DAYLIGHT SOLUTIONS®

MIRcat™

Ultra-Broadly Tunable Mid-IR Laser

User Manual

Models: MIRcat-QT-2xxxx & MIRcat-1xxxx

D11-00028-02 Rev. A

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I. INTRODUCTION & USER SAFETY

The safe and effective use of our products is of the utmost importance to Daylight Solutions. This manual describes the safe installation, use, and maintenance of the 'MIRcat™ family of widely tunable mid-IR laser systems. This product family includes MIRcat-QT-2xxx (tuning slew rates to >5,000 cm^{-1}/s) and MIRcat-1xxx (slew rates up to 100 cm^{-1}/s) systems. All information in this manual applies interchangeably to MIRcat-QT and MIRcat-1xxx product models unless stated otherwise. Please read this manual, including Laser Safety Warnings section, before attempting to operate the laser. A basic knowledge of laser safety is assumed. Consult the relevant portions of Laser Institute of America's (LIA) document 21 CFR Part 1040 Section 1040.10 for Class IIIB lasers (or Class IV lasers, if your system provides Class IV output).

This symbol is intended to alert the user of this equipment to the presence of exposure to hazardous invisible or, depending on options selected at time of order*, visible laser radiation.

This symbol is intended to alert the user to the presence of dangerous voltages associated with the product that may be of sufficient magnitude to constitute a risk of electrical shock.

This symbol is intended to alert the user of this equipment of the potential injury hazards. Obey all safety messages that follow this symbol to avoid possible injury or death.

CAUTION: Caution used with the safety alert symbol indicates a potentially hazardous situation which, if not avoided, may result in property damage.

WARNING: Warning indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate injury.

DANGER: Danger indicates an imminent hazardous situation which, if not avoided, will result in death or serious injury.

NOTE: To shut-off power to the unit completely, disconnect AC power.

1. Laser Safety Warnings

CAUTION: UNDER NO CIRCUMSTANCES SHALL THE USER ATTEMPT TO OPEN THE LASER HEAD. Opening the laser head will void the warranty, and may result in and/or irreparable damage to internal components. The laser head is also purged with a dry inert gas before sealing to minimize moisture. Breaking this seal will also void the warranty.

CAUTION: The laser radiation emitted from MIRcat laser systems is invisible to the naked eye and may be harmful if the beam makes direct and prolonged contact with the eye. In some units, depending on options selected at time of order*, the laser may also emit visible laser radiation. In all cases, avoid direct exposure to the beam or looking directly towards the laser beam. These lasers emit light in the wavelength range from **3µm to 14 µm**, depending on the wavelength range options selected at the time of order. If the visible aiming beam option was selected at time of order, these lasers will also emit in the range **~0.6 to 0.7 µm**. The specific range of each laser is listed on the safety label affixed to each MIRcat. An example of the safety labels is shown below.

*For more information, please contact Daylight Solutions or your authorized distributor.

2. Safety Warning Labels

1a

2a

1b

2b

1c

2c

1d

2d

Figure 1. MIRcat safety warning labels. (1) Aperture warning label: (1a) invisible output only; (1b) invisible & visible output; (1c) invisible output only, French text; (1d) invisible and visible output, French text. (2) Combination warning/certification/identification label stating emitted wavelengths and maximum emitted average power: (2a) invisible output only, (2b) invisible & visible output; (2c) invisible output only, French text; (2d) invisible and visible output, French text.

DANGER – non-interlocked housing label. Warns of invisible laser radiation when housing is open. AVOID DIRECT EXPOSURE TO BEAM(S). NOTE: MIRcat housing must never be opened by users. Warranty is void if housing is opened by user.

DANGER – non-interlocked housing label. Warns of invisible and visible laser radiation when housing is open. AVOID DIRECT EXPOSURE TO BEAM(S). NOTE: MIRcat housing must never be opened by users. Warranty is void if housing is opened by user.

DANGER: The laser radiation emitted from this unit is invisible to the naked eye and may be harmful if the beam makes direct and prolonged contact with the eye. Avoid direct exposure to the beam or looking directly towards the laser beam.

DANGER: The laser radiation emitted from this unit is visible and invisible to the naked eye and may be harmful if the beam makes direct and prolonged contact with the eye. Avoid direct exposure to the beam or looking directly towards the laser beam.

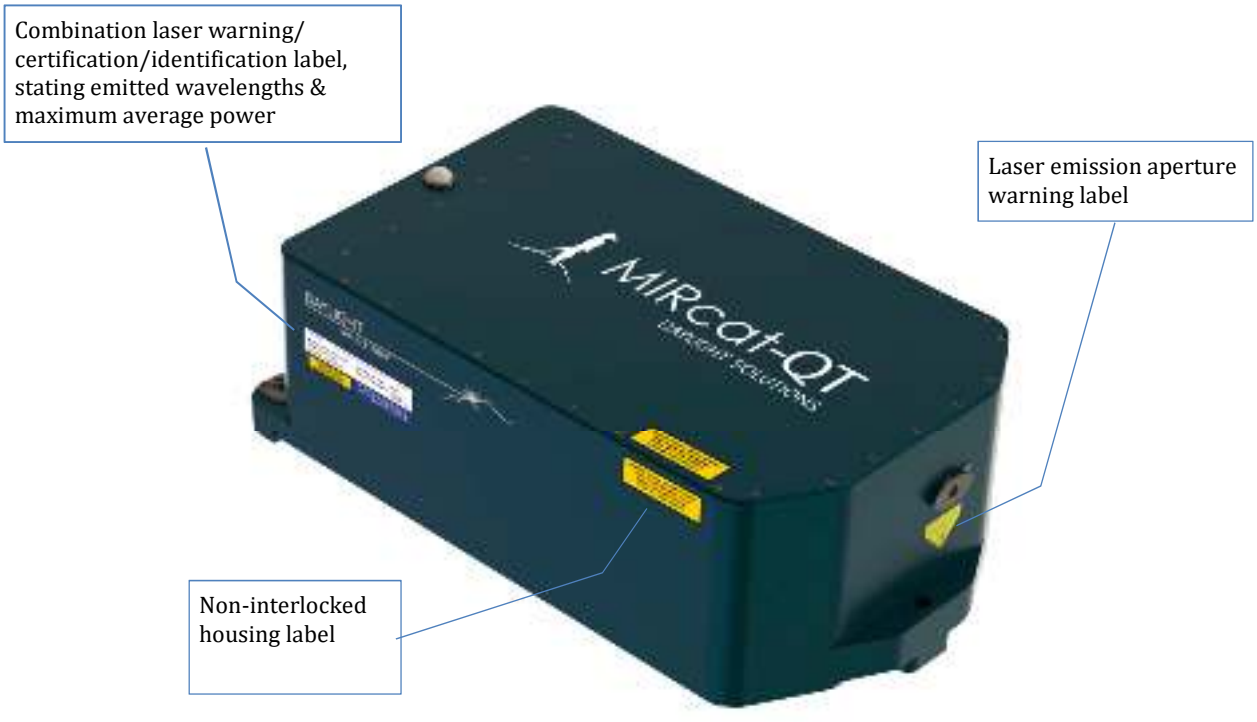


Figure 2. Radiation control diagram - position and type of laser safety warning labels used on MIRcat-QT / MIRcat laser heads.

3. Laser Emission Warning Indicators

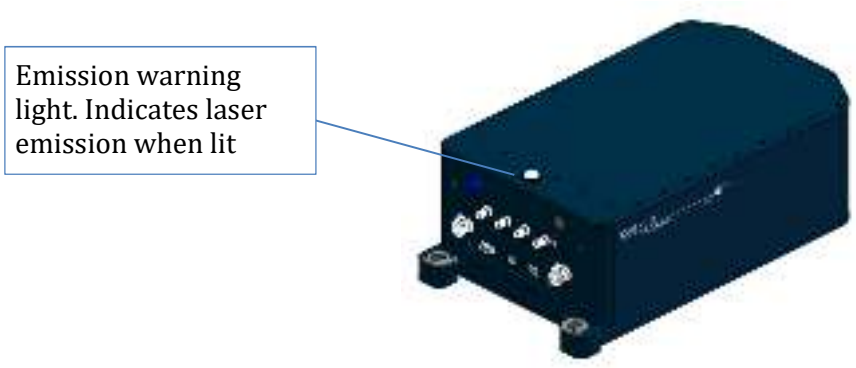


Figure 3. Position of laser emission warning indicator (white LED) on MIRcat laser heads.

CAUTION: Laser emission may be present whenever the laser emission warning indicator light is on (white LED is lit). This includes cases where the laser may be operating in 'External Pulse' mode, but the user has disconnected the 'External Pulse' trigger signal from the laser. Always observe all laser safety precautions and procedures and assume laser emission is present whenever the emission warning indicator is lit.

A white-light LED emission warning indicator on MIRcat laser heads flashes for 3-5 seconds whenever the laser is first Armed and readied for laser emission. The laser is Armed and ready for mid-infrared laser emission when the white light on the top of the unit is lit, and the button on the right side of the Control Panel GUI next to "Disarm Laser" or "Stop Scan" has a green light. For those units fitted with an optional visible laser aiming beam, the white-light emission warning indicator turns on immediately, as soon as the v beam is activated via the GUI. (Unlike the mid-infrared output, there is no 3-5s warning delay before the visible aiming beam output is activated). There is also an optional acoustic beeping sound that can be selected to warn users of mid-infrared laser emission.

4. Eye Protection

The laser radiation emitted from this unit is invisible to the naked eye and may be harmful if the beam makes direct and prolonged contact with the eye. In some units, depending on options selected at time of order, the laser may also emit visible laser radiation. The user must review this safety label and/or the final test data sheet included with your system to determine laser safety glasses that will provide suitable protection for the range of wavelengths and output power emitted. As general guidelines, however: a) recommended Optical Density (OD) for safety glasses is at least 5 for wavelengths in the range 3µm to 14µm; b) provided direct or prolonged viewing of the visible aiming beam (if included in your system) is avoided, safety glasses that protect against this visible wavelength should not be necessary. Regardless of general guidelines given here, users should consult with laser protective eyewear vendors for help selecting laser safety glasses, and to confirm that selected eyewear will provide sufficient eye protection.

5. Operating Conditions

MIRcat lasers are designed to operate in an indoor laboratory environment. A normal operating environment is defined as: within a temperature range of 15°C to 30°C; Relative Humidity in the range 10% - 80% (non-condensing), and altitude from sea level up to 6500 ft (2000m). MIRcat lasers must be operated in a well-ventilated area that allows airflow around the unit. Do not position MIRcat lasers such that the Laser On/Off button is not easily accessible, or the back panel is not easily accessible.

CAUTION: If the operation of this laser system is in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired. Do not operate this laser system if its panels are removed or if any of the interior circuitry is exposed.

CAUTION: Do not operate this laser system in wet or damp conditions, or in an explosive environment.

CAUTION: Back reflections can cause damage to the quantum cascade gain media and could void your warranty. Care must be taken to minimize all back reflections into the laser cavity. Ensure that no optical surface is normal to the propagating beam. Linear or non-linear amplification systems or parametric frequency conversion devices (for example 'OPOs' or 'OPAs') can cause intense back reflections. These amplified back reflections can cause immediate and irreparable damage to the ECqcL™ and should scrupulously be prevented from reentering the ECqcL™ cavity.

5.1 Power Requirements

MIRcat lasers are rated to operate with 90VAC to 264VAC single-phase AC input power. The input AC frequency must be in the range from 47Hz to 63Hz. Plug the unit into an earth grounded receptacle. Verification of proper grounding is recommended. A power cord with the proper configuration from the wall to the power supply input may be substituted for the supplied cable.

CAUTION: Operate this laser system only within the specified voltage range and with proper grounding. Electrical shock hazard can occur if the equipment is not properly grounded.

5.2 Cooling Requirements for CW or High-Duty-Cycle Pulsed Operation

When operating a MIRcat in CW or high duty cycle (>10%) pulsed mode, water cooling of the laser head is required to remove the higher heat load produced by these modes. A water chiller with a cooling capacity of up to 150W should be used. Suitable compact, closed-loop chillers are available from Daylight Solutions – please inquire. The chiller should be connected to the MIRcat laser head via cooling lines (clear vinyl tubing with 3/8" OD and ¼" ID) connected to the two quick-disconnect coolant ports located at the rear of the MIRcat laser head. MIRcat-QT uses 2 male quick-disconnect plugs with 7/16" OD, such as McMaster-Carr part# 51545K69. MIRcat 1xxx uses 5/16" OD plugs, such as McMaster-Carr part# 51545K68. Refer to chiller manufacturer manual for coolant specification. Normally, only distilled water should be required as the coolant for short period of time. The chiller should be set to keep the temperature of the MIRcat laser housing at either 20°C, or the temperature stated in the final test report that shipped with your MIRcat.

5.3 Cooling Lines – Preventive Maintenance

Periodically, and after moving the laser system, inspect the system for contamination and verify that cooling ports are clear and all cable connections are visibly secure. If liquid cooling is employed, verify the cooling connections are secure. For cleaning and decontamination of the laser system, use only mild detergent and moist paper towel. Do not submerse in water or cleaning solvent.

5.4 Laser Safety Preventive Maintenance – Maintaining Regulatory Compliance.

It is recommended that all laser safety features and safety interlocks included in your system are tested and their proper function verified every 6 months to ensure they are still operating correctly. If any safety feature or interlock fails to perform as described in Section VI of this manual, stop use of the laser system immediately, prevent others from using it (by removing the key, for example), and contact Daylight Solutions or your authorized representative for further instructions.

II. SYSTEM OVERVIEW

Figure 1. MIRcat system architecture.

NOTE: This manual describes the safe installation, use, and maintenance of Daylight Solutions' MIRcat™ family of widely tunable mid-IR laser systems. This product family includes MIRcat-QT (tuning slew rates to >5,000 cm^{-1}/s) and MIRcat-1xxx (slew rates up to 100 cm^{-1}/s) systems. All information in this manual applies interchangeably to MIRcat-QT and MIRcat-1xxx product models unless stated otherwise.

As shown in Figure 4, MIRcat™ laser systems comprise the following major system components:

- Sealed, maintenance-free MIRcat™ laser head with integrated controller
- AC-DC power supply
- Computer running control software
- Optional water chiller for CW and/or high duty cycle operation

The key features and main components of the MIRcat™ system are explained in more detail below.

2. System Features

MIRcat's modular design provides users with great flexibility to select a MIRcat configuration optimized for their applications. The modular design allows users to factory-configure their system for one, two, three or four pulsed or CW/pulsed modules, add a visible aiming beam*, or factory-upgrade their configuration (type and number of modules) later. The laser modules in each MIRcat can be addressed and operated individually, or multiplexed together (automatically, via the included control software) to create a collectively ultra-wide tuning range. Each MIRcat laser module incorporates a mid-IR Quantum Cascade Laser (QCL) chip as the gain medium. By using advanced packaging and miniaturization technology, Daylight is able to provide room-temperature operation of all its QCLs, and a wide selection of QCL chip

options with center wavelength spanning ~3 to >13 µm. (We continue to expand the performance envelope of our QCLs – please inquire.)

Each QCL is built into a proprietary External Cavity QCL (ECqcL™) optical configuration, in which one end of the laser cavity is formed by the QCL and the other by a diffraction grating that can be rotated. By using an ECqcL design, the emission wavelength and linewidth can be carefully controlled. All MIRcat laser modules can provide tunable mid-IR pulsed output. If a CW-capable QCL has been selected for a laser module, that module will also be capable of Continuous Wave (CW) operation (water cooling is required). Unlike many other laser source types, changing between pulsed and CW operation in Daylight's QCL-based lasers is effortless and instantaneous, and requires only a simple change of operating mode (change in drive current profile) via the GUI or SDK. Compared to pulsed operation, CW operation provides narrower linewidth, higher average power, and fine amplitude and wavelength modulation via MIRcat's standard external current modulation input.

NOTE: The linewidth of a pulsed MIRcat laser module is typically about 0.5 cm^{-1} (FWHM). In CW operation, linewidths can be as low as <0.01 cm^{-1} (less than a few 100MHz) if MIRcat is tuned to a single longitudinal mode.

Typical tuning curves (output power versus wavelength) are shown below for a Daylight Solutions' pulsed (Figure 5) and CW (Figure 6) ECqcL™. The plots show the high peak (Figure 5) and average (Figure 6) power and wide tuning ranges attainable with the ECqcL design. Figure 7 also shows the extremely broad—and gapless—tuning across the important mid-IR 'spectral fingerprint' range that can be achieved with a MIRcat configured with four pulsed QCL's selected for maximum wavelength coverage.

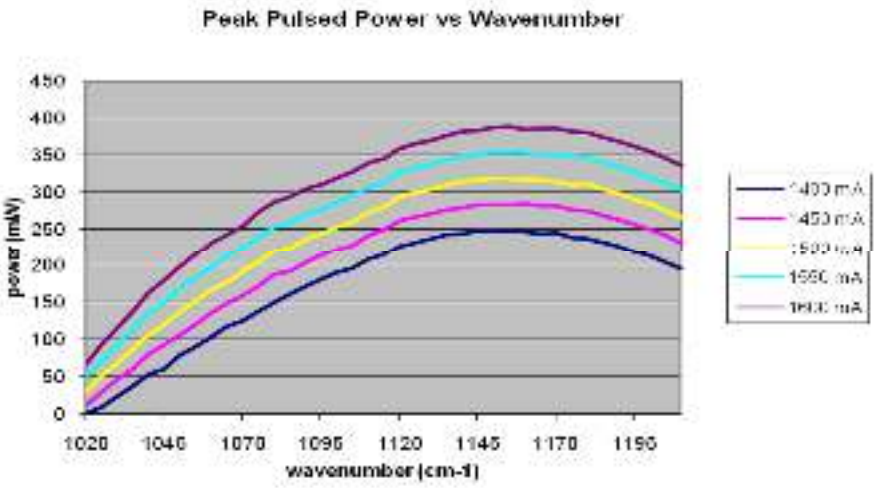


Figure 5. Typical peak power versus wavelength curves for pulsed operation of a Daylight external cavity quantum cascade laser (ECqcL™) at different QCL drive currents. Data recorded at: 500 ns pulse width and 5 % duty cycle at 15°C.

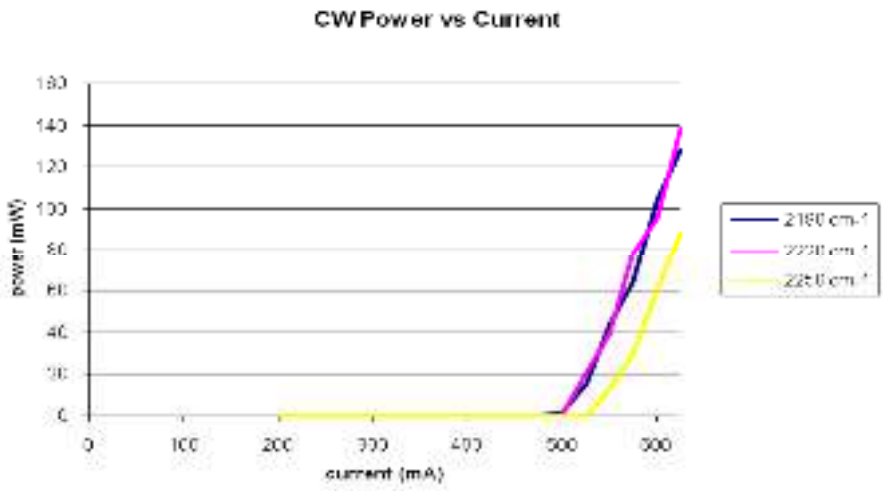


Figure 6. Typical CW (average) power output versus QCL drive current recorded at three different wavelengths for CW operation of a Daylight external cavity quantum cascade laser (ECqcL).

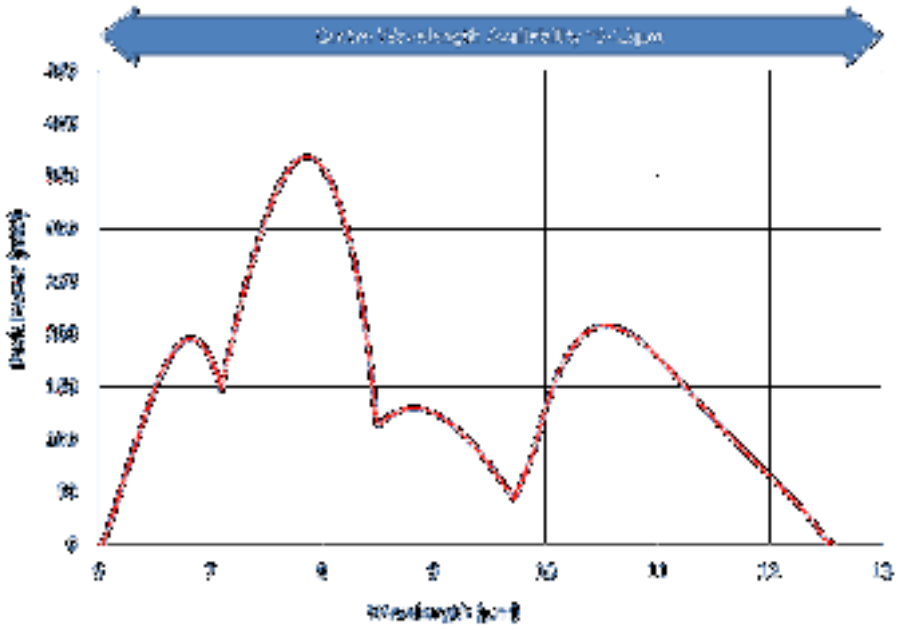


Figure 7. Typical tuning curve for an example MIRcat configuration of four pulsed QCL lasers.

User control of the MIRcat laser system is via a user-supplied computer running a GUI or SDK command set, both of which are included as standard with each MIRcat system. Using these interfaces, MIRcat users can control: wavelength set-points; scans; power; triggering (and pulse width, duty cycle, and repetition rate in pulsed operation). Information stored in an EEPROM in the MIRcat laser head prevents the user from attempting to tune the module beyond the laser's range, or applying incorrect drive currents to the QCLs in

MIRcat laser head. Daylight's proprietary HFQD™ (High-Fidelity QCL Drive) circuitry also ensures MIRcat's QCL chips are protected electronically.

MIRcat provides three different wavelength tuning modes: Sweep Mode, Step and Measure Mode, or Multi-Spectral Mode. These are selectable via either the GUI or SDK. MIRcat's Sweep Scan provides rapid scanning of the QCL across its programmed gain profile, either uni- or bi-directionally. In this mode, users can select scanning parameters such as start/stop wavelengths, step size, tuning rate, number of scans and time between steps (Dwell). MIRcat-1xxx can perform sweep scans at up to 100cm-1/s, while MIRcat-QT systems provide tuning slew rates as high as 5,000 cm^{-1}/s. Multi-Spectral Mode allows jumping to up to 20 different fixed wavelengths across the tuning range. In this mode, the operator can select scanning parameters such as start/stop wavelengths, step size, tuning rate, number of scans and time between steps.

With this wide range of options, MIRcat delivers uncompromised performance in application-critical areas. Depending on laser modules and configuration selected, MIRcat can provide; tuning ranges to >900 cm^{-1}; CW RIN as low as -145dBc/Hz; peak power output up to 1W; average power output up to 0.5W, and wavelength repeatability as high as <0.1cm^{-1}. All MIRcats also provide a single TEM_{00} output beam, regardless of the number of modules selected, which ensures high on-target beam intensities and enables high-efficiency fiber coupling. In addition, the new MIRcat-QT also adds faster wavelength tuning and scanning (to >5000 cm^{-1}/s) and higher spectral repeatability to the field-proven MIRcat-1xxx design.

*MIRcat's optional integrated visible laser aiming beam provides a high-quality, low-divergence visible aiming beam that is bore-sighted accurately to the path of the mid-infrared output. It can be used for straightforward visual pre-alignment of the MIRcat output beam path prior to switching to the mid-infrared output. The visible beam is activated by an 'Enable Aiming Laser' command on the GUI. Activating the visible beam switches the MIRcat from mid-infrared out to the visible beam output, and vice versa. (Simultaneous mid-infrared and visible laser output is not possible.)

3. MIRcat Laser Head - Precautions

The MIRcat laser head is a sealed, alignment-free design that neither requires nor allows internal maintenance. Pulsed and CW operation (with water cooling) is supported by the same laser head. There are no internal adjustments available to the user. **NEVER** attempt to remove the cover or open the optical head in any way, or the warranty will be voided.

CAUTION: UNDER NO CIRCUMSTANCES SHALL THE USER ATTEMPT TO OPEN THE MIRcat LASER HEAD. Opening the MIRcat laser head will void the warranty, resulting in misalignment of the laser cavity, and/or cause irreparable damage to the internal components. The MIRcat laser head is purged with a dry inert gas before sealing to minimize moisture. Breaking this seal will also void the warranty.

CAUTION: The laser radiation emitted from this unit is invisible to the naked eye and may be harmful if the beam makes direct and prolonged contact with the eye. Avoid direct exposure to the beam or looking in the direction of the laser beam directly. The safety labels shown in Section I-2 are attached to this product.

The optical output port of the laser is covered by a manual shutter, should users want to block the laser output beam. The base of the MIRcat laser head has three holes, aligned to match up with standard hole

patterns found on metric of English optical benches. If the MIRcat laser head is mounted directly onto an optical table or breadboard, the height of the beam is 4.0 inches (10.61cm).

CAUTION: Back reflections can cause damage to the quantum cascade gain media and could void your warranty. Care must be taken to minimize all back reflections into the laser cavity. Ensure that no optical surface is normal to the propagating beam. Linear or non-linear amplification systems or parametric frequency conversion devices can cause intense back reflections. These amplified back reflections can cause immediate and irreparable damage to the ECqcL™ and should scrupulously be prevented from reentering the ECqcL™ cavity.

4. Computer Control

Figure 8. Back panel for computer control

The MIRcat control GUI offers a simple interface that allows manual tuning of the laser, as well as manual control over laser drive current (laser output power), temperature, pulsed parameters, scanning modes, and communications ports.

Computer control of the laser is available through the USB 2.0 (or Ethernet - not yet supported but please inquire). This allows the user to automatically synchronize tuning of the laser's wavelength to a detection scheme for applications that include spectroscopy, as well as adjusting the current, pulse parameters, tuning, and temperature of the MIRcat. The back panel of the MIRcat also provides TTL signals to help synchronize the MIRcat to a data acquisition unit. See Section IV-2 for signals and timing diagrams.

The Control Panel GUI is necessary to operate the MIRcat laser. A Software Development Kit (SDK) is available and has examples for LabView VI's with example scripts. A 64-bit version is also available upon request.

See Section IV. Manual Operation for further details on back panel functionality.

5. Power Supply

Figure 9. MIRcat Power Supply (AC-DC converter)

The power supply connects to the back panel of the MIRcat laser head. It converts the local AC power to the DC voltage and current required for safe operation of MIRcat. It accepts AC input voltages in the range 90-264 VAC, and 47-63 Hz. Ensure the cable is firmly seated and secured on the back panel before turning on the unit. The power cord can be changed to match local receptacles.

CAUTION: Never unplug the Power Supply connector while the laser is operating and the computer is communicating to the system. Damage to the laser can occur if power is removed during operation or tuning.

III. GETTING STARTED

This section outlines the basic procedures for installing your MIRcat. See Section V - Computer Control for details on computer control of the MIRcat and its associated instruction list.

CAUTION: The laser system was shipped in a custom shipping container. This container was custom-designed and tested to ensure protection of the MIRcat during transportation. **Save this container in a safe place.** Should your laser require repair or upgrade, you will need to ship the unit back to the factory in this same container. Failure to do so could void your warranty. If you need to return the laser to Daylight Solutions but can no longer locate the original shipping container, please contact Daylight Solutions' Customer Service using contact information listed in Section VI 'Service and Support' or visit the web site.

1. Packing List

Each MIRcat ships with the following components:

Power Supply	Laser system power supply (AC-DC converter)
MIRcat laser head	MIRcat laser head
Power cable	Power cable for 110VAC, 60 Hz
Laser enable key	Enable/disable laser power (key interlock)
Hose connectors (Qty 2)	For water chiller connection (required for CW or high duty cycle operation)
User Manual (on CD or USB memory stick)	Contains: introduction and copies of user manual, GUI, and SDK

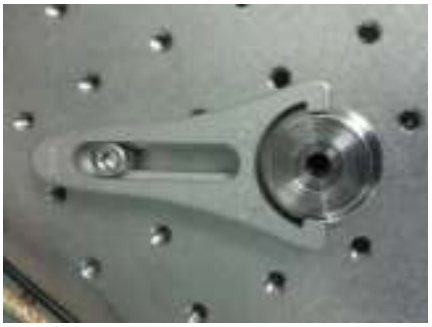
To mount the MIRcat on an optical bench, you will need (not included):

Optical bench or table	Metal optical bench to mount MIRcat laser head assembly.
3 hex head bolts, 2" (50mm) length	(¼-20 for English, or M6 for Metric). Used for mounting MIRcat laser head to optical bench.
Hex (Allen) Key	(3/16 for English, or M5 for Metric) Used for mounting MIRcat laser head to optical bench.
3 Mount pedestals (optional)	3 pedestal adaptors to raise beam height to desired height Example: For a 4.5" beam height, use 0.5 inch (M6) New Focus pedestals, #9910, with ¼-20 counterbore.
3 Pedestal clamping forks (optional)	Used to clamp down the 3 pedestals above. Example: New Focus 9909 (1 inch).
Tubing for connecting liquid cooling	Clear vinyl tubing with 3/8" OD, and ¼" ID, (CW or high duty cycle operation).

2. Setting Up

1

If the desired beam height is greater than the 4.0 in. beam height specified for your laser, attach 3 pedestals to the base of the MIRcat laser head with the additional beam height. For example, if the desired beam height is 4.5 inches and the laser beam height is 4.0 inches, use New Focus 3" pedestals, model# 9910 and optical holding forks #9909 for a final beam height of 4.5 inches.



2

Mount MIRcat laser head on an optical bench using three (3) screws and/or 3 holding forks listed above (or similar device). Beam height is fixed at 4.0 inches if not using any pedestals. See Section VII-Specifications for more details on beam height for MIRcat laser heads.

3

Connect USB cable to MIRcat laser head and Computer:

- Connect the USB cable to a computer USB port
- Connect USB connector to the MIRcat laser head

CAUTION: Use caution when connecting the USB cable if the unit is plugged in and running. Never unplug the USB cable during laser operation.

4

For CW Operation:

Connect liquid cooling to the inlet and outlet ports on the base of the MIRcat laser head. Use the 7/16" plug with 1/4" hose barbs provided to attach clear vinyl tubing, with 3/8" OD and 1/4" ID, to the cooling port quick disconnects, and the other ends to a chiller. Set the chiller temperature to 20°C for normal CW operation.

NOTE: To ensure proper cooling and longer lifetime for the QCL, CW operation requires water cooling of the MIRcat laser head. Since the thermal load in the MIRcat laser head is small, a minimum of 50W thermal cooling capacity should be sufficient for most laboratory use conditions. Program the chiller to keep the MIRcat baseplate at 20°C (or the temperature listed on your final test sheet).

5

Plug the MIRcat Power Supply into a standard 3-prong, single-phase, AC outlet that provides AC power within the following range: 90-264VAC, 47 to 63 kHz. A different AC power cord may be required, depending on country of use.

6

With the Rear Panel Enable Key Switch in the vertical "OFF" position, turn the MIRcat laser head on with the rear Power switch by momentarily pressing the black button. The white LED on top of the MIRcat will come on. After initial power up, the MIRcat Laser will perform a self-test. The system is ready to use after an audio beep is heard, usually 30-45 sec.

7

Launch the MIRcat Control Panel program on the computer and it will automatically connect. Allow approximately 15 minutes for the MIRcat laser head to reach thermal equilibrium before taking any precision measurements.

8

Turn on the laser light:

a. When a safe path for the beam has been prepared, open the manual shutter on the output of the MIRcat laser head.

b. Make sure the proper Safety Interlock is connected on the back panel of the MIRcat laser head for your lab configuration in order to safely turn on the laser. (Note: the laser is shipped with a BNC shorting plug).

c. Turn the rear panel Laser Enable key to the horizontal "ON" position. Click the Arm Laser button on the Tuning tab on the GUI. After a 5 sec delay, the white light on top of the MIRcat Laser unit will illuminate to indicate the laser is armed.

d. On the Tuning menu, click on the "tune to wavelength" button and click the **TURN EMISSION ON** button. The button label will change to **Turn Emission Off** and an optional audible chirp will sound to indicate the laser is emitting light.

e. The laser beam is now propagating parallel to the optical table.

9	**For CW-Pulsed Operation:** See Section IV-9 on Current Modulation.

IV. OPERATION

CAUTION: Use of controls or adjustments or performance of procedures other than those specified herein may result in hazardous radiation exposure.

This section describes the operation of the MIRcat using the Control Panel GUI (i.e., with external computer control). The laser can be turned on and off via the Laser Power button, and all laser parameters can be adjusted using the menu on the Control Panel program. The menu operation and complete command set are described below under Menu Functions.

The back panel offers access to a safety interlock, TTL inputs and output synchronous with the laser output, and other features described below.

1. Back Panel Interface

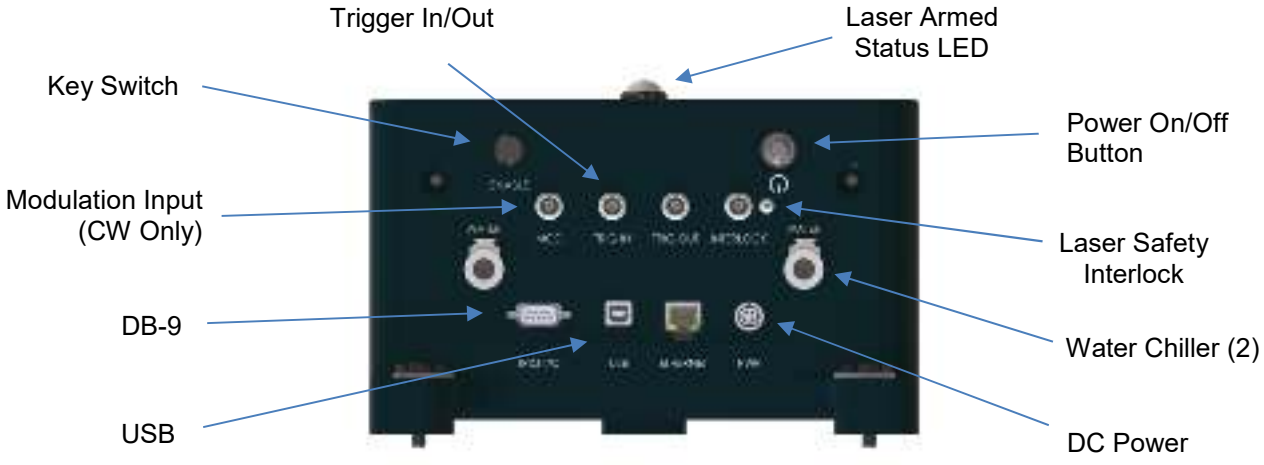


Figure 10. MIRcat Back Panel

Power On/OFF Button and DC Power Cord	ON/OFF switch and power plug connector from block power supply. Accepts either 110VAC, 60Hz or 220VAC, 50Hz.
Interlock (Safety Interlock)	BNC connector: Turns off the laser when connection is opened. Each unit is shipped with a shorting cap for immediate operation. Replace this cap with an interlock from your lab door or other device to provide a safer laser operating environment.
Water Chiller (2)	Used to connect a flow thru water chiller for external cooling. Required

	for CW mode or Pulsed >10% Duty Cycle only.
Ethernet	RJ-45 connector. Not yet supported.
DB-9	Used to connect the MIRcat to an external Data Acquisition System. See next section for pin out and signal description.
	Continued from last page.
USB connector	Used to connect the MIRcat to an external computer. Uses HID interface. See USB communication later in manual.
Key Switch	Used to Enable Laser Arming. Key cannot be removed in Armed (horizontal) position.
Trigger In/Out	BNC connectors: A TTL input/output pulse into 50Ω load is provided for synchronizing external instruments and data acquisition equipment with the rising edge of the laser trigger pulse. See timing diagrams in section 3 on Triggering and Acquisition Signals.
Modulation Input (CW only)	Allows an external signal to be applied to the QC current bias for external modulation. CW only, not yet supported.
Laser Armed Status LED	Laser is Armed when illuminated. Key switch must be horizontal, and Arm laser selected in Control Panel GUI.

2. Triggering and Acquisition Signals on DB-9 Connector

The DB9 connector on the back of the MIRcat has the following TTL signals for timing and control with a Data Acquisition System (DAQ):

Pin ***Signal description***

1 Scan direction:
Active HI output. It is always HI when going from a lower to higher wavelength/wave number, and LO when going in the opposite direction. For example, if scan units are cm^{-1}, going from 1200 to 1400 cm^{-1} will cause the signal to go HI, and LO in the other direction. If scan units are in um, going from 7 to 10 µm will cause the signal to go HI, and LO in the other direction. This signal is dependent on scan units.

2 Tuned: HI when the laser has scanned to a step wavelength
Active HI output. This signal goes HI when the laser is tuned to a correct wavelength and is emitting light. When scanning it will go HI while the laser is emitting light and LO when laser is off.

3 Wavelength trigger: HI when laser has scanned to wavelength
Active HI output. This signal is only used when Wavelength Trigger is selected in the Settings. When in this mode, the laser will emit a single laser pulse using the pulse width specified in the settings at the specified interval. For example, if scanning from 7 to 10 µm, and the WL trigger start and stop are set to 7.5 µm and 9.5 µm, respectively, and the WL trigger interval is every 0.1 µm, this signal will go HI when the scan crosses 7.5 µm, 7.6 µm, 7.7 µm, etc. The duration of the HI pulse on the WL trigger

output is software controlled by the motion board and will vary, but will generally be in the 100 to several hundred-microsecond range. The actual laser pulse and trigger output (BNC) will be HI for the pulse width specified in the settings screen.

Pin ***Signal description (cont.)***

4 Process trigger: HI when the laser has performed a favorite scan or other process

Active LO Input. This signal is used when "Use External Step Mode" is selected in "Process Trigger Modes". In either Step & Measure or Multi-Spectral Mode, the laser will move to the first wavelength and turn on. It will then stay at that wavelength and continue to fire the laser until this signal is pulled LO. The signal should be pulled LO to ground for between 250 and 500 ms, at which point the laser will move to the next wavelength and then start firing.

5 Laser Output On/Off

Active LO Input.

6 Interlock: Ext control of system interlock

Provides status of the interlock signal

7, 9 GND

8 Control Pin, On/Off

TTL signal to turn the laser on and off remotely.

The signals "Tuned", "Scan Direction", and any "Trigger" can be used to synchronize the data acquisition with a Data Acquisition System. The scan mode can be set-up thru the computer controlled GUI commands. The "Tuned" and "Scan Direction" signals are internally supplied output signals. For Sweep Scan mode, once a laser wavelength scan range is set, a rising edge on the "Tuned" signal will signal the laser is scanning across the Start Wavelength, and the falling edge corresponds to scanning across the Stop Wavelength.

For Step Scan mode, the "Scan Direction" signal goes Hi during the time the laser is performing the step scan, from the time the laser stops on the Start Wavelength, until the laser finishes the last step and pause on the Stop Wavelength. The "Tuned" signal will go Hi once the laser has stopped scanning and is ready for a data point to be taken. It should be noted that once a Step Scan is initiated, the laser will tune to the Start Wavelength, set the "Scan Direction" signal Hi and set the "Tuned" Signal Hi. This means that for a scan of one wavenumber, with 0.5 cm-1 steps, the Tuned will go Hi three times. See Laser Scan> Step section for further details.

A rising edge on the "Scan Direction" signal tells the data acquisition system in which direction the laser is scanning. A TTL Hi denotes the laser is scanning up in wavelength/wave number. This signal is operational during the Sweep Scan and the Step Scan function. In pulsed mode, the laser outputs an optical pulse on the rising edge of each "trigger" signal. This corresponds to the set Pulse Width and Pulse Repetition Frequency. Using rear panel commands, optical trigger delays can be implemented to fine tune the data acquisition system.

3. Using the System Interlock

The MIRcat comes with a safety interlock switch, located on the back panel of the Controller. The interlock must be shorted for the laser to generate an output beam. If you remove the "Safety Switch", the output beam will be shut off. The interlock can be coupled to a user-device to turn the laser off, and is provided as a means of allowing the user to implement any desired environmental safety features.

The interlock is triggered by opening the contacts on the interlock loop. FDA regulations require that if electrical contact is broken between the interlock connections, the laser must turn off.

4. Using the Optional Visible Aiming Beam

If your MIRcat system was purchased with the visible aiming beam option, this beam may be toggled on and off via the 'Enable Red Laser'/'disable Red Laser' command on the supplied software GUI, as shown below in Figure . Activating the visible beam switches the MIRcat from mid-infrared out to the visible beam output, and vice versa. (Please note: simultaneous mid-infrared and visible laser output is therefore not possible.)

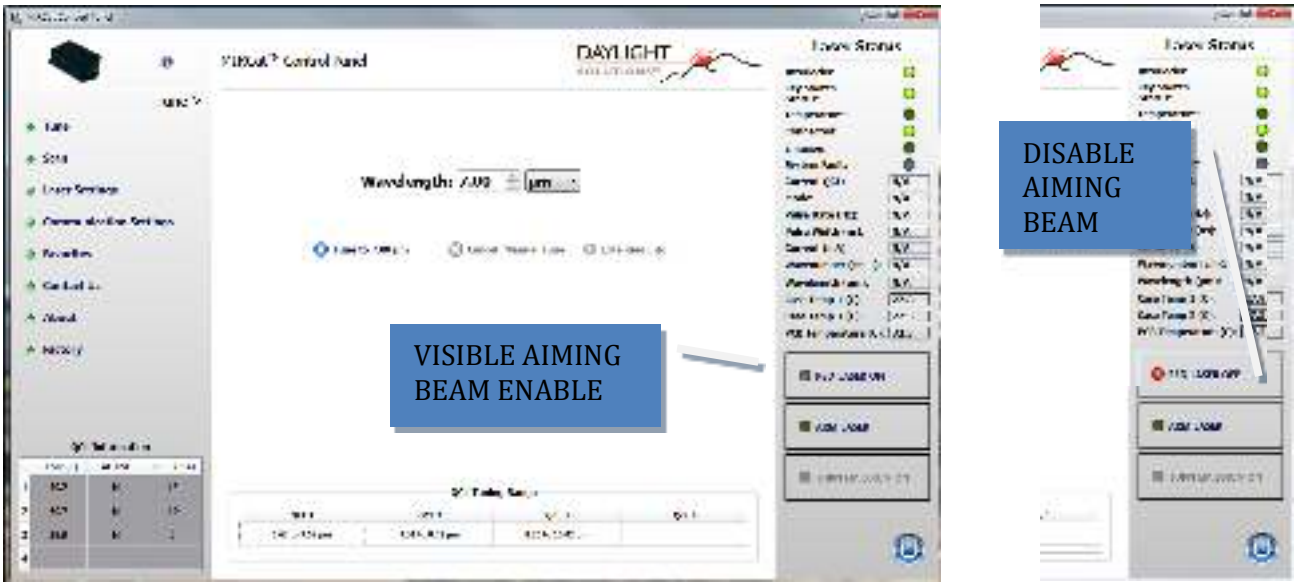


Figure 11 GUI screenshots showing how to activate/deactivate the visible aiming laser by toggling the 'Enable/Disable' GUI command.

5. Power the System On/Off

Power the system on:

Before turning the MIRcat on, make sure that the power supply is plugged into an AC outlet, and that the USB cable is properly connected to the PC and the MIRcat laser head (see Section III - Getting Started for details).

Turn the MIRcat Laser on via the Push button power switch on the back panel.

This will trigger a startup sequence as follows:

1. Booting application
2. Reading laser data from module EEPROMs (e.g., laser serial number)
3. Power on self-test

After 15 seconds, run the Control Panel GUI to connect to the MIRcat Laser. Note that the laser light itself is not yet turned on, as this requires an explicit command from the Control Panel GUI or an external system.

Power the system off:

Turning the MIRcat Laser main power OFF is accomplished via the On/Off switch on the lower right corner of the Control Panel GUI and then the Power push button on the back panel. Pressing and holding the Power button will also cycle the laser off.

NOTE: On power down, the system will save the last programmed values in the EEPROM. The next time the system is powered up, these values will be automatically loaded into the MIRcat Laser, bringing the system on-line with the last values used.

6. Turn the Laser Output On/Off

Prior to making precision measurements with the laser on, it is recommended that the user allow the MIRcat laser head to reach temperature stabilization. This will minimize any potential drifting of the wavelength once it has been set. Temperature stabilization usually occurs within 15 minutes of initial "Armed" and will enable the laser's output beam to be fully wavelength and power stabilized.

CAUTION: As described in Section I-5.2, CW operation of MIRcat requires water cooling. Setting the chiller to a temperature lower than the recommended MIRcat set point (see the final test sheet shipped with your system) may cause a self-test failure in the Control Panel on power up. If you get an error upon power up, allow the laser to come to room temperature and check the chiller set point before powering up the MIRcat laser again.

To comply with FDA rules for Class IIIB lasers (and Class IV lasers, if applicable), a delay is required between a request for laser arming, and any actual lasing. The user will therefore encounter a five second delay after clicking on the ARM LASER button on the Control Panel GUI before the laser is in the "Armed" mode.

Turning the laser on:

Before turning the laser on, the PC must already be connected to the MIRcat Laser via the USB cable. It is also recommended that the MIRcat Laser be turned on and allowed to reach temperature stabilization prior to any critical measurements.

- Make sure Safety Interlock is connected on the back panel of the MIRcat.
- Turn MIRcat Laser on by pressing the POWER ON button on the back panel.
- Wait 30-45 seconds for the audio beep and start the Control Panel GUI.

- Once the laser is connected, turn the Enable key on the back panel to the horizontal or "On" position.
- On the Control Panel GUI, in the Tuning menu, press the grey "Arm Laser" button to switch from "Standby" mode to "Armed" mode.
- When a safe path for the beam has been prepared, open the shutter on the MIRcat laser head.
- Click on the "Tune to wavelength" button. When the TURN ON emissions button becomes active click on it to emit laser light.
- The MIRcat Laser gives the user an audio beep feedback that the laser light is on.

Turning the laser off:

On the Control Panel GUI, click the On/Off button in the lower right corner of all Tabs to switch the laser off. A screen will appear to confirm shut-down. The laser GUI will close and the MIRcat will safely power down.

NOTE: The laser can also be turned off via the safety interlock on the back panel, the Laser Power Key on the back panel, or by pressing and holding the main power switch on the back panel of the MIRcat.

7. GUI Menu Functions

This Section describes how to perform all MIRcat functions using the MIRcat Control Panel GUI.

The following diagram outlines currently available Control Panel GUI menu options:

Main Menus	
Tune	Wavelength or wavenumber
	Tune to XX.XX µm/cm^-1
	Cancel Tune
Scan	Scan Modes
	Sweep Mode
	Step and Measure Mode
	Multi-Spectral Mode
Laser Settings	Display Units
	Notifications
	Global Options
	Laser Parameters
	Process Trigger Modes
	Pulse Modes
	Save Settings
Favorites	Recall Favorites
	Create Favorites
	Erase Favorites
	Save to Selected Favorites
Contact Us	Address
About	General Information
	QCL Information
	Update Firmware
	Import or Export Configuration

Menu Template

The standard menu template allows the user to monitor the MIRcat from each of the six main menus. The left side bar allows the user to navigate between menus and monitor each QCL module temperature and active status. On the right side, there is a Laser Status section that quickly allows the used to see green lights for all major interlocks required for the laser to emit light, as well as the value of the selected QCL module, wavelength and wavenumber, etc. The user can also Arm the laser, and enable laser light emission from the right side. The bottom bar lists the four QCL module tuning ranges as a quick reference for the user. Clicking on a QCL Header makes that the preferred QCL for tuning. The entire tuning range will be used for that Preferred QCL during manual or scan modes. See the Next Section for preferred tuning. Please note: if your MIRcat system was purchased with the visible aiming beam option, an 'Enable Red Laser'/'Disable Red Laser' command will be present on the GUI sidebar (as shown in Figure 11).

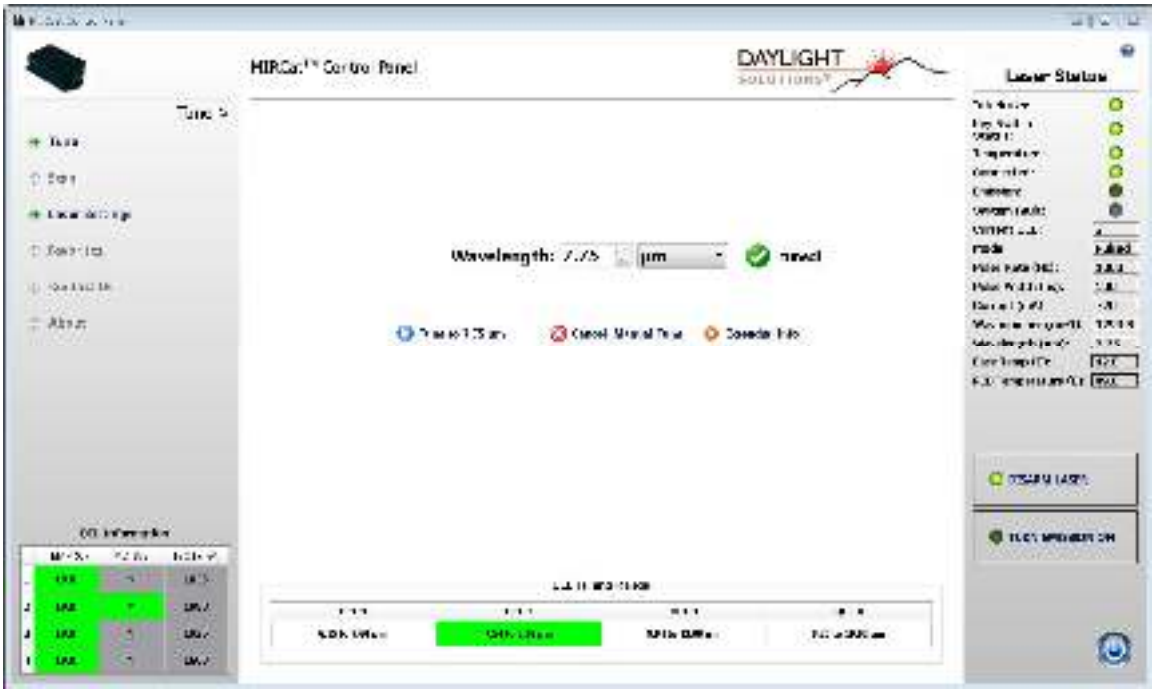
Tune Menu

The first menu is used to manually tune the laser modules to a desired wavelength or wavenumber. You can see which laser module is ready and monitor the require parameters for normal operation.

The user can choose units of either micrometers(µm) or wavenumbers(cm^{-1}) in the pulldown menu on the left. Note how the QCL Tuning Ranges at the bottom will change units too.

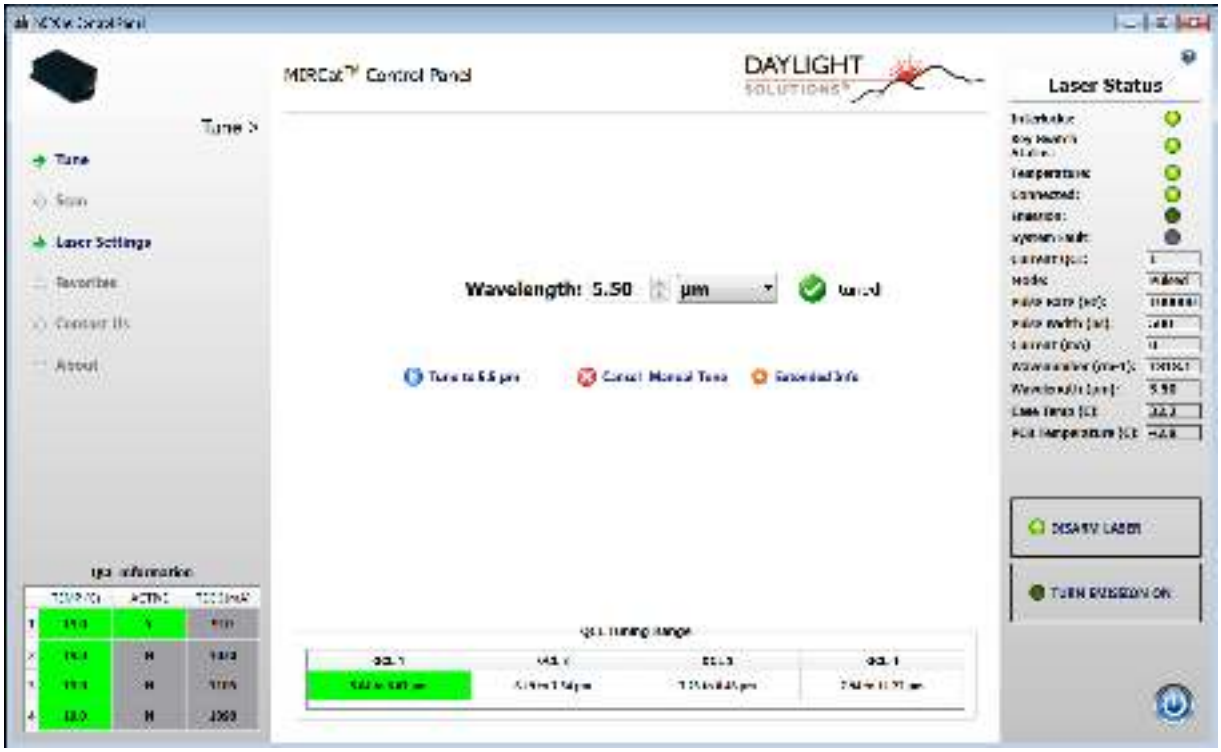
The user can now manually tune to a different wavelength:

For example, to tune the laser to 7.75µm on QCL 2, select µm in the pulldown menu, then type in 7.75, then click the "Tune to 7.75µm" bottom. Once the laser has tuned to that wavelength, the menu will indicate a green tuned arrow and a check mark.

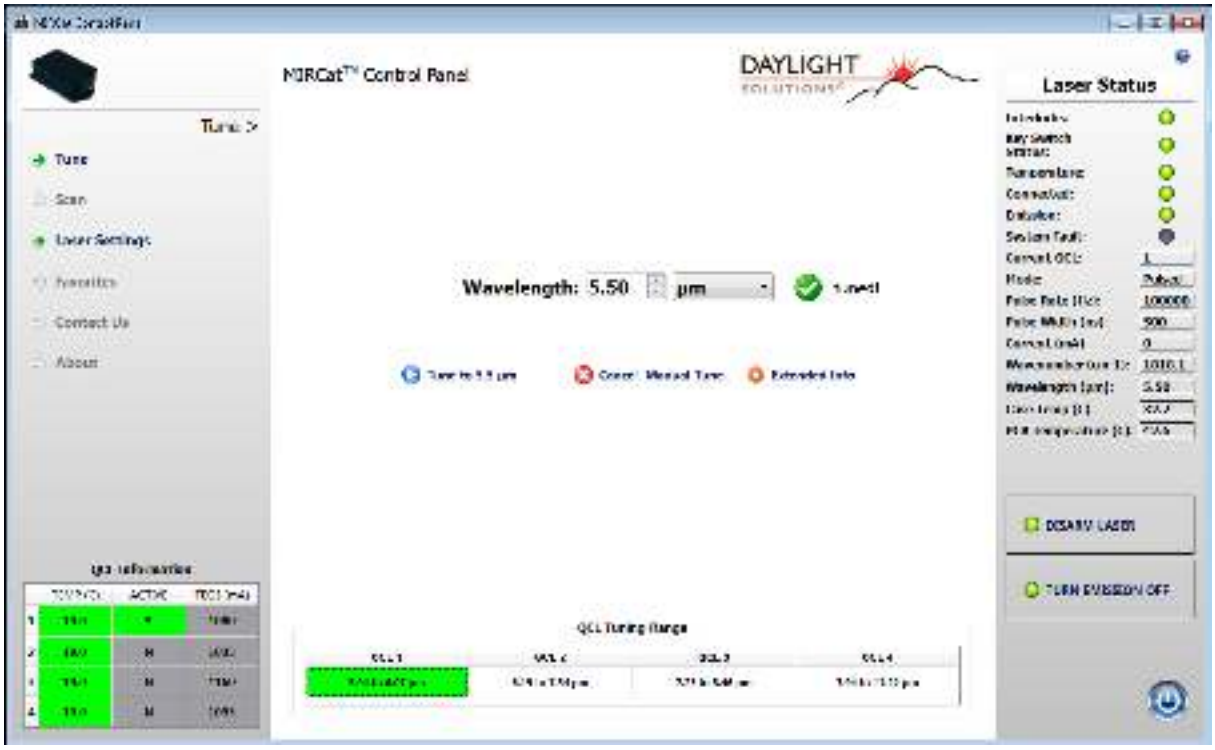


NOTE: Manual Tune can be cancelled at any time. Other menus will gray out when inactive.

Click on the Arm Laser button, and the laser beeps for a 5 second delay, before Arming the Laser, and turning the Laser Armed LED on top of MIRcat ON, to indicate the laser is armed and ready for light emission. Note the Button function has changed to **DISARM LASER**.



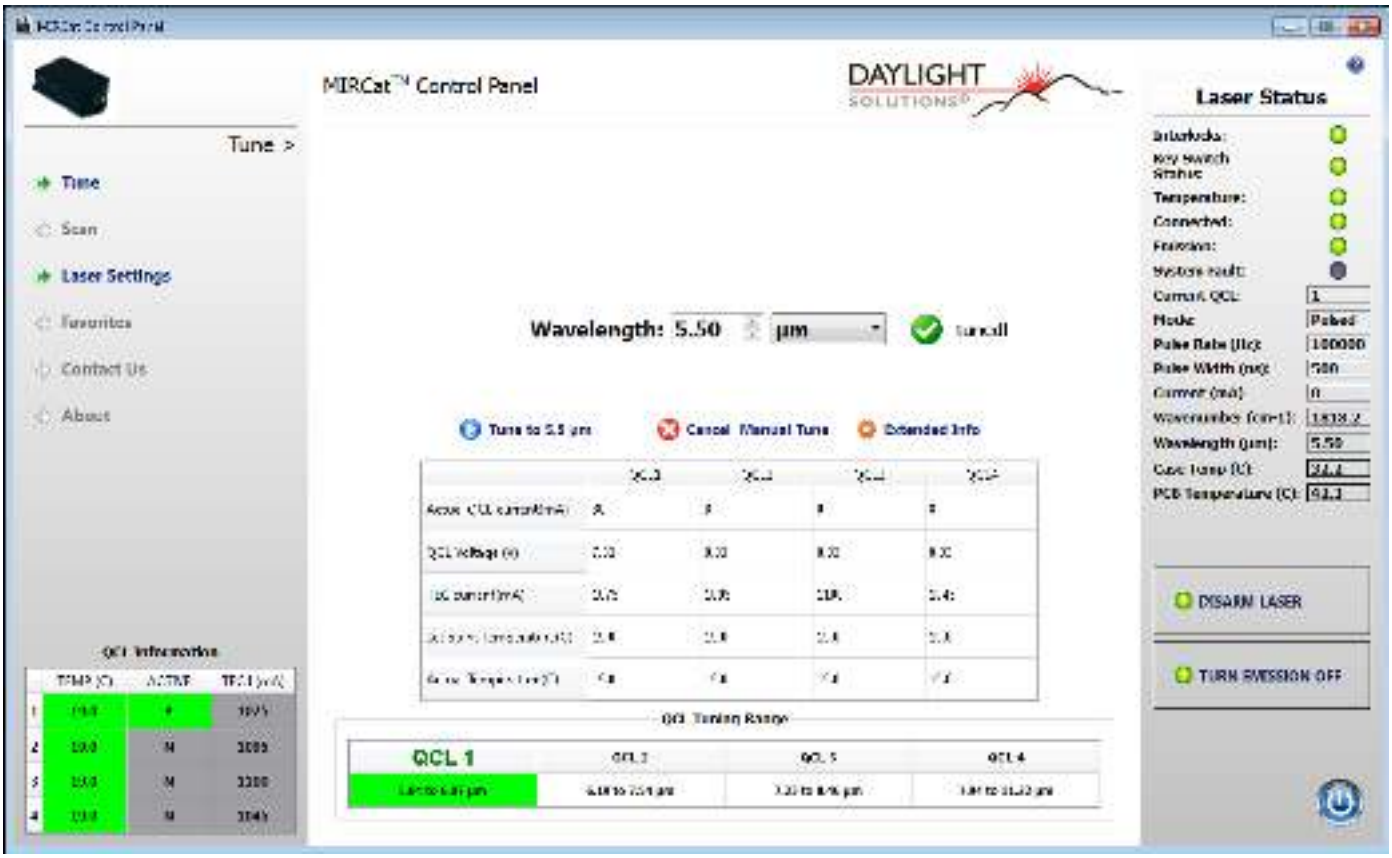
Once the laser has completed tuning to the entered wavelength, the **TURN EMISSION ON** button becomes active and the user can choose laser light out. The button changes to **TURN EMISSIONS OFF**.



To return to the menu options, click on **Cancel Manual Tune** to exit Tune menu and select another menu.

Preferred Tuning

If the user would like to remain on a QCL during manual tuning, they can click on the header above the QCL number in the QCL Tuning Range Table to select that QCL as '*Preferred*". Below, *QCL 1* is selected as the Preferred QCL. The cross-over points for tuning are now ignored and the preferred QCL and tuning will stay on the Preferred QCL as long as the requested tuning range is within the listed QCL tuning range.



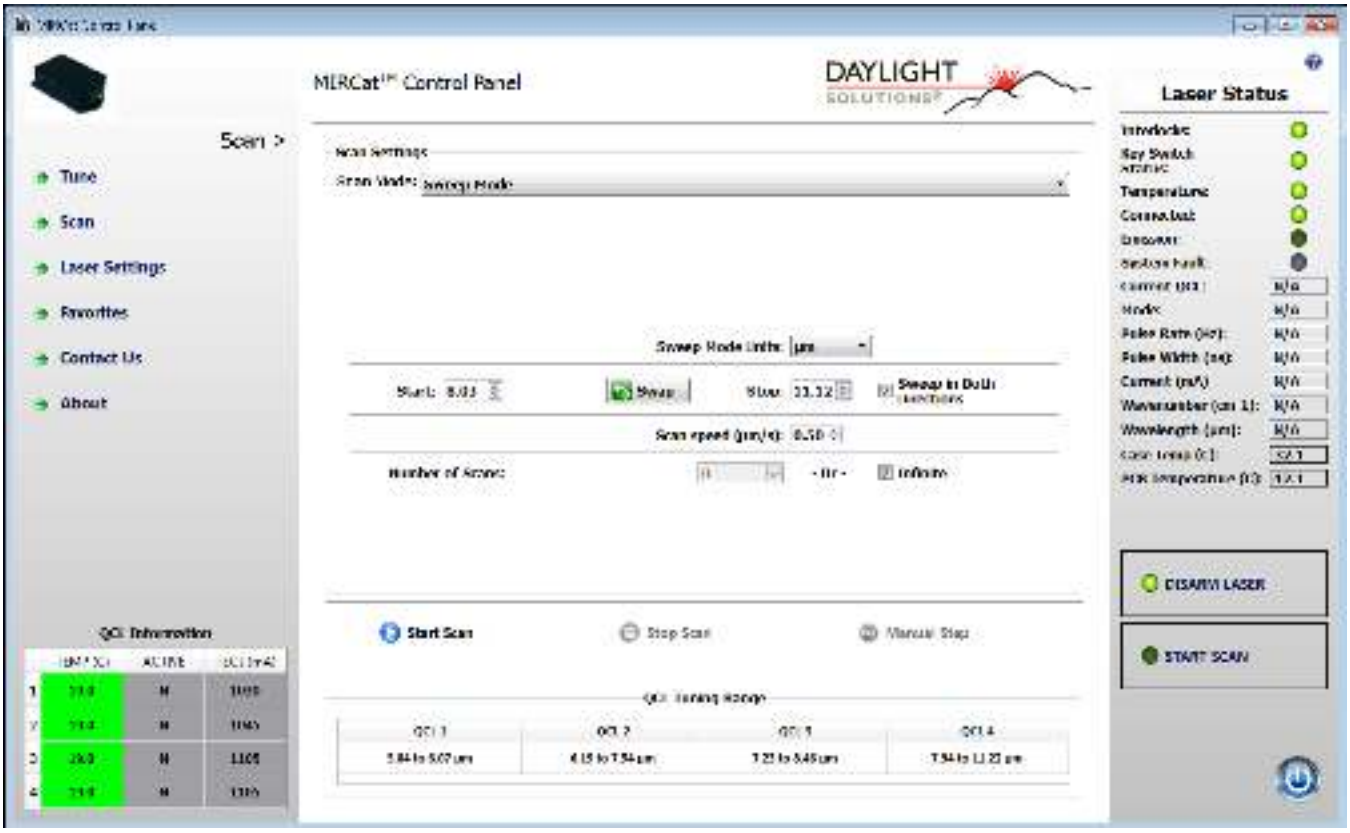
Extended Information is also available by clicking on the **Extended Info** button. This will display information about each of the QCL channels. It will display the actual QCL current, QCL Voltage, TEC current, QCL set temperature and actual temperature. To change any settable values, click **Cancel Manual Tune**, and go to the Laser Settings menu to make changes.

Scan Menu

Scan Settings:

The Scan Mode menu allows the user to choose from several different scan modes. The 3 main types are: Sweep Mode, Step and Measure Mode, and Multi-Spectral Mode. The user can also select Sweep Mode Units, Start/Stop values, Bi-directional Scan, Swap Start/Stop values, set the Number of Scans or an infinite number of scans. Once these values are entered, the user can Arm the laser and click either of the Start Scan buttons to enable laser emissions from MIRcat and start the scan. Clicking either button will stop the scan and stop emissions.

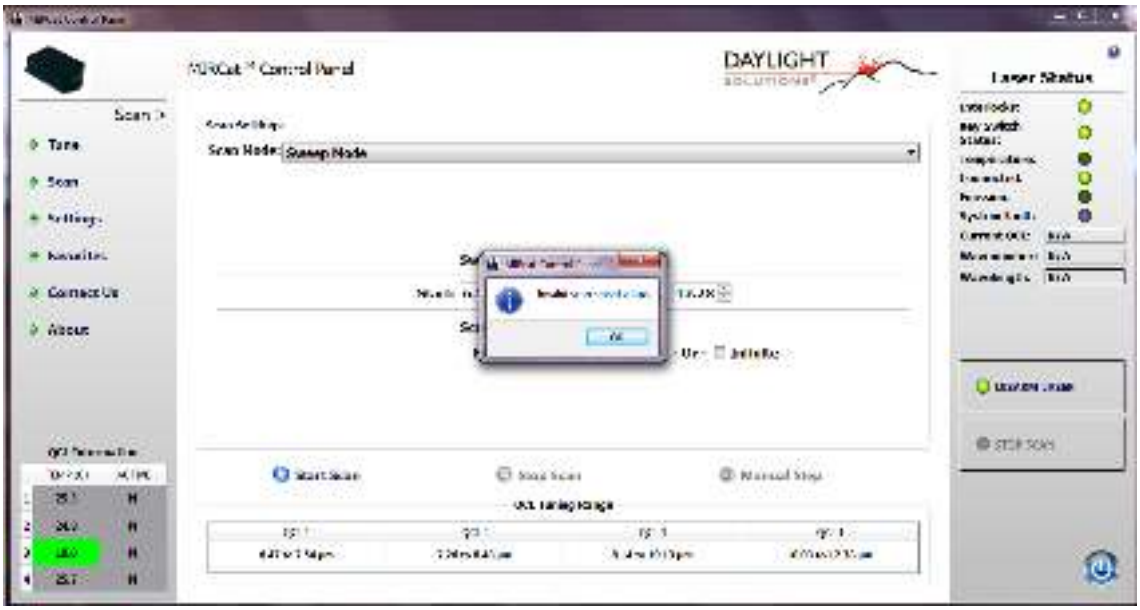
The Sweep mode offers the option of adding Wavelength Triggers during the scan to calibrate where the laser is tuned to during the scan. This mode emits an electrical pulse on Pin3 of the DB-9 connector on each interval as the laser tunes across the set range, using the Start/Stop Wavelength Trigger parameters specified in the Laser Settings at the specified wavelength interval. For example, if scanning from 7 to 10 µm, and the WL trigger start and stop values are set to 7.5 µm and 9.5 µm, respectively, and the WL trigger interval is every 0.1 µm, an electrical pulse will be emitted when the laser scans crosses 7.5 µm, 7.6 µm, 7.7 µm, etc.



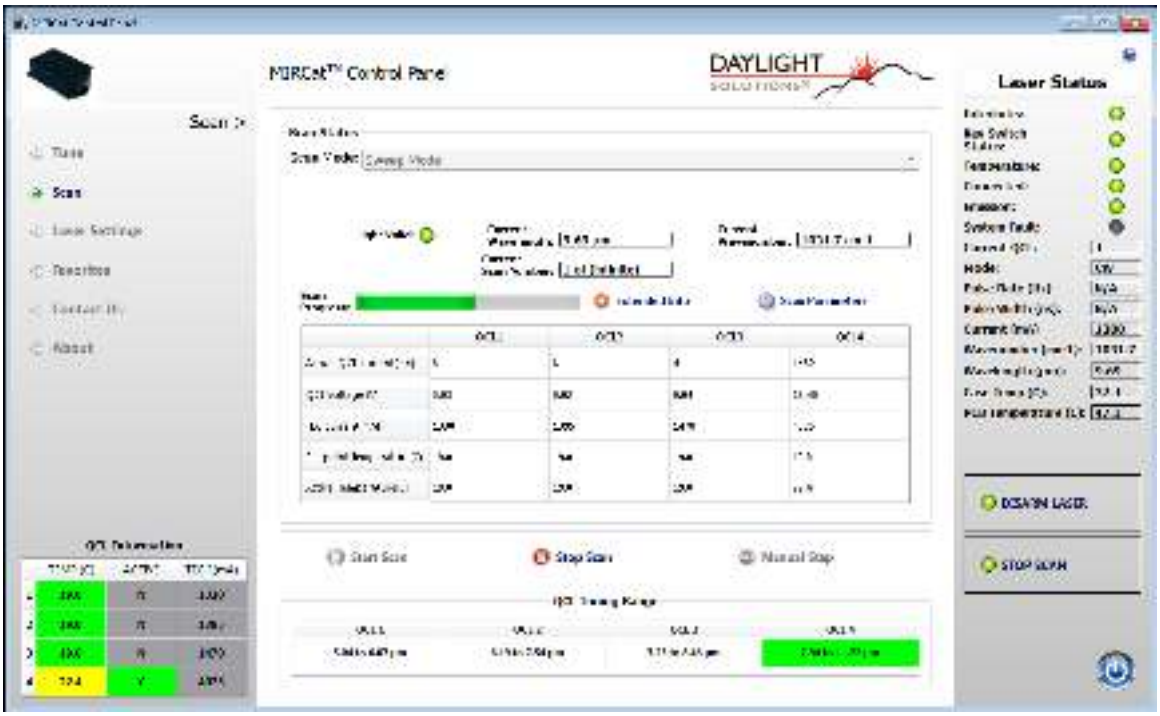
Sweep Mode:

Once the Sweep mode is selected from the Scan Mode pull down menu, the user can select between units, enter a Start and Stop wavelength or wavenumber, enter a scan speed, and choose the number of scans, or infinite scans. The user can also swap Start/Stop wavelengths using the Swap button and choose to scan in both directions.

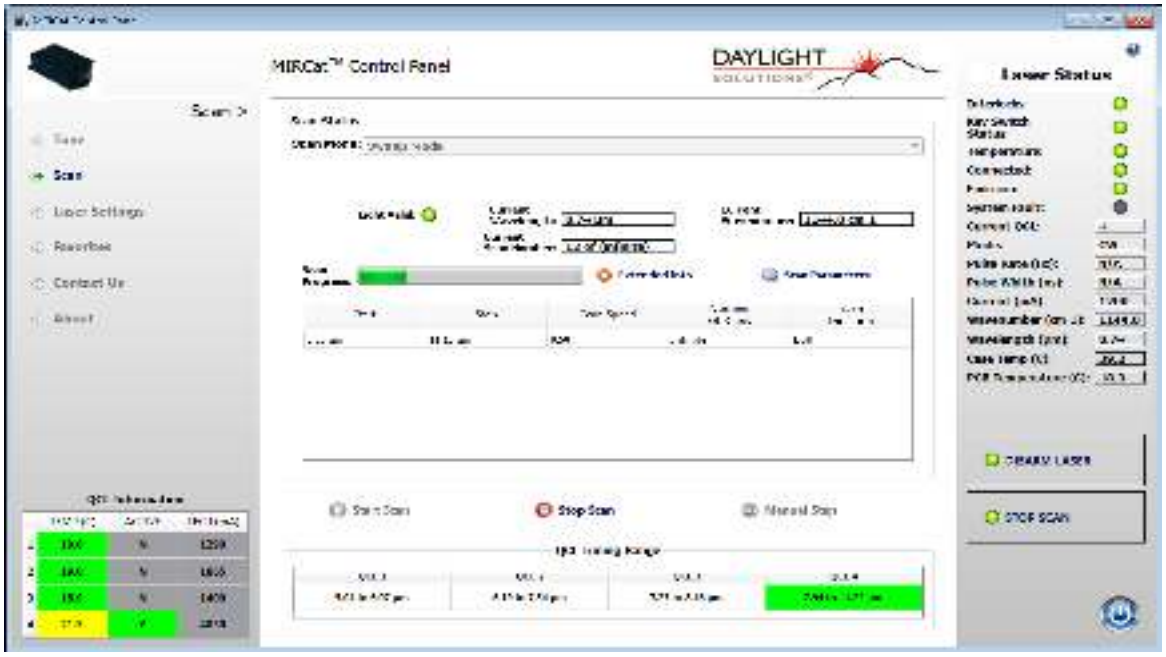
If the user selects Start scan before all parameters have been selected, then than an error message is displayed. Close the box, and enter the complete scan parameters.



Once the Start Scan button is depressed, the screen will change and update the user on the scan's progress. The Laser Valid light will come on while each module is on while scanning.

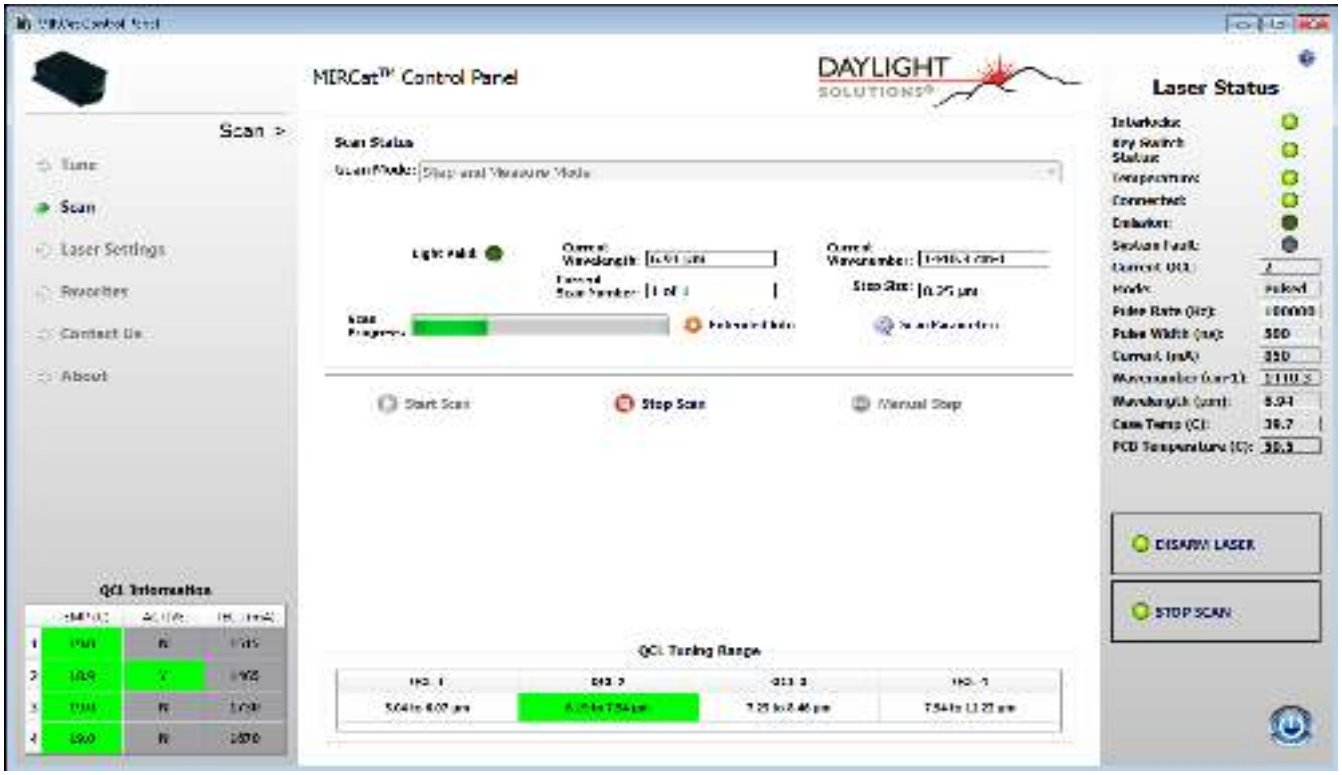


The above screen shot is an example of clicking the Extended Info button during a sweep mode. The below screen shot displays the Scan Parameter info. NOTE: The user can terminate a scan by depressing either of the two STOP SCAN buttons.

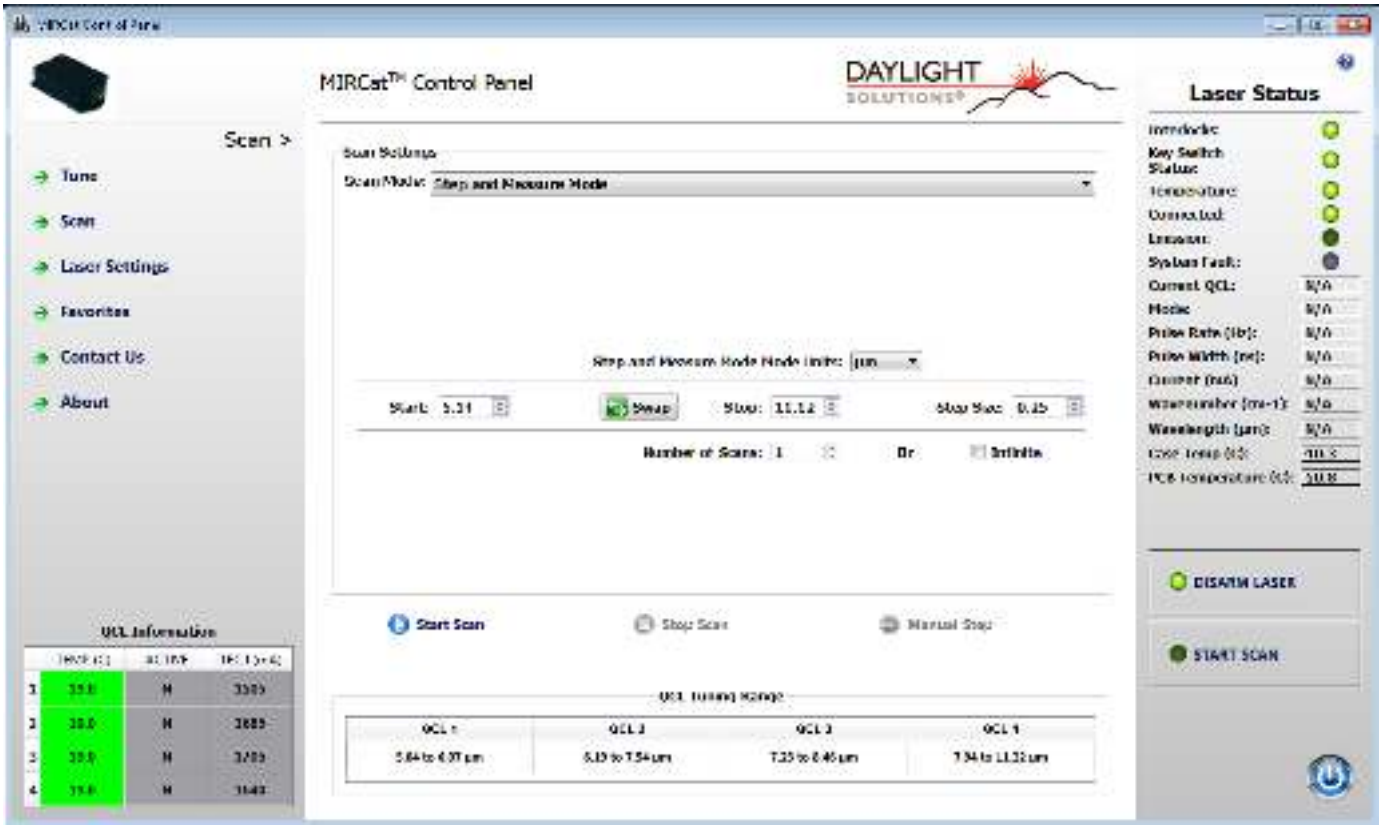


Step and Measure Mode

The Step and Measure Mode allows the user to enter a Start, Stop wavelength/wavenumber, Step size in the selected units, enter number of scans or select infinite. The laser will tune to the Start wavelength or wavenumber, turn ON for the preset Internal Trigger Step Time, then turn OFF for the preset Internal Trigger Step Delay Time, and then scan to the next step. Once the Start Scan button is depressed, the menu changes and allows the user to monitor progress of the programmed scan. The Internal Trigger Time parameters are set in the Laser Settings menu.

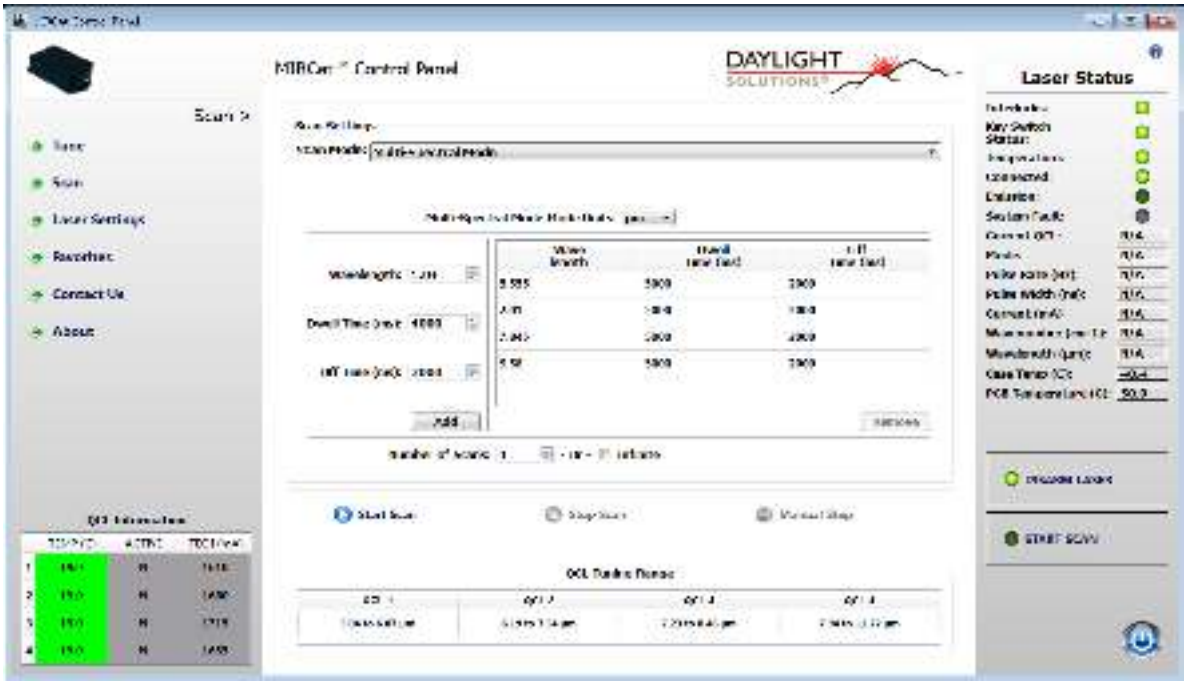


When the laser has completed the scan, it will return to the Step and Measure Screen.

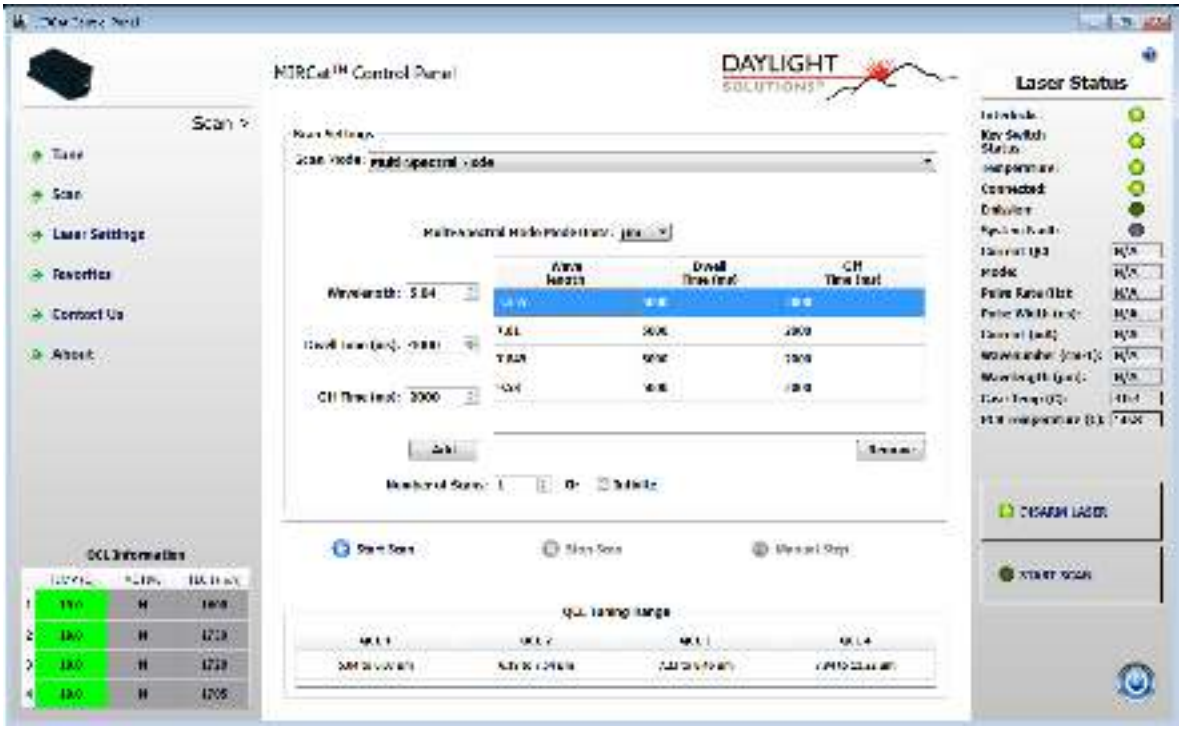


Multi-spectral Mode

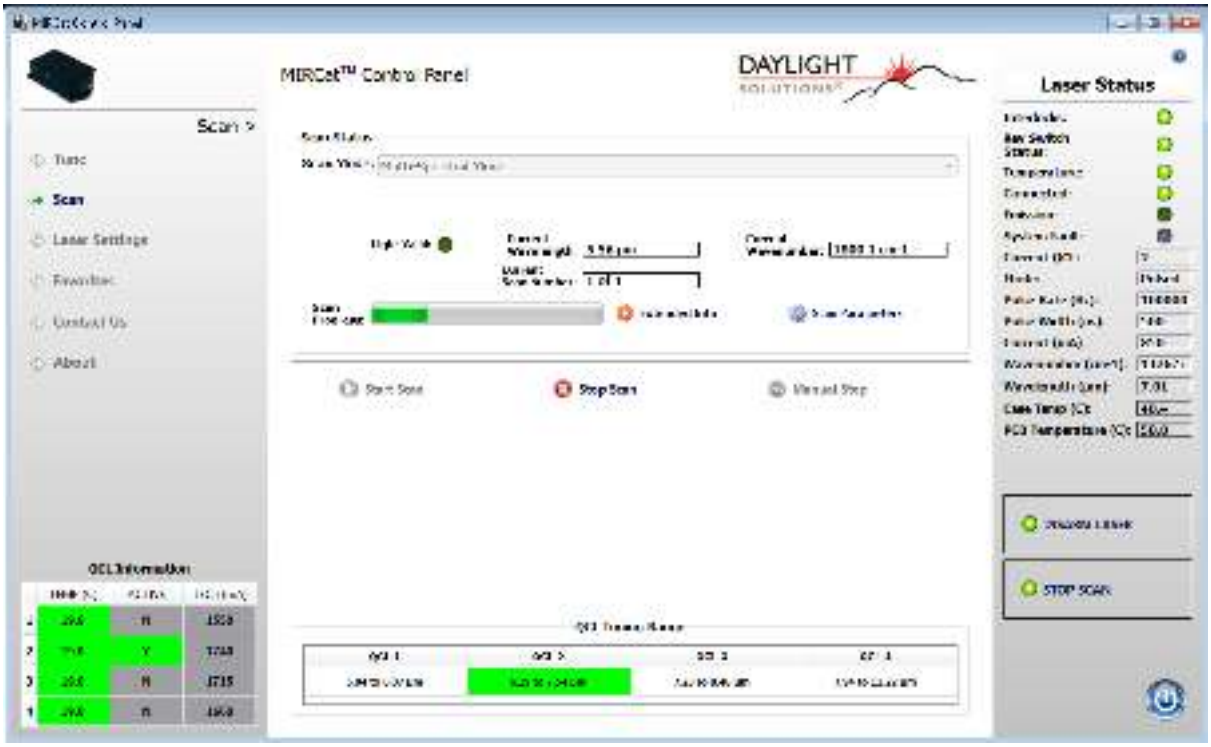
This mode allows the user to enter data on what wavelength or wavenumber the laser is going to scan to, dwell with laser ON, then move to the next command. The user can store up to 20 different parameters, such as Wavelength, Dwell time, and Laser Off time. The trigger modes available are Internal or External Modes and are set in the Setting menu.



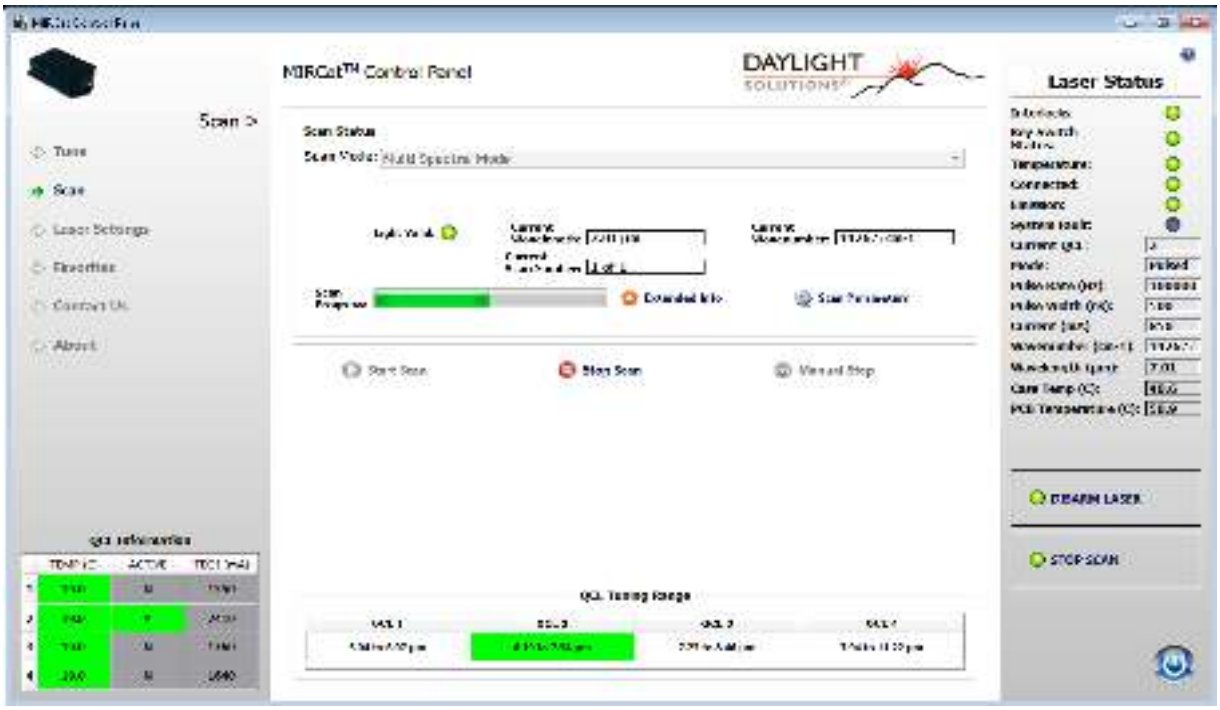
The user can program a scan sequence by adding or removing lines by selecting the row and entering the data.



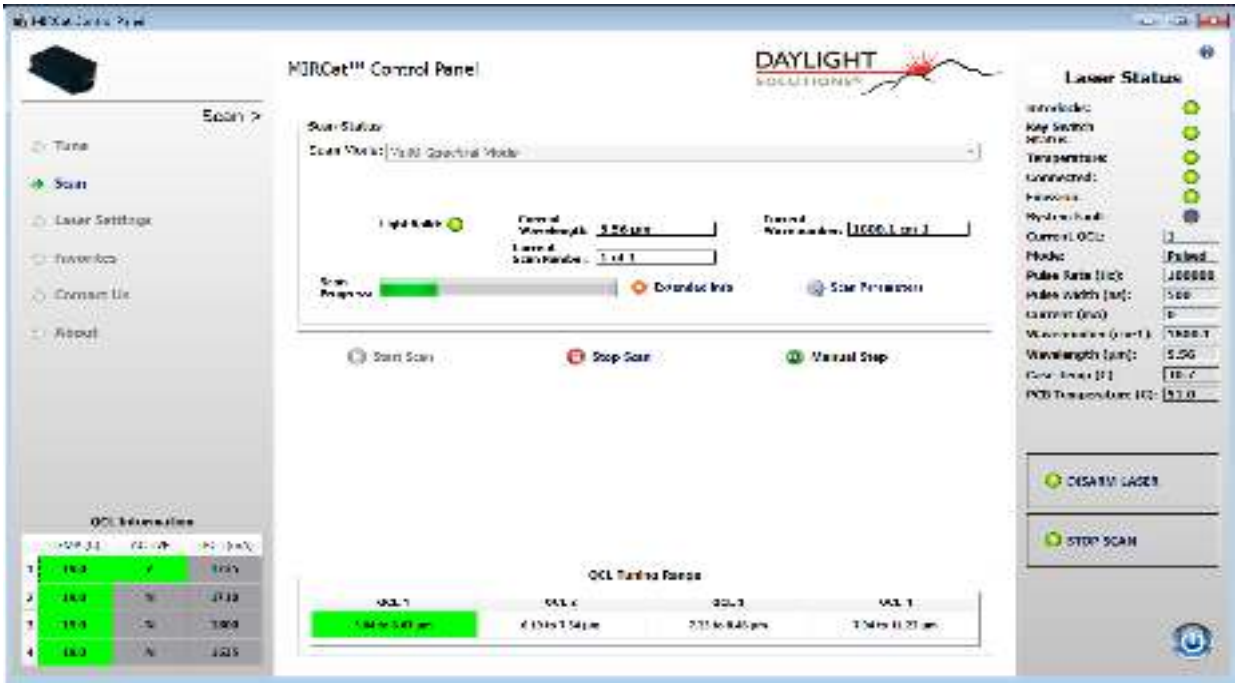
To start the scan, click the Start Scan button. The screen changes to the below display to indicate which module the laser is tuning to. There is a progress bar that helps track the scan's progress. The user can stop the scan at any time by clicking the Stop Scan button.



Above, Module 2 is active, but the Light Valid light is not on while it pauses during the set Off Time. Now the Light Valid button is on while the laser emits. An Audio beep can be heard if selected in the Settings menu.



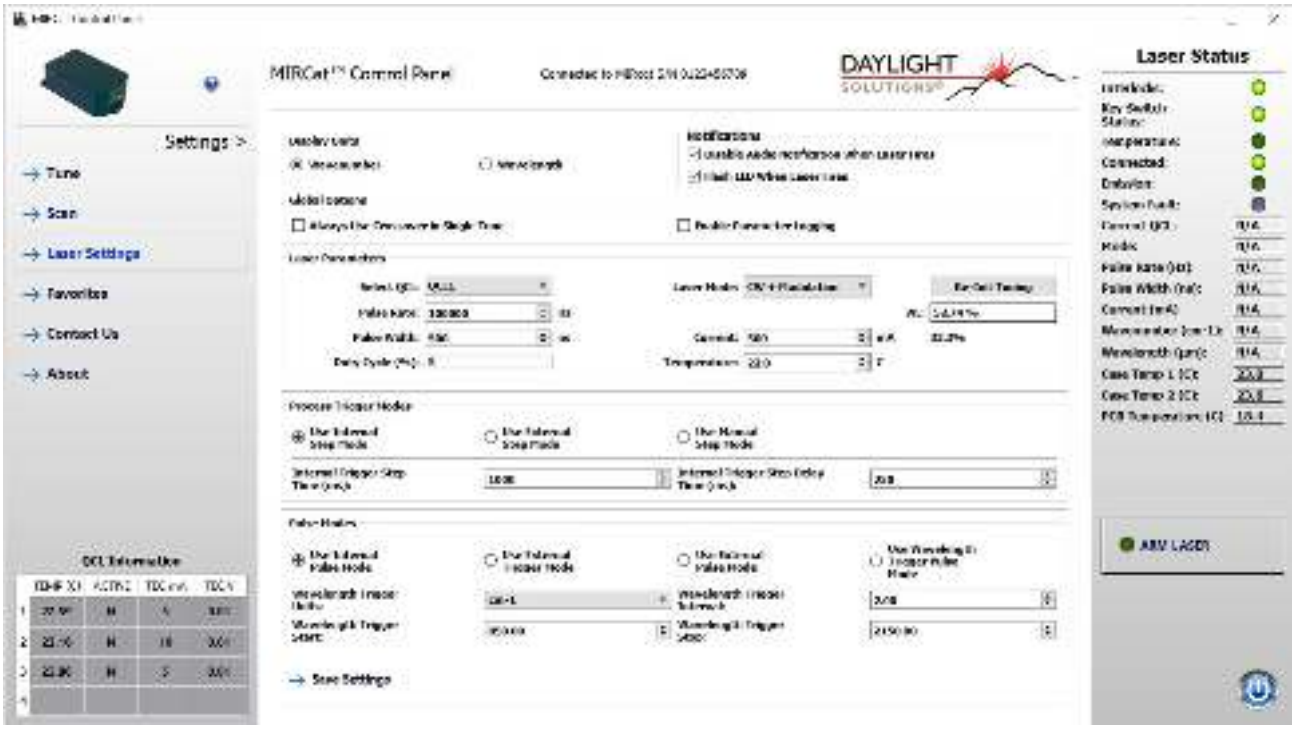
The other option is to set the Manual Scan mode under the Setting menu. The laser will tune to the programmed position. Light will be on for the programmed dwell time and wait for the user to click the Manual Step button to allow the laser to tune to the next programmed step. See below.



Settings Menu

The Settings Menu allows the user to set the Display Units, Notifications, Global Parameters, Laser Parameters, Process Trigger Modes, and Pulse Modes. The parameters are entered using pull down menus or entering data and the user can use the Tab key to move between fields.

NOTE: Users must click the Save Settings button to save the changes before leaving the screen.



Display Units- The user can set the desired units in either wavelength or wavenumber. When done, click the Save button at the bottom of the menu to store the parameters.

Notifications- The user can set the desired state of audio or visual external notifications. When done, click the Save button at the bottom of the menu to store the parameters.

Global Options- The user can set options that will work across Internal or External modes:

If "Always use crossover in single tune" is checked then the laser will use the crossover points for 'Tune' mode. If this is unchecked, the laser will tune across the full tuning range of the QCL, ignoring the programmed cross-over point.

If the "Enable Parameter Logging" is checked, the laser will save a *.txt file in the Home directory of the GUI with critical parameters for the QCLs. This can help troubleshoot problems with the lasers in the field. When done, click the Save button at the bottom of the menu to store the parameters.

Laser Parameters- The user can set the laser parameters for each of up to 4 modules. Select the QCL # in the pulldown menu and make any changes to the parameters. The user can change parameters on all QCLs,

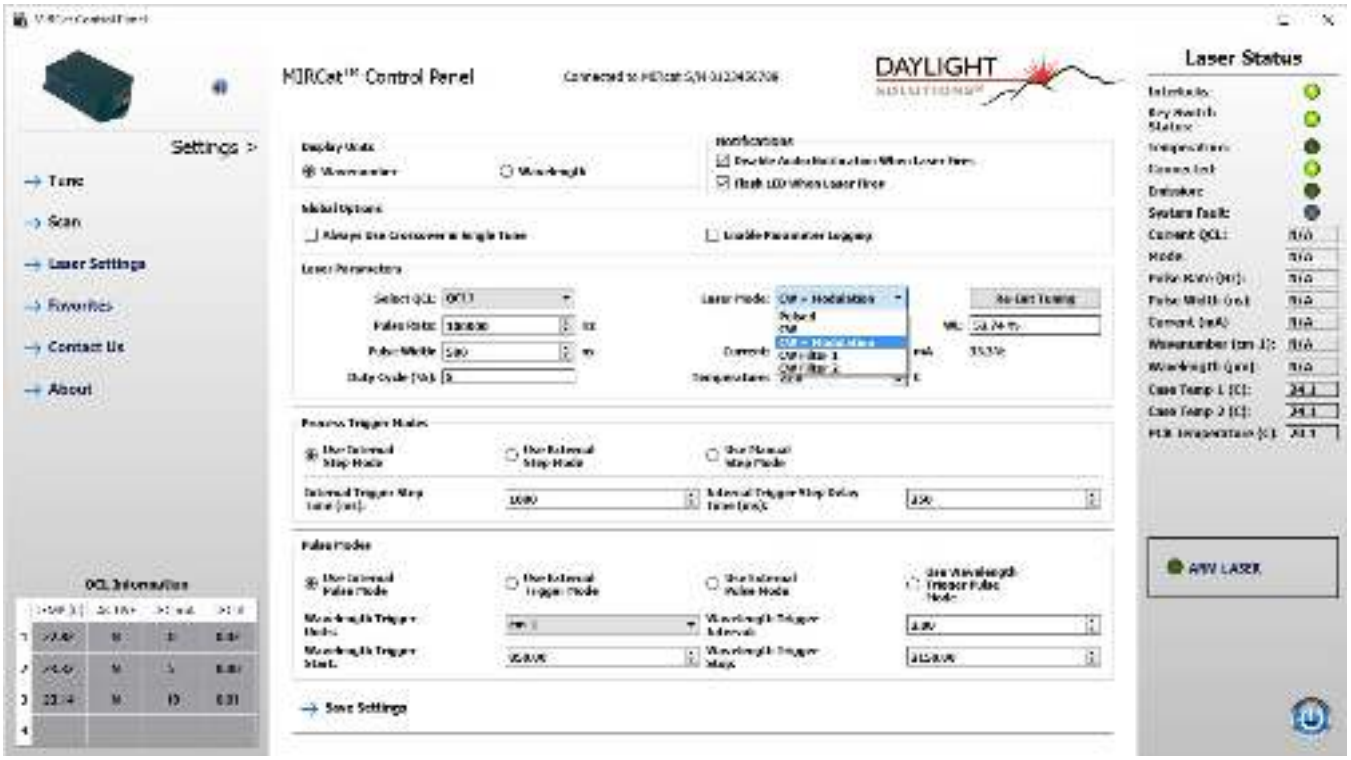
before clicking the Save Settings on the bottom of the screen and all changes will be saved.

The “Re-Initialize Tuning” button allows the user to reset the tuning index on the currently selected QCL. This will force the QCL motor to find home index, rather than re-booting the entire system.

The “Wavelength (WL:)” meter shows what percent of full tuning the QCL is currently tuned to. A negative number indicates the motor is out of normal tuning range on the index mark and is a normal operation.

The ‘%’ field below this indicates what percentage of full current the QCL is set to. For example, if the maximum current is 750mA, then the indicator should read 100%. This helps the user know if the QCLs are set to maximum allowed current.

NOTE: Users must click the Save Settings button to save the changes before leaving the screen.



Laser Modes are selected using the pull-down menu. If the modes are not available, or not installed, then the selections are not displayed. Newer versions of MIRcats have CW-modulation, and selectable noise filters for CW performance. CW-Modulation is described in Sec IV-9 Modulation Functions (CW). The CW-Filter Mode 1 reduces the laser driver corner frequency to 14KHz which in turn reduces the CW laser RIN about 5 dB (typical). This setting allows for some limited modulation of the laser (limited by the 14KHz corner). CW-Filter Mode 2 reduces the laser driver corner frequency to 3Hz which reduces the CW laser RIN by about 20 dB (typical). At this setting, laser modulation is not feasible.

Process Trigger Modes- These modes affect Sweep Scan, Step and Measure Scan and Multi-Spectral Scan modes. The DB-9 Pin 4 is active LO. This signal is only used when “Use External Step Mode” is selected. In Sweep Scan mode, the laser will set up the requested sweep and wait for Pin 4 to go LO before starting the

first sweep. Each process trigger only causes the system to sweep one channel and not all of the channels in a sweep. Once done, the system will return to the start position, set up the next scan and wait for Pin 4 to go LO before starting the next channel scan. In either Step & Measure or Multi-Spectral Mode, the laser will move to the first wavelength and turn on. It will then stay at that wavelength and continue to emit light until this signal is pulled LO. The signal should be pulled LO to ground for between 250 and 500 ms, at which point the laser will move to the next wavelength and then start firing.

Use Internal Step Mode- This mode allows the system to automatically control the next step in the scan and outputs a TTL signal on the DB-9 Pin 2 "Tuned" signal. This allows the MIRcat Laser to be in the Master timing mode for data acquisition. The user can program Dwell Time for the laser to pause at the step before moving with the Internal Trigger Step Time (ms), as well as programming Off Time for the laser to turn off between scans using the Internal Trigger Step Delay Time (ms).

Use External Step Mode- This mode waits for the user to apply a LO signal on the Process Trigger signal, Pin 4 of the DB-9 connector. This allows the MIRcat Laser to be in the Slave timing mode for external control, like data acquisition.

Use Manual Step Mode- allows the user to click on a button in the SCAN menu GUI to step the laser thru the scan steps. The laser will emit light while waiting for the next manual step command.

Pulse Modes- The user can select the Internal Pulse Mode, External Trigger Mode, External Pulse Mode or Wavelength Trigger Pulse Mode.
Use Internal Pulse Mode- uses the parameters set by the user in the Laser Parameters menu.

Use Ext. Trigger Mode- This mode uses the TTL signal applied to TRIG IN on the back-panel BNC connector; will initialize a single optical pulse per trigger whose width is set in the Laser Parameters menu.

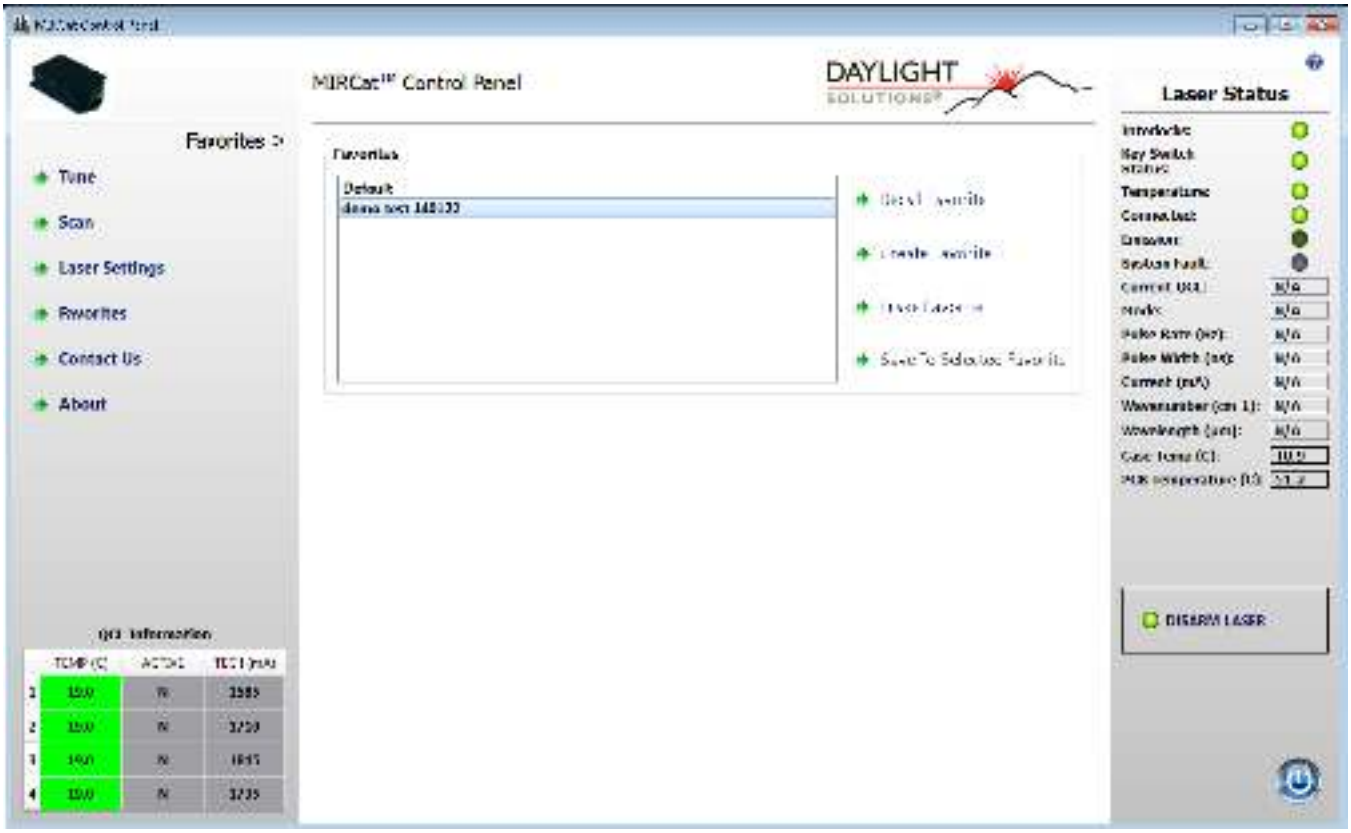
Use Ext. Pulse Mode- This mode uses the TTL signal applied to TRIG IN on the back-panel BNC connector; will initialize a single optical pulse per trigger whose width is determined by the applied pulse width.

Note: If the user exceeds the allowed pulse frequency or pulse width, no optical pulse will emit and an error message is issued.

Use Wavelength Trigger Pulse Mode- Active during the Sweep Scan mode only, uses the same pulse parameters as Internal Pulse Mode. This mode also emits a TTL electrical pulse on Pin3 of the DB-9 connector as the laser tunes across the set range at each preset interval, using the Start/Stop Wavelength Trigger parameters specified in the Laser Settings menu. For example, if scanning from 7 to 10 μm, and the WL trigger start and stop are set to 7.5 μm and 9.5 μm, respectively, and the WL trigger interval is every 0.1 μm, an electrical pulse will be emitted when the laser scans crosses 7.5 μm, 7.6 μm, 7.7 μm, etc.

Favorites Menu

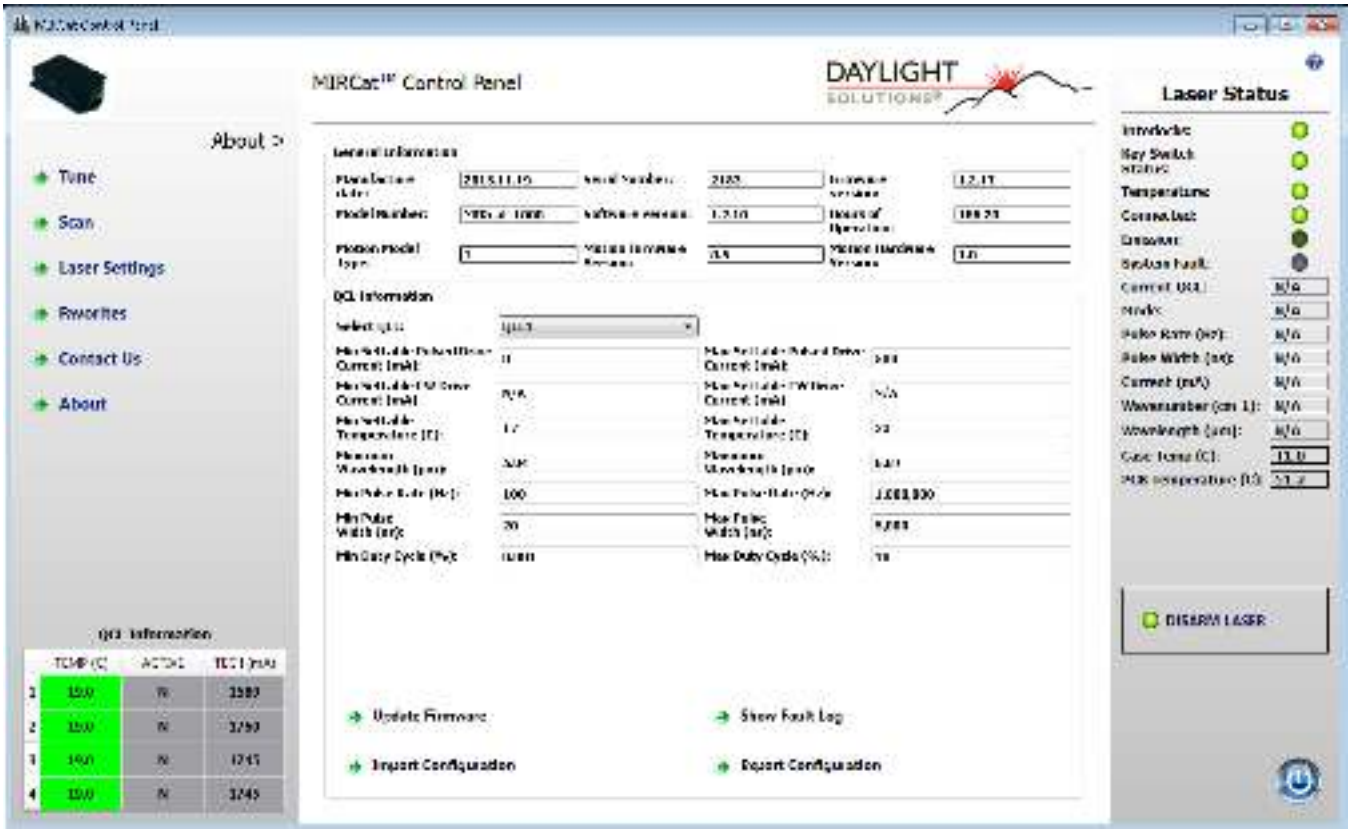
The Favorites Menu allows the user to save settings that are used most often. The maximum allowed is 8. If the maximum has been reached the user can select and delete all favorites except for the default.



Contact Us Menu

The menu is a quick reference for the user to contact Daylight Solutions for customer support or general information.

About Menu



This menu displays all the laser parameters for the individual modules. This data is not changeable, but allows the user to see general information about the system and what QCL limits are available for changing in other menus.

This screen also contains the Update Firmware function. As new features are supported, the new firmware file will be released by Daylight Solutions. Once connected to the laser head, the user can click on this button and will be asked to load the firmware update file. The system will automatically update the firmware and reboot.

The user can also save the factory set laser parameters in a file by clicking on the Export Configuration. This will make a file that can be sent back to the Daylight Solutions factory for evaluation. A new file with new parameters can be returned from Daylight Solutions factory and loaded into the MIRcat by clicking on Import Configuration. This does not save customer parameters such as PW, PRF, scan type, Start/Stop wavelengths, etc.

7. Laser Modes

Trigger Modes (Tune)	Description
Internal Trigger	➢ Normal Pulsed Operation. A TTL pulse is output on the back panel **TRIG OUT** BNC that corresponds to the leading edge of the optical pulse. ➢ Pulse parameters are set on the Settings>Laser Parameters menu. Users must click 'Save Settings' to activate and store any changes.
External Trigger	➢ A TTL pulse is Input on the **TRIG IN** BNC that corresponds to the leading edge of the optical pulse. There is an inherent pulse delay. ➢ Set External Trigger Mode in Settings menu. ➢ Pulse parameters are set on the Settings>Laser Parameters menu.
Manual Trigger	➢ The GUI will provide a button for the user to click on for the laser to step to the next location in the Scan>Step and Measure menu. ➢ Set Manual Trigger Mode in Settings menu

Pulse Modes (Scan)	Description
Internal Pulse	➢ Laser pulses are generated with width, repetition rate and duty cycle determined by user GUI or SDK settings, up to factory-programmed limits. The TRIG OUT BNC issues TTL pulses with timing synchronized to the leading edge of the laser pulse. Pulse parameters are set in the Settings menu. Users must 'Save Settings' to store changes.
External Trigger	➢ In this mode, applying an electrical TTL pulse to MIRcat's 'Ext Trig' input will generate a laser output pulse with optical width determined by MIRcat's internal clock settings, provided factory-programmed pulse width, repetition rate and/or duty cycle limits are not exceeded. ➢ Width, Frequency and Duty Cycle settings are inactive on the GUI.
External Pulse	➢ Applying an electrical TTL pulse to MIRcat's 'Ext Trig' input will generate a laser pulse with the same width. The laser will follow the width, repetition rate and duty cycle of electrical pulses applied to this input provided factory-programmed pulse width, repetition rate and/or duty cycle limits are not exceeded. This mode allows external control of the laser pulse train without introducing clock jitter. ➢ NOTE: Because of an internal delay between activating the laser current and optical emission, in this mode optical pulse width may be shorter than the corresponding external electrical pulse width. To compensate this, the user should apply electrical pulses that are longer (typically by 100-200 ns) than the desired laser output pulse width. The electrical pulse width may need to be fine-tuned.

Wavelength trigger	➢ A TTL pulse is generated on Pin3 of the DB-9 connector at each wavelength step once the step size and wavelength range is entered.

8. Width, Frequency and Duty Cycle

The following sections define how to set the width, frequency and duty cycle for the MIRcat laser head using the MIRcat GUI Laser Settings menu. The dependencies between these three values are defined by this formula:

```
Duty Cycle (%) = Width x Frequency x 100
```

Changing the value of one parameter in this equation will cause other values to change automatically, as defined by the table below:

Action	**Width**	**Frequency**	**Duty Cycle**
Change Width	As Requested	Does not Change	Changes
Change Frequency	Changes	As Requested	Does not Change
Change Duty Cycle	Changes	Does not Change	As Requested

Note: The firmware defines a maximum allowable value for pulse width and duty cycle to prevent thermal stress to QCLs in the MIRcat laser head:

Maximum Width value	1.0 µs
Maximum Duty Cycle value	10%

9. Modulation Functions (CW)

Current Modulation

Unlike typical laser diodes, current modulation of a QCL generally does not produce a large change in wavelength. Nevertheless, the MIRcat laser head includes an external Current Modulation input (BNC socket) and associated internal circuity to allow external modulation of the QCL current at up to ~10% of the nominal set value. This, produces Frequency Modulation (FM) and Amplitude Modulation (AM). The ratio of FM to AM produced will depend on the laser wavelength set, namely where the laser is being operated relative the peak of its gain curve. It is possible to achieve up to 100% AM modulation at some places on the laser gain curve. Modulation is accomplished by applying up to a 4 V_{pp} (sine wave) to the Current Modulation input on the MIRcat laser head. Although QCL dependent, a typical transfer function for applied modulation current is approximately 3.8 GHz pp modulation for 100 mA (38 MHz/mA). This level of current modulation typically produces FM of ≥ 0.02 cm^{-1} for modulation frequencies up to ~500 kHz.

Modulation Type	**Input to CW MIRcat laser head**	**Connector**
FM (with AM)*	0-4.0 V_{pp} (± 2.0 V_{pp}) 10 kHz – 500 kHz	BNC

*Ratio of FM to AM depends on laser wavelength

CAUTION: Applying a voltage higher than 4V_{pp} to the BNC may result in damage and will void the warranty. Also use standard grounding precautions when connecting to the modulation input to prevent potentially damaging electrostatic discharge to the unit.

V. COMPUTER CONTROL

1. Interfaces

The MIRcat system includes hardware for two different computer control interfaces:

USB 2.0 - allows for control and communication through a standard USB cable and PC. The laser controller hardware provides a full-speed USB connection. It is a self-powered device; namely, it draws no current from the +5V line of the USB cable. MIRcat is designed to be compliant with USB Human Interface Device (HID) class. This means that no additional drivers need to be installed on your computer to use the USB interface. You will, however, need to install suitable third-party software to send commands via the USB interface.

An SDK command set is available for the MIRcat, and is available for use with your system, if required. This command set emulates the functionality of many of the commands available via MIRcat's rear panel connections and GUI. Check the CD that was shipped with the MIRcat, or contact customer support for the latest revision.

For more information regarding USB computer control of your MIRcat, please contact support@daylightsolutions.com.

Ethernet – although an RJ-45 jack is built into each MIRcat, this is in preparation for potential future Ethernet control of the system. Presently the MIRcat GUI does not support Ethernet control and communication. For more information, please contact Daylight Solutions or your authorized distributor.

VI. SERVICE AND SUPPORT

1. Warranty

Unless stated otherwise in your order documentation, Daylight Solutions, Inc. guarantees its lasers to be free of defects for one year from the date of shipment, or for 2000 hours of operation, whichever comes first. This is in lieu of all other guarantees, expressed or implied, and does not cover incidental or consequential loss.

2. Service and Calibration

Your MIRcat has been designed to provide years of trouble-free operation. Virtually no maintenance is required except for ensuring that the unit is not damaged, contaminated, or used in an unsafe manner. The MIRcat laser head is a sealed unit that requires no user internal adjustments or internal maintenance. (Users should not open the laser head under any circumstances, as this will void your warranty and could introduce optical contamination into the laser head or damage it.)

If using the MIRcat in CW mode, which requires water cooling with a suitable closed-loop water chiller, users should also follow the recommended maintenance procedure for the water chiller used, including changing the chiller fluid at regular intervals to avoid the potential buildup of algae in the circulating water.

Any questions regarding the operation or performance of the laser will be gladly answered by Daylight Solutions engineers. Engineers are on duty from 8:00am–5:00pm PST, Monday through Friday (excluding holidays). Or try emailing your question to support@daylightsolutions.com for quicker service.

NOTE: For service, repair, or calibration, please call for a Return Material Authorization (RMA) number before shipping the unit to Daylight Solutions, Inc.

Periodic Safety Checks Required to Maintain CDRH Compliance

MIRcat has been designed with many laser safety features that ensure compliance with laser safety regulations applicable in your region. To ensure that your MIRcat remains in compliance with applicable safety regulations, users should check at least once every six months that all included safety features are operating correctly.

Specifically, users should check: a) that all safety labels, as shown and described in Chapter 1, are still firmly affixed and legible; b) the laser cannot be activated (armed) with the key switch set to the 'off' position, and that this key cannot be removed in the 'on' position; c) the white LED 'emission warning' indicator on the laser head illuminates for 3-5 seconds after activating laser output but before laser output is observed, and that the status of this emission warning indicator is duplicated correctly on the supplied GUI; d) the mechanical shutter on the laser output port opens and closes freely, and blocks all laser emission when shut; e) laser emission cannot be enabled unless the remote interlock connector terminals are shorted; f) removing the short connection from the remote interlock connector terminals, or interrupting the primary AC power to the MIRcat head, requires a manual reset of the laser system, including cycling the key switch.

If you have any questions about your MIRcat, you can reach us at:

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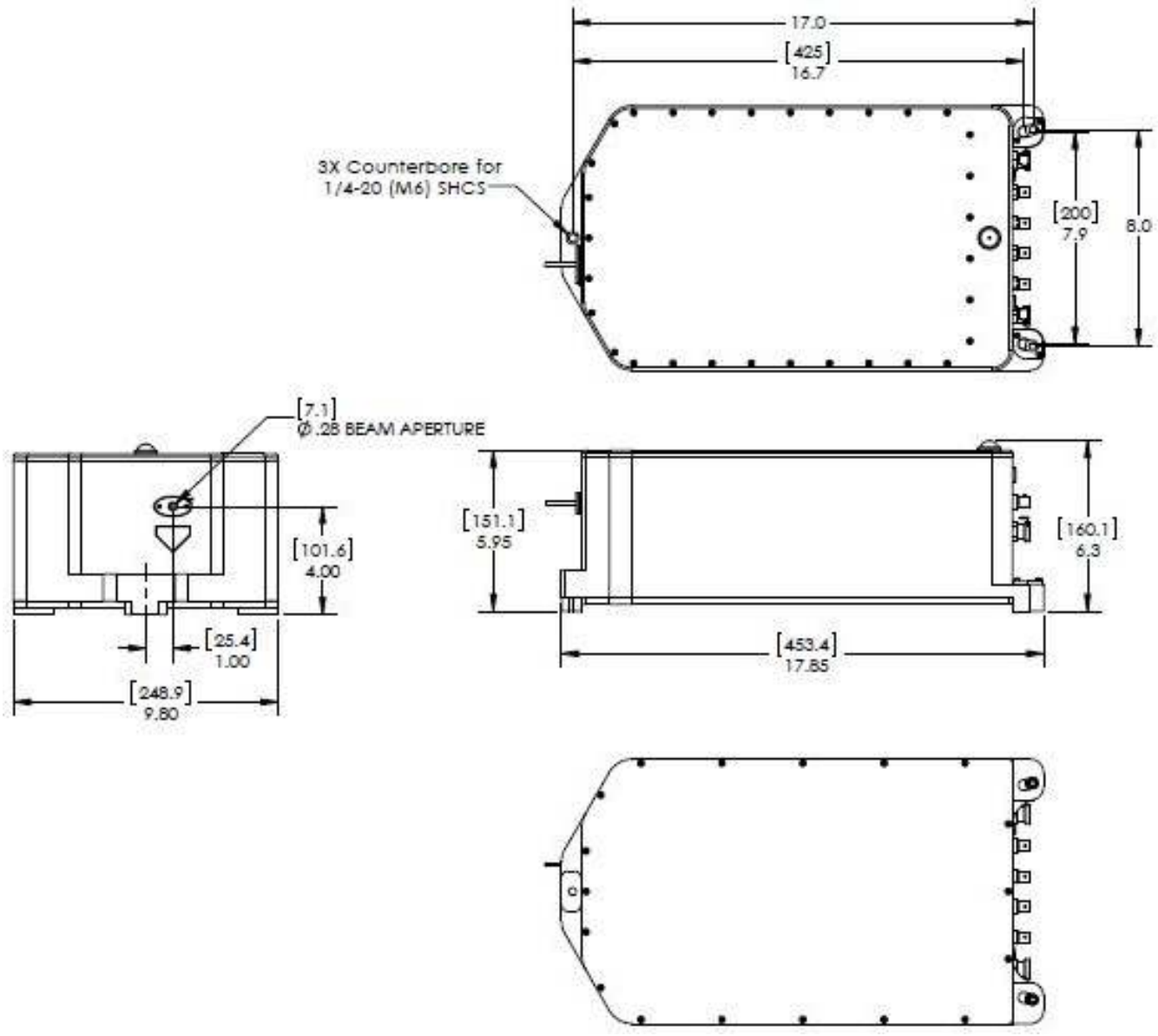
VII. SPECIFICATIONS: MIRcat Laser Systems

Configuration Options	
System Configuration	Factory-configured for 1, 2, 3 or 4 QC laser modules – refer to the test sheet for your system
Modes of Operation	Pulsed only, or CW-Pulsed, depending on laser modules selected. Refer to test sheet for your system
Wavelength Coverage	3 to 13 μm - depends on QCLs selected. Refer to test sheet
Tuning Parameters	
Max. Tuning Speed	MIRcat-QT: 5,000 cm^{-1}/s. MIRcat-1xxx: 100 cm^{-1}/s
Tuning Range	Up to 400 cm^{-1} per QCL - depends on QCLs selected. Refer to test sheet
Wavelength Accuracy	< 1 cm^{-1}
Tuning Modes	Set λ, step λ & measure, continuous λ sweep scans
Pulsed Operation	
Max. Peak Power	Up to 1W - depends on QCL. Refer to test sheet
Max. Average Power	Up to 0.5W - depends on QCL. Refer to test sheet
Pulse to Pulse Energy Stability	MIRcat-QT: < 3% (std. dev.). MIRcat-1xxx: < 5% pk-pk
Pulse Repetition Range	100 Hz – 1MHz (user selectable in 0.1 kHz increments)
Pulse Width Range	40 ns to 500 ns (20-ns increments)
Max. Duty Cycle	10%
Linewidth	< 1 cm-1 (FWHM)
CW Operation (Requires CW Modules)	
Max. Average Power	Up to 0.5W - depends on QCL. Refer to test sheet
Average Power Stability	< 3% (1 hour)
Linewidth	< 100 MHz (typical value, FWHM, measured over 1s, when tuned to single longitudinal mode)
Beam Properties	
Spatial Mode	TEM_{00} (nominal)
Pointing Stability	MIRcat-QT: < 2 mrad (centroid change) MIRcat-1xxx: < 2mrad per 100 cm-1 of tuning (centroid change)
Beam Waist	< 2.5 mm ($1/e^2$ intensity radius, typical value, varies with λ) 30 to 50 cm from output port (typical value, varies with λ)
Beam Divergence	< 4 mrad (full angle, $1/e^2$ intensity width, varies with λ, measured at with λ = 4 μm)
Linear	>100:1, vertically polarized, perpendicular to laser base
Operating Parameters	
Current Range	0 to factory-set limit. Refer to system GUI
Laser Temperature	Factory set default +/- 5.0 °C
Cooling Requirements	Water cooling for CW operation or pulsed duty cycle ≥10%

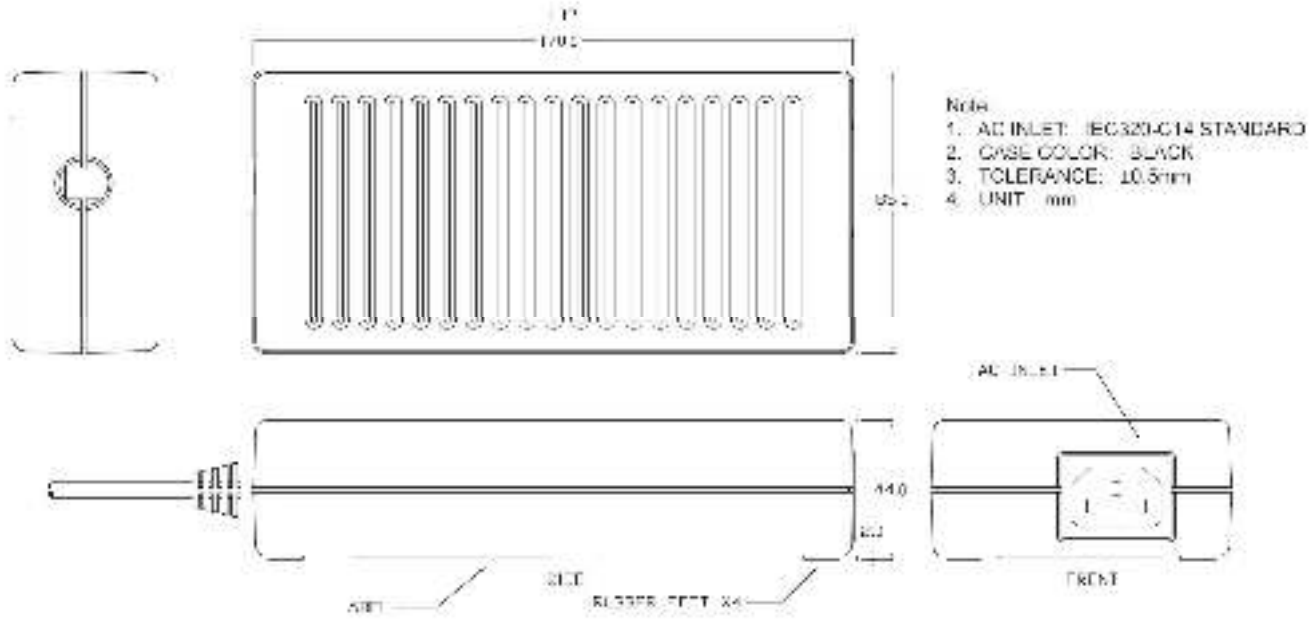
APPENDIX A: Dimensions

1. MIRcat Laser Head (-QT & -1xxx models)



Note: Dimensions are in inches or [mm]

2. Power Module



Note: Dimensions are in inches or [mm]