltage, low noise, [-1 V, 10 V] for setting the optical output power level (see page 26).
- Setting appropriate digital control signals (0 V / 5 V logical levels) (see page 20).
- Reading the status of appropriate digital status signals (0 V / 5 V logical levels) (see page 22).

The electrical signals are accessible via the two connectors located on the rear side of the INTUN TL-T and shown in Figure 8. The top (6 pin) connector connects the DC power supply to the INTUN TL-T and the lower (40 pin) connector contains all other electrical control and status signals.

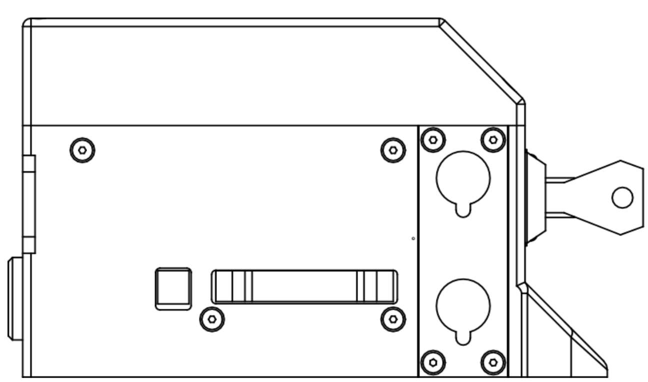


Figure 8: Power (upper) and signal (lower) connectors

This table lists the signals used to control and monitor the INTUN TL-T.

Signal	Type	Note
_WAVELENGTH_TUNING	Analog Control	-10 to 10 V
_FINE_TUNING	Analog Control	-10 to 10 V
_OPTICAL_POWER	Analog Control	-1 to 10 V
_FINE_TUNING_ENABLE	Digital Control	On = 0 V Off = +5 V
_OPTICAL_POWER_ENABLE	Digital Control	On = 0 V Off = +5 V
_WAVELENGTH_TUNING_ENABLE	Digital Control	On = 0 V Off = +5 V
_COHERENCE_CONTROL_ENABLE	Digital Control	On = 0 V Off = +5 V
_CONSTANT_CURRENT_ENABLE	Digital Control	On = 0 V Off = +5 V
TBD	Digital Status	TRUE = 0 V FALSE = +5 V Duration time > 100 µs
_SYSTEM_ERROR	Digital Status	TRUE = 0 V FALSE = +5 V
_TEMPERATURE_ERROR	Digital Status	TRUE = 0 V FALSE = +5 V Internal temperature
_WAVELENGTH_ERROR	Digital Status	TRUE = 0 V FALSE = +5 V
_OPTICAL_POWER_ ERROR	Digital Status	TRUE = 0 V FALSE = +5 V

Grounding Issues

Prior to connecting the INTUN TL-T to any electrical power or signal source, care must be taken to avoid ground loops. The ground loops may pick up noise and other disturbances from the surrounding electromagnetic environment. Such disturbances may lead to reduced performance (or malfunctioning) of the INTUN TL-T.

There are two connectors on the rear side of the INTUN TL-T: one connector for electrical power and one connector for the control and status signals. Both connectors have pins connected to ground. All pins labeled GND are physically joined inside the INTUN TL-T.

We recommend that the INTUN TL-T is connected to the (signal) ground via the electrical power connector; physically join all Row B pins and keep them at 0 V. This connection scheme ensures that the +5 V, +15 V, and –15 V supplies can be used for the user's control electronics. However, a ground connection between the Row B pins (see page 29) and the ground of the user's control electronics must be made.

The three analog control voltages (TUNING_VOLTAGE, OPTICAL_POWER, and FINE_TUNING) are connected to differential input stages having a high common-mode rejection ratio (CMRR). Hence, grounding is not recommended for any of the analog control voltage terminals (see Figure 9).

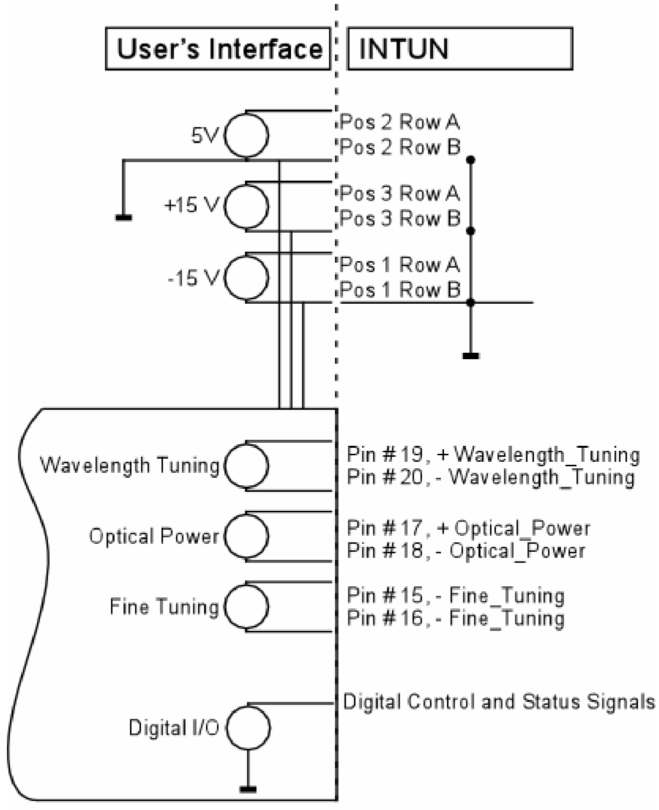


Figure 9: INTUN TL-T recommended connections for electrical power and analog signals

Part 4. Power Supplies

The TL-F control box, which is shown below, provides all the power and control signals necessary to run the INTUN TLX-T laser. More details about this all-in-one control box can be found in the next section.

Figure 10: TL-F control box for the INTUN TLX-T laser.

Alternatively, three user-supplied external power supplies can be used to run the INTUN TL-T unit. If using this option to power the INTUN laser, the DC Power Supply table below lists the required voltages; the specifications that these power supplies should meet are outlined in the DC Power Supply Requirements table. In addition, the pin configuration of the DC power connector can be found on page 29. The full pin configuration of the INTUN TL-T power and signal connectors are shown on page 28.

DC Power Supply	
Voltage	**Comments**
+5 V	+5 V supply
GND (+5 V)	Return for +5 V connected to the circuit board ground
+15 V	+15 V supply
GND (+15 V)	Return for +15 V connected to the circuit board ground
-15 V	-15 V supply
GND (-15 V)	Return for -15 V connected to the circuit board ground

DC Power Supply Requirements				
Nominal Voltage Input	**Voltage**	**Max Voltage Ripple**	**Max Operating Current**	**Comment**
+5 V	4.9 to 5.2 V	25 mV_{pp}	2 A	Current surge at power-on C = 100 nF
+15 V	14.6 to 15.4 V	150 mV_{pp} (up to 2 MHz)	0.3 A	Current surge at power-on C = 470 µF, R_{min} = 0.3 Ω
-15 V	-15.4 to -14.6 V	150 mV_{pp} (up to 2 MHz)	0.3 A	Current surge at power-on C = 470 µF, R_{min} = 0.3 Ω
Overall Power Consumption			< 20 W	

The electrical power is connected to the top (6 pin) connector, which is located on the left side of the INTUN TL-T.

4.1. Triangular Generator TL-F

The INTUN TLX-T comes with a TL-F control box, which provides all the power and control signals needed to run the laser.

Connecting the TL-F

To detach the TL-F from the INTUN, remove the screw at the back (see arrow in the picture below), lift up, and then out. The TL-F does not need to be attached to the INTUN to work so long as the signal cable is connected.

Figure 11: Connecting the TL-F with the INTUN

There are three connectors on the back of the TL-F and INTUN as shown above. One cable is connected to both the INTUN and the TL-F (cream cable), enabling signals to be transferred between the two while the other is for connecting the power adapter (black cable).

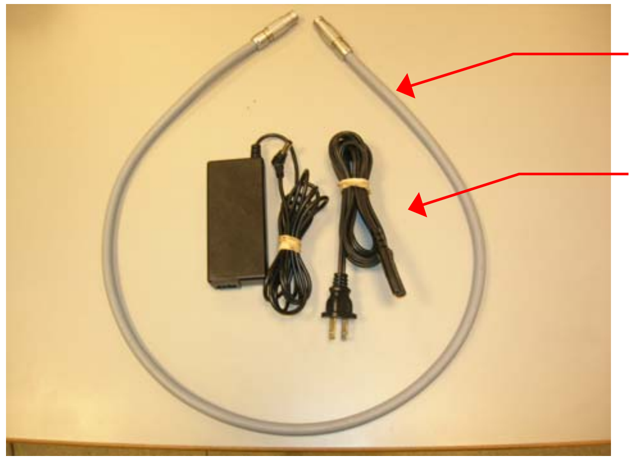


Figure 12: TL-F to INTUN Connection Cables

Controlling the INTUN with a TL-F

Power On

First, turn on the TL-F, and then turn on the INTUN.

Controls

There are four knobs on the top of the TL-F, each of which allows you to control a different aspect of the INTUN:

1. **Output Power:** Sets the output power between its minimum and maximum values. Look in the test data for maximum output power. To totally extinguish the output power, you need to use the shutter.

2. **Wavelength:** Sets the wavelength between its minimum and maximum values or at the center wavelength for the sweep. See the test data for the wavelength range. Note that 0 corresponds to the shortest wavelength.

3. **Tuning Range:** Sets the range you want to sweep; 0 holds the unit at one wavelength and 10 corresponds to sweeping over the entire range. Note: To sweep over the entire range, the wavelength must be set to 5.

4. **Tuning Speed:** Sets the tuning speed from approximately 10 nm/s to 100 nm/s (0 ≈ 10 nm/s and 10 ≈ 100 nm/s).

Figure 13: Control knobs for the TL-F Control Box

Constant Wavelength

The TL-F is not made for this type of application and will have a jitter of about ±20 pm or more. To stand still on a certain wavelength, set the tuning speed to 5 and the tuning range to 0.

4.2. Digital Control and Status Signals

If desired, three user-supplied external power supplies can be used instead of the TL-F control box to run the INTUN TL-T unit.

Definition of the Logical States

The digital control signals are defined with 0 V (LOW) as ON/TRUE/active/able and with 5 V (HIGH) as OFF/FALSE/inactive/disable.

Important!
If the input signal is not connected, its default logical state is 5 V (i.e. disabled).

Digital Control Signals

The digital logic control signals are used to enable (or disable) certain INTUN TL-T features. The control signals could be either TRUE or FALSE. Carefully read through the Digital Control and Status Signals section starting on page 18 before connecting the INTUN TL-T. The digital input circuitry is shown in Figure 10.

Definition of the Control Signals

The table below lists the available control signals. Prior to connecting the INTUN TL-T, carefully read the important note above, which defines the default logical state. The full pin configuration of the INTUN TL-T power and signal connectors are shown on page 28.

The Digital Control Signals	
Name	**Short Description**
_WAVELENGTH_TUNING_ENABLE	When enabled, the INTUN TL-T is ready to accept and respond to wavelength tuning input
_COHERENCE_CONTROL_ENABLE	When enabled, a dither signal is added to the wavelength control signal to minimize the influence of standing waves.
_OPTICAL_POWER_ENABLE	When enabled, optical power is emitted from the output fiber.
_CONSTANT_CURRENT_ENABLE	When enabled, the unit is operated in constant current mode.
_FINE_TUNING_ENABLE	When enabled, the cavity temperature can be adjusted to fine tune the wavelength.

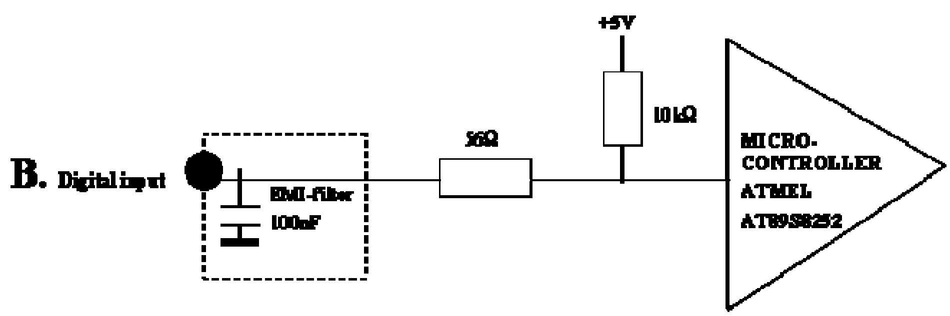


Figure 14: Digital Input Circuitry

Digital Control: _WAVELENGTH_TUNING_ENABLE

When the digital control signal _WAVELENGTH_TUNING_ENABLE is set to LOW (0 V), the unit is ready to accept and respond to wavelength tuning (using the analog control WAVELENGTH_TUNING control discussed on page 24).

When the _WAVELENGTH_TUNING_ENABLE signal is set to HIGH (5 V), the wavelength CANNOT be tuned (changed), and it is set to the middle of its range (i.e., the wavelength that corresponds to 0 V on the control analog WAVELENGTH_TUNING) regardless of the analog WAVELENGTH_TUNING control voltage (see page 24).

Digital Control: _COHERENCE_CONTROL_ENABLE

When the digital control signal _COHERENCE_CONTROL_ENABLE is set to LOW (0 V), the effective optical linewidth of the outputted light is broadened.

Digital Control: _OPTICAL_POWER_ENABLE

When the digital control signal _OPTICAL_POWER_ENABLE is set to LOW (0 V), the output optical power from the unit is set according to the voltage of the analog optical power input.

When the digital control signal _OPTICAL_POWER_ENABLE is set to HIGH (5 V), the laser diode inside the INTUN TL-T unit is turned off regardless of the analog optical power input voltage.

The _OPTICAL_POWER_ENABLE signal is well suited to the implementation of a safety circuit that switches off the laser in critical situations.

Important!
The _OPTICAL_POWER_ENABLE signal should NEVER be used for modulation of the optical power!

Digital Control: _CONSTANT_CURRENT_ENABLE

The digital control signal _CONSTANT_CURRENT_ENABLE is used to enable current tuning. Read the appropriate section starting on page 23 carefully prior to using this feature.

Digital Control: _FINE_TUNING_ENABLE

This digital control signal is used to fine tune the wavelength by adjusting the cavity temperature.

Digital Status Signals

The digital status signals are defined with 0 V (LOW) as ON/TRUE/ERROR and 5 V (HIGH) as OFF/FALSE/Safe. The digital status signals can be read form the interface. Carefully read the Definition of the Logical States at the top of page 20 before connecting the INTUN TL-T. The digital output circuitry is shown in Figure 11.

Digital Status Signals	
Name	**Short Description**
_SYSTEM_ERROR	This status signal indicates a major fault such as overheating of the turning motor or overloading of a control loop
_WAVELENGTH_ERROR	This status signal indicates that the INTUN TL-T does not follow the applied wavelength sweep voltage.
_OPTICAL_POWER_ERROR	This status signal indicates that the laser current has exceeded 100 mA.
_TEMPERATURE_ERROR	This status signal indicates that the laser cavity is not operating at the correct temperature

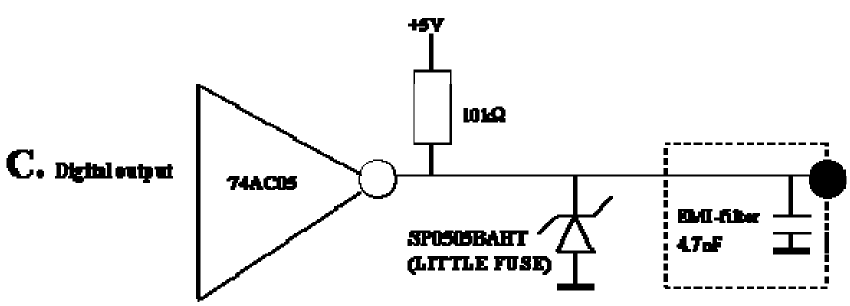


Figure 15: Digital output circuitry

Digital Status: _SYSTEM_ERROR

When the digital status signal _SYSTEM_ERROR is TRUE – LOW (0 V), the INTUN TL-T unit has an internal error (e.g., overheating) and should not be used. When this error occurs, the laser will turn off regardless of the logical status of the _OPTICAL_POWER_ENABLE signal or any other control signal.

When the digital status signal _SYSTEM_ERROR is FALSE – HIGH (5 V), the unit is in its normal operation mode.

Please note that the _SYSTEM_ERROR may be TRUE during the startup phase. This is quite normal.

If a _SYSTEM_ERROR occurs during operation, it can only be reset by switching the INTUN TL-T unit off.

Digital Status: _WAVELENGTH_ERROR

This signal indicates that the electronic controller has experienced an error. When the _WAVELENGTH_ERROR is TRUE – LOW (0 V), the electronic wavelength error is more than ±15 pm.

When the digital status signal _WAVELENGTH_ERROR is FALSE – HIGH (5 V), the error in the wavelength reading is approximately ±15 pm. Since it is the electronic error, other optical effects are not included such as mode hops and drift.

Digital Status: _OPTICAL_POWER_ERROR

When the digital status signal _OPTICAL_POWER_ERROR is TRUE – LOW (0 V), the output optical power from the unit is lower than that set by the applied voltage to the analog OPTICAL _POWER control signal (see page 26).

When the digital status signal _OPTICAL_POWER_ERROR is FALSE – HIGH (5 V), the difference between the actual output power and that set by the applied voltage to the analog OPTICAL _POWER control signal is within the stated tolerance.

If the +OPTICAL_POWER is increased beyond the voltage corresponding to the maximum recommended laser diode drive current, the _OPTICAL_POWER_ERROR will change its logical state to TRUE – LOW (0 V). If the +OPTICAL_POWER is increased even further, some laser units will increase their optical output power. The increase will vary from model to model. The INTUN TL-T control electronics will protect the laser diode; however, it is not recommended to operate the laser if the _OPTICAL_POWER_ERROR is TRUE – LOW (0 V).

Digital Status: _TEMPERATURE_ERROR

When the digital status signal _TEMPERATURE_ERROR is TRUE – LOW (0 V), the laser cavity has not yet reached the right working temperature. Although the INTUN TL-T unit can still be used, the optical power and wavelength may not meet specifications.

When the digital status signal _TEMPERATURE_ERROR is FALSE – HIGH (5 V), the unit is at the correct laser cavity working temperature.

Analog Control Signals

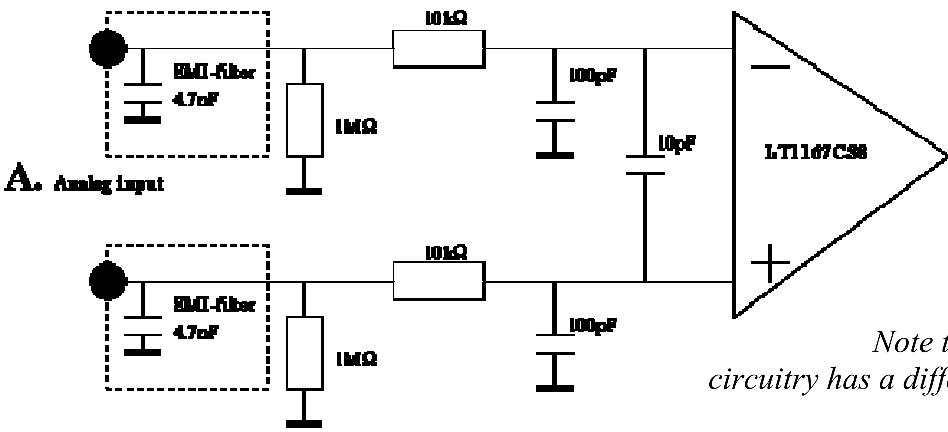
The interface allows the user to set the wavelength, optical power, and internal (cavity) temperature via analog signals. These inputted values will be realized within the tolerances associated with the INTUN TL-T unit.

To reach the specified accuracy, one must correct for small nonlinear deviations between the control signals and their corresponding counterparts (wavelength, optical output power, or cavity temperature). Therefore, a calibration table is necessary to set the optical output to a specified power and wavelength (see section **5.3**).

In order to achieve optimal performance, the control signals must be well defined. Ideally, the input signal accuracy would need to be within a tenth of a millivolt to achieve ultimate wavelength thuning performance. Resolutions of this order are easily disturbed by stray ground return potentials, which are typically on the order of tenths of a volt. Therefore, to help the user achieve this level of accuracy, we have incorporated a differential input amplifier (see Figure 12) that has a very high CMRR (Common Mode Rejection Ratio).

Note that this is a differential input stage; therefore, both the + and – voltage terminals must be connected.

Analog Control Signals	
Name	**Short Description**
WAVELENGTH_TUNING	This signal, -10 to +10 V, tunes the wavelength of the laser.
OPTICAL_POWER	This signal, -1 to +10 V, sets the optical output power.
FINE_TUNING	This signal, -10 to +10 V, controls the wavelength piezo.



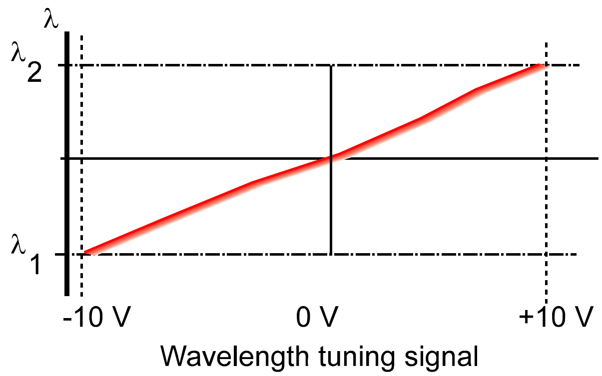
Note that this input circuitry has a differential input

Figure 16: Analog input circuitry.

Analog Control: WAVELENGTH_TUNING

Provided that the _TUNING_ENABLE signal is set to TRUE – LOW, the wavelength can be set and tuned by applying a voltage to +WAVELENGTH_TUNING and –WAVELENGTH_TUNING as specified in the table and graph below.

WAVELENGTH_TUNING Voltage	
Desired Wavelength	**Voltage Settings**
Shortest wavelength corresponds to –10V	- WAVELENGTH_TUNING set to 0 V +WAVELENGTH_TUNING set to -10V
Longest wavelength corresponds to +10V	- WAVELENGTH_TUNING set to 0 V +WAVELENGTH_TUNING set to +10V



λ1 and λ2 correspond to the shortest and the longest wavelengths, respectively (see the technical specifications for numerical values).

Figure 17: Wavelength tuning signal verse laser wavelength

Note that a differential input stage is used, and thus both +WAVELENGTH_TUNING and –WAVELENGTH_TUNING must be connected.

In order to achieve the 1 pm wavelength resolution, a high-quality, noise-free voltage should be applied to the +WAVELENGTH_TUNING terminal. The following example illustrates this critical issue:

If we assume that a 110 nm tuning range (110,000 pm) is associated with a 20 V control voltage (peak-to-peak), the corresponding voltage step is

$$20\ \text{V}/110{,}000\ \text{pm} \approx 180\ \mu\text{V/pm},$$

and the D/A converter resolution is better than

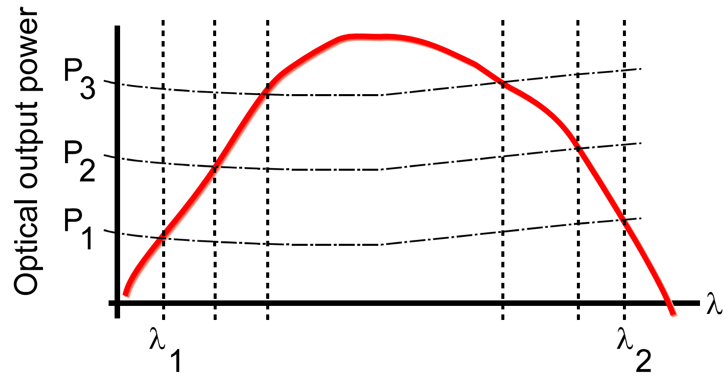
$$\log_2(110{,}000) > 16.7\ \text{bits}.$$

Hence, we recommend using a D/A converter with an 18-bit minimum capacity

Analog Control: OPTICAL_POWER

Provided that the _OPTICAL_POWER_ENABLE signal is set to TRUE – LOW, the optical power can be set and changed by applying a voltage to +OPTICAL_POWER and –OPTICAL_POWER as specified in the table and chart below.

OPTICAL_POWER Voltage	
Desired Power	**Voltage Settings**
Optical power off corresponds to –1 V	-OPTICAL_POWER set to 0 V +OPTICAL_POWER set to -1 V
Lowest optical power corresponds to 0 V	-OPTICAL_POWER set to 0 V +OPTICAL_POWER set to 0 V
Maximum optical power corresponds to +10 V	-OPTICAL_POWER set to 0 V +OPTICAL_POWER set to +10 V



λ_1 and λ_2 correspond to the shortest and longest wavelengths, respectively, for a given ITUNE . For numerical values, see the specific model's technical specifications.

Figure 18: Output powers compared to wavelength tuning range.

Note that a differential input stage is used, and thus, both +OPTICAL_POWER and -OPTICAL_POWER must be connected.

It should also be noted that for a given wavelength, the maximum output power is achieved by running the laser at its current limit. Consequently, as the wavelength is changed, the maximum output power will vary considerably. This is a direct result of wavelength dependence of the cavity gain.

The INTUN TL-T unit is set at the factory to deliver 1 mW of optical power when the analog control signal +OPTICAL POWER is set to 1 V. Typical operation would be at 1 V, thus guaranteeing an output of 1 mW over the entire wavelength range.

If the +OPTICAL_POWER is increased beyond the voltage corresponding to the maximum allowable laser diode drive current, the _OPTICAL_POWER_ERROR will change its logical state to TRUE – LOW (0 V). Additional increases in the +OPTICAL_POWER signal will, for some laser units, further increase the optical output power. The amount of power increase will vary from model to model. The INTUN TL-T control electronics will protect the laser diode; however, operation of the laser is not recommended if the _OPTICAL_POWER_ERROR is TRUE – LOW (0 V).

The minimum possible optical output power is difficult to define; since this state is close to the lasing threshold, working at this power is not recommended.

NOTE: When in constant current mode, the OPTICAL_POWER control signal is rescaled by 10 mA/V:

OPTICAL_POWER = 1 mV → laser diode current = 10 mA

OPTICAL_POWER = 10 mV → laser diode current = 100 mA

Analog Control: FINE_TUNING

Provided that the FINE_TUNING_ENABLE is set to TRUE – LOW, the fine tuning can be set and tuned by applying a voltage to +FINE_TUNING and –FINE_TUNING as described in table below.

FINE_TUNING Voltage	
Desired Wavelength	**Voltage Settings**
Shortest wavelength corresponds to –10 V	-FINE_TUNING set to 0 V +FINE_TUNING set to –10 V
Longest wavelength corresponds to +10 V	-FINE_TUNING set to 0 V +FINE_TUNING set to +10 V

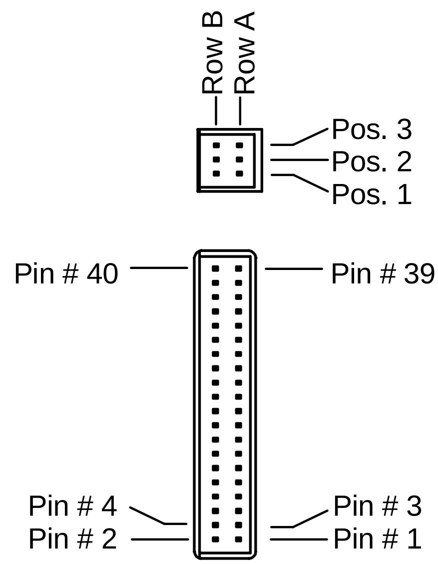
Note that a differential input stage is used, and thus, both +FINE_TUNING and –FINE_TUNING must be connected.

Electrical Power and Signal Connectors

There are two connectors located on the left side of the INTUN TL-T. The top connector (6-pin) is the power connector, and the 40-pin connector carries all digital and analog signals. The figure below shows the pin configuration of the two connectors. The electrical power connector carries all the required DC power lines.

The table below lists the signal interface's pin configuration.

The type of connectors used is specified in the Power Connections section on page 29.



The top (6-pin) connector is the electrical power connector, and the lower (40-pin) connector is the signal connector.

Figure 19: The rear connectors on the INTUN TL-T.

Pin Configuration for the electrical power connector. Note that an increased cable area is recommended for the +5 V and GND (+5V) connections. The full pin configuration of the INTUN TL-T power and signal connectors is shown in the following table.

Position	Row	Voltage	Recommended AWG	Cable Area (mm2)
Pos 1	Row A	-15 V	AWG 22	0.36
Pos 1	Row B	GND (-15 V)	AWG 22	0.36
Pos 2	Row A	+5 V	AWG 20	0.56
Pos 2	Row B	GND (+5 V)	AWG 20	0.56
Pos 3	Row A	+15 V	AWG 22	0.36
Pos 3	Row B	GND (+15 V)	AWG 22	0.36

The pin configuration for the signal interface (pins 25-38 are exclusively for internal use):

Pin	Signal Name	Description	Pin	Signal Name	Description
1	Service 0	DO NOT CONNECT	21	Spare	DO NOT CONNECT
2	Service 0	DO NOT CONNECT	22	Spare	DO NOT CONNECT
3	_SYSTEM_ERROR	Status Signal	23	Service 0	DO NOT CONNECT
4	_WAVELENGTH_TUNING_ENABLE	Control Signal	24	Service 0	DO NOT CONNECT
5	_WAVELENGTH_ERROR	Status Signal	25	Service 1, internal use only	Service
6	_COHERENCE_CONTROL_ENABLE	Control Signal	26	Service 2, internal use only	Service
7	_OPTICAL_POWER_ERROR	Status Signal	27	Service 3, internal use only	Service
8	_OPTICAL_POWER_ENABLE	Control Signal	28	Service 4, internal use only	Service
9	_TEMPERATURE_ERROR	Status Signal	29	Service 5, internal use only	Service
10	_CONSTANT_CURRENT_ENABLE	Control Signal	30	Service 6, internal use only	Service
11	TBD	Status Signal	31	Service 7, internal use only	Service
12	_FINE_TUNING_ENABLE	Control Signal	32	Service 8, internal use only	Service
13	Spare	DO NOT CONNECT	33	Service 9, internal use only	Service
14	Service 0	DO NOT CONNECT	34	Service 10, internal use only	Service
15	+FINE_TUNING	Analog	35	Service 11, internal use only	Service
16	- FINE_TUNING	Analog	36	Service 12, internal use only	Service
17	+OPTICAL_POWER	Analog	37	Service 13, internal use only	Service
18	- OPTICAL_POWER	Analog	38	Service 14, internal use only	Service
19	+WAVELENGTH_TUNING	Analog	39	Service 0	DO NOT CONNECT
20	- WAVELENGTH_TUNING	Analog	40	Service 0	DO NOT CONNECT

Power Connector

The power connector on the INTUN TL is a 6-way connector with two rows of pins. (FCI Connectors, Part Number 78207-106HLF). The mating connector is a housing for crimp terminals (FCI Connectors, Part Number 69176-006LF). The crimp terminals for the mating connector are (FCI Connectors, Part Number 47746-000LF for AWG 18-20 or 47745-000LF for AWG 22-26).

Signal Connector

The signal connector on the INTUN TL-T is a dual-row, 40-pin, male connector (Honda Part Number RPS-40RLMG1). The mating connector is a dual-row female IDC connector for ribbon cable (Honda Part Number RPS-D40RFBG1). The cable for the mating connector is a 40-way ribbon cable with a pitch of 0.025" (0.635 mm). Thorlabs recommends 30 AWG (7/38 AWG) (Amphenol Spectra Strip Part Number 191.3005.040).

4.3. Optical Interface

Shutter

The optical port is protected by a mechanical shutter.

Beam

The beam exiting the INTUN TL-T is collimated with a diameter of less than 5 mm.

30 mm Cage System

The INTUN TL-T is equipped with four threaded #4-40 holes, allowing for easy integration into a 30 mm cage system from Thorlabs. Fiber coupling is normally done using the cage system.

SM1 Thread

The INTUN TL-T is equipped with SM1 threading on the optical exit port, thus enabling seamless integration into a Thorlabs SM1 lens tube system.

Part 5. Operation

This chapter describes how to operate the INTUN TL-T. Be sure to read it carefully before you mount and start the INTUN TL-T.

An external computer is generally used to supply the required analog signals for tuning the wavelength and setting the optical power output level for the INTUN TL-T. The computer is also used to read the digital status signals and to set the digital control signals.

The signal used for tuning the wavelength is typically an analog voltage ramp (saw tooth or triangle wave) generated by the digital to analog converter (DAC) interface in the computer. Hence, the tuning speed is completely determined by the analog signal. The same holds true for the optical power control. We recommend that a DAC with 18 bit resolution is used.

The INTUN TL-T must be calibrated in order to achieve optimal performance. In practice, this means that a "calibration matrix" containing tuning voltages as a function of wavelengths for a set of optical output powers must be used to linearize the tuning voltage vs. wavelength.

As mentioned, the INTUN TL-T can be swept between any two wavelengths within the tuning range. Alternatively, it can be tuned to a specific wavelength or jump between a random sequence of fixed wavelengths.

5.1. Switching ON the INTUN TL-T

The wavelength and optical output power of the laser are controlled using the connector located on the rear side of the INTUN TL-T.

The following step-by-step instructions should be followed to switch on the laser:

1. Connect the +5 V.
2. Connect the +15 V and –15 V supplies.
3. Turn the key on the front of the unit clockwise to the "ON" position.
4. When the system has started, the _TEMPERATURE_ERROR signal will turn TRUE and the other status signals will turn FALSE. The digital status signal _TEMPERATURE_ERROR will be TRUE until the correct working temperature has been reached.

It normally takes about 30 minutes for the INTUN TL-T to reach the correct working temperature, but the warm-up time is dependent on the temperature of the environment.

5. Wait until the _TEMPERATURE_ERROR switches from TRUE to FALSE, indicating that the correct working temperature has been reached. Please note that the technical specifications for the INTUN TL-T are not valid until the _TEMPERATURE_ERROR indicates FALSE.
6. To enable control of the INTUN TL-T, set the following digital control signals to LOW (0 V): WAVELENGTH_TUNING_ENABLE and OPTICAL_POWER_ENABLE.
7. The INTUN TL-T unit can now be tuned by applying a voltage between -10 and 10 V to the +WAVELENGTH_TUNING and the –WAVELENGTH_TUNING terminals. Furthermore, the

optical output power can be changed by applying a voltage between 0 V to 10 V to the +OPTICAL_POWER and –OPTICAL_POWER terminals. (Note: -1 V switches the laser off).

5.2. Switching OFF the INTUN TL-T

To turn OFF the INTUN TL-T, repeat the steps listed in Section 5.1 but in reverse order.

5.3. Calibration of the INTUN TL-T

The INTUN TL-T does not have either internal wavelength references or optical power references. Hence, the INTUN TL-T must be calibrated using external instrumentation such as a wavemeter or optical power meter.

The optical length of the cavity depends on the refractive index of the laser diode, which in turn depends on the current injected into the laser chip. Consequently, wavelength and optical power must be calibrated simultaneously. For a constant wavelength control voltage, the wavelength shift will be less than 40 pm between the minimum and maximum power. By calibrating both the power and wavelength simultaneously, any change in the wavelength for different output powers will be compensated.

A small portion of the light is split off from the optical fiber and used to control the optical output power. Due to the nonlinearity of the output power that occurs at the onset of lasing (as well as at the threshold current), the output power can only be controlled between the threshold of lasing and the point at which saturation occurs.

Using linear interpolation and a sufficiently dense grid, the unit can be calibrated to provide an accuracy of at least a few picometers. Theoretically, the unit can be calibrated down to 1 pm using 40 calibration points, but realistically, calibration will require a denser mesh of calibration points to account for irregularities. For example, if we assume that we need a 50% increase in the number of calibration points for a realistic calibration and scan a TL1300 over a 110 nm wavelength range at 100 nm/s while requiring a maximal wavelength error of 1 pm, then the number of calibration points necessary is

(safety margin) x (recommended # of points) x (tuning speed) / (wavelength range)

= (1.5 x 40 x 100) / 110 = 55 lookups per second.

Similarly, if a TL1550 was to be tuned over 100 nm at 70 nm/s, then the lookup rate becomes

(1.5 x 40 x 70) / 100 = 42 lookups per second.

Important!
The optical power value scales linearly and is factory adjusted so that 1 mW of output power corresponds to an input voltage of 1 V being applied to the OPTICAL_POWER signal input.

Finally, since the cavity is sensitive to internal heat sources (i.e., the laser itself), the calibration data is only valid once equilibrium conditions have been established.

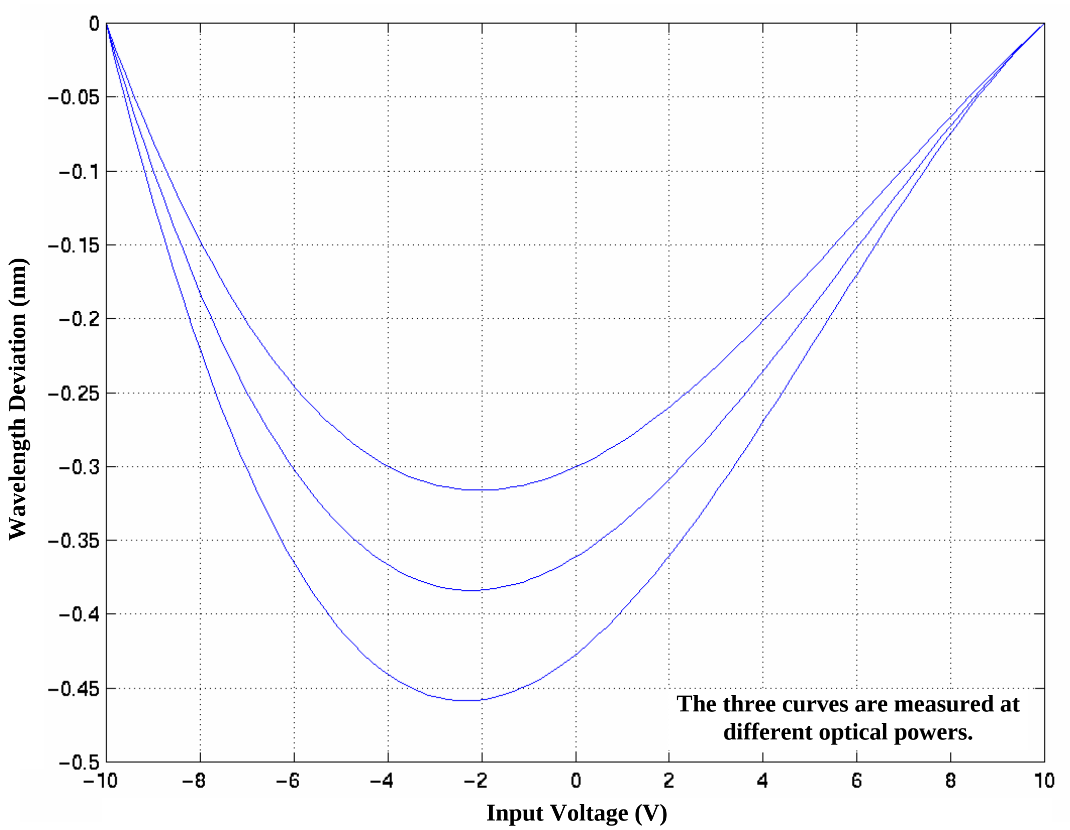


Figure 20: Typical wavelength deviation as a function of input voltage.

Calibration Methods

There are several methods that can be used for calibrating the INTUN TL-T. The following are two general guidelines:

- The INTUN TL-T should be calibrated in the same way that it will be used.
- Never use the digital control signal _POWER_ENABLE to turn on the optical power.

The general purpose start-up and calibration procedures given are recommended by Radians for their tunable laser source modules.

Start-Up

The purpose of the start-up procedure is to find a stable mode to ensure that the calibration procedure will be successful.

- Set the WAVELENGTH _TUNING to 0 V
- Set the Wavelength _TUNING_ENABLE to TRUE
- Set the OPTICAL_POWER to 0 V
- Set the Optical _POWER_ENABLE to TRUE
- Set the OPTICAL_POWER to 1 V

- Wait 2 s
- Set the OPTICAL_POWER to –1 V
- Wait approximately 100 ms
- Set the OPTICAL_POWER to 1 V

Repeat the following four-step procedure five times:

1. Set the WAVELENGTH_TUNING to –9.5 V
2. Wait 1 s
3. Set the WAVELENGTH_TUNING to 9.5 V
4. Wait 1 s

- Set the WAVELENGTH_TUNING to 0 V

The laser start-up procedure is finished.

Calibration

For every optical power level repeat the steps below. The method is illustrated in the figure below.

- Perform the start-up procedure before starting calibration.
- Set the OPTICAL_POWER to the desired value. Measure the actual optical power using a power meter.
- Increase the WAVELENGTH_TUNING monotonically between the calibration points. Measure the actual wavelength using a wavemeter.
- Perform the start-up procedure (see section 0).
- Set the OPTICAL_POWER to the desired value.
- Decrease the WAVELENGTH_TUNING monotonically between the calibration points.

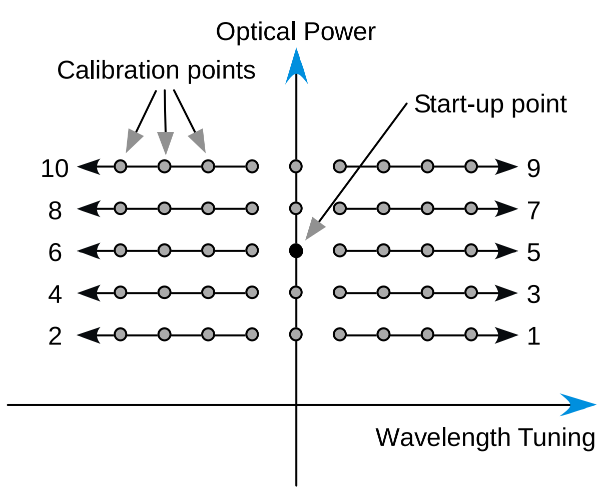


Figure 21: Illustration of the calibration sequence

Part 6. Maintenance and Service

This chapter describes the recommended preventive and corrective maintenance for the INTUN TL-T.

6.1. Transporting, Storage, Packaging, and Unpacking

A Radians INTUN TL-T tunable laser source module is a delicate device that is sensitive to cold, humidity, condensation, and shock. It is therefore important to follow these unpacking and packing instructions carefully. The INTUN TL-T is sensitive to humidity and rapid variations of temperature, which can cause damage to the INTUN TL-T.

Note that the INTUN TL-T module must be shipped and stored within the following environmental specifications:

ETS 300 019-1-1.1: Storage in partially temperature-controlled locations where the temperature is always between -10 to 50 °C (14 to 122 °F).

ETS 300 019-1-2.1: Very careful transport.

The INTUN TL-T should always be transported inside its original packaging, which is special designed for the INTUN TL-T. In addition, the INTUN TL-T unit should always be stored in a vertical position. Detailed information about proper packing, unpacking, and transporting the INTUN TL-T are found in a separate document that comes with the INTUN TL-T.

Warning!
Carefully read the transporting, storage, packing, and unpacking instructions before you open any shipment containing an INTUN TL-T module.

6.2. Cleaning

To obtain the specified performance, it is very important that the fiber optical connector is clean. Always clean the optical connector with a proper cleaning tool prior to operating the laser.

Part 7. Troubleshooting and FAQ

This chapter helps service personnel to troubleshoot the INTUN TL-T. It contains step-by-step troubleshooting information as well as support information.

7.1. Troubleshooting, Step-By-Step

No Output Power is Detected

1. Check that the digital status signal _POWER_ENABLE is TRUE. (Section 0 defines the logical states)
2. Check that the digital status signal _TUNING_ENABLE is TRUE. (Section 0 defines the logical states)
3. Check the voltage on the 5 V power supply.
4. Check the grounding of the system.

The Output Power is Lower than Expected

1. Check that the shutter is fully open.
2. Check the set voltage.

Part 8. Technical Specifications

Specifications are given after one hour of warm-up time. Although the laser can be used before the warm-up time, the optical specifications listed below may not be met.

Parameter	TL780-T	TL980-T	TL1300-T	TL1550-T
Central Wavelength	780 nm	980 nm	1320 nm	1550 nm
Tuning Range	10 dB (15 dB Typ)	20 dB (25 dB Typ)	100 dB (110 dB Typ)	110 dB (150 dB Typ)
Optical Output Power (Over 5 nm)	2 dBm Min (>5 dBm Typical)	10 dBm Min (>20 dBm Typical)		
Optical Output Power (Over Tuning Range)	1 dBm Min (>5 dBm Typical)			2 dBm Min (>5 dBm Typical)
Mode Hops *	0			
Tuning Speed Continuous	0-100 nm/s (0-130 nm/s Typical)			
Tuning Speed **				
1 nm Step	50 ms Max (30 ms Typical)			
10 nm Step	150 ms Max (100 ms Typical)			
100 nm Step	1000 ms Max (800 ms Typical)			
Wavelength Resolution[†]	1 pm Max (0.6 pm Typical)			
Wavelength Repeatability	2 pm Max (1 pm Typcial)			
Absolute Wavelength Accuracy[†]	±10 pm			
Wavelength Stability Over 1 Hour[‡]	±2 pm			
Minimum Output Power	-3 dBm*** (-10 dBm Typical)			
Power Resolution	0.1 µW			
Power Stability (1 Hour)[‡]	±0.02 dB			
Power Set Bandwidth	100 kHz Min (130 kHz Typcal)			
Spectral Line Width (FWHM)	150 kHz (120 kHz Typical)			
Side Mode Suppression Ratio (SMSR)	45 dBc			
Signal to Source Spontaneous Emision Ratio (SSE)	40 dB/nm (45 dB/nm Typical)			
Signal to Total Source Spontaneous Emission Ratio (STSSER)	23 dB (60 dB Typical)			
RIN	-140 dB/Hz			
Operating Temperature Range	15 to 30 °C			
Dimentions (W x L x H)	49 x 93 x 273 mm			
Weight	2.5 kg (5.5 lbs)			

*) *At 0 dBm (±0.2 dB) output power applying a sweep mode.*
**) *Including rise and settling times*
***) *Lower power available at limited performance*
†) *Dependent on customer interface*
‡) *Constant temperature (± 0.5°C)*

Part 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 13th 2005
- Marked correspondingly with the crossed out "wheelie bin" logo (see)
- 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.

9.1. *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.

9.2. *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 live products will thereby avoid negative impacts on the environment.

Part 10. Thorlabs, Inc. 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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