Wasatch Photonics
X series Raman Spectrometer
Operation Manual

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1. Introduction

Congratulations on obtaining a Wasatch Photonics X series Raman spectrometer! This operator's manual should either provide or point you to all the information you need to perform fast, safe, and accurate Raman measurements of the world around you.

1.1. Applicability

This manual is applicable to all Wasatch Photonics X series Raman spectrometers, including all laboratory and OEM variants of the following:

- WP 532X
- WP 638X
- WP 785X
- WP 830X
- WP 1064X

1.2. Model Nomenclature

Wasatch X series Raman spectrometers have model names like the following:

WP-*excitation***X-F***ratio-cooling-coupling[-slit]*

where:

- *excitation* = excitation wavelength of the laser (532, 638, 785, 830 or 1024)
- *ratio* = focal ratio (13 indicating ƒ/1.3, or 18 indicating ƒ/1.8)
- *cooling* = detector cooling type ('R' indicating "TEC Regulated" to 10°C, or 'C' indicating "TEC Cooled" to -15°C)
- *coupling* = optical coupling between spectrometer, laser and sample (ILP, ILC, IC and IP) — see section 4, Optical Coupling, for details
- *slit* = optional slit width in µm (typically 10, 25, 50, 100 or 200). Slit width is only specified for freespace couplings (ILP and IP), as the other configurations support "interchangeable couplings" (which includes interchangeable slits)

1.3. Referenced Documents

Please see the following documents for additional information relevant to your Wasatch Photonics spectrometer:

- X series Raman Spectrometer QuickStart Guide
- ENLIGHTEN™ Spectroscopy Software
  - includes application installers and ENLIGHTEN™ manual
- Software Drivers and Libraries
- Technical References
  - ENG-0001 USB API
  - ENG-0034 EEPROM Specification
- Regulatory Standards
  - IEC 60825-1:2014

2. Laser Safety

Wasatch Photonics X series Raman spectrometers with integrated lasers include a number of safety features to minimize risk of exposure and injury to the operator and any bystanders.

Nevertheless, be aware that **these remain Class 3B laser products** and are therefore **fundamentally unsafe for use without appropriate Personal Protective Equipment (PPE)**, such as laser goggles, and user training from a qualified instructor and syllabus.

Caution - use of controls or adjustments or performance of procedures other than those specified herein may result in hazardous radiation exposure.

DO NOT MAKE ADJUSTMENTS TO THE SPECTROMETER OR LASER CONTROL SYSTEMS OTHER THAN THOSE RECOMMENDED IN THIS MANUAL. DOING SO COULD VOID YOUR WARRANTY AND COMPROMISE OPERATOR SAFETY.

2.1. Laser Safety Fundamentals

Whether your Wasatch Photonics Raman spectrometer contains an integrated laser (ILP and ILC models), or you are using your spectrometer with an external laser (IC and IP models), please review the following safety guidance and familiarize yourself with all applicable laser safety features of your Raman spectrometer.

It is of particular importance to know the wavelength (nm) and output power (mW) of all lasers in operation. This information informs the selection of appropriate laser protective eyewear (glasses or goggles). Wasatch Photonics recommends laser safety goggles of at least OD5+ at the nominal excitation wavelength.

Users should be aware that some or all of a laser's emitted laser radiation may be invisible to the human eye. For instance, 785 nm and 830 nm lasers are only partially visible to human vision, and may be perceived as a faint red dot on an unfocussed white surface (textured wall paint or business card). Do not be misled by the relative dimness of the laser spot — the vast majority of the coherent laser light is actually outside your visible spectrum, and remains extremely dangerous.

Other laser wavelengths, such as 1064 nm, are entirely invisible. These are actually the most dangerous lasers from an eye safety standpoint, as the human eye has no innate "flinch" or "blink" reflexes to respond to infrared light, allowing your pupil to remain fully dilated and thus serve as an open aperture actively focused on the sensitive tissue of your retina.

For additional information on laser safety issues, please see the following online resources:

- https://en.wikipedia.org/wiki/Laser_safety
- https://www.lia.org/store/laser-safety-standards/ansi-z136-standards

2.2. Safety Markings

Your spectrometer includes regulatory-standard labels and markings identifying laser wavelength, maximum output power, and the location of the laser aperture.

It is important that operators are aware of the laser wavelength and output power of the product, as that is necessary to select appropriate PPE (Personal Protective Equipment), such as laser goggles at the correct wavelength and OD (Optical Density).

Sample laser marking indicating power, wavelength and pulse rate

Sample laser aperture indication (attenuator not shown)

For reference, find reproductions of all labels in Appendix C, Housing Labels.

2.3. Permanently Affixed Laser Attenuator

ILP spectrometers with an integrated laser will include a permanently attached (chained) laser attenuator which may serve as a protective lens-cap. This can protect the optics from dust and damage when not in use, and represents an additional safety feature by physically preventing inadvertent laser emission when emplaced. For convenience, a magnetized clip is provided to hold the attenuator when not engaged.

Permanently affixed ILP attenuator with storage clip

ILC units similarly have a metal FC/PC screw-on cap chained to the front face, offering device and operator protection of the exposed emission fiber connector.

Permanently affixed ILC attenuator

2.4. Light-Tight Optical Bench

Wasatch Photonics Raman spectrometers are designed such that coherent laser light cannot escape the optical bench and radiate into the environment, save through the intended optical coupling (freespace front optic for ILP models, and FC/PC fiber connector for ILC models).

To maintain this protective seal, it is important that users do not attempt to disassemble the spectrometer or modify the mechanical assembly.

A key aspect of the light-seal in systems with integrated multi-mode lasers is the internal fiber connecting the housed multi-mode laser butterfly package to the integrated probe or external FC/PC connector. If this fiber breaks or snaps, it is possible for laser radiation to emit into the environment through holes and vents in the product housing.

Therefore, it is important that, if you have any reason to suspect internal fiber breakage (i.e. inability to generate Raman spectra), you should contact Wasatch Photonics for investigation and repair.

2.5. Laser Warning LEDs

Wasatch Photonics Raman spectrometers with integrated lasers have two warning LEDs on the front panel. These LEDs are designed to be visible both from the front and top of the spectrometer. When operational, the LEDs will flash in synchronization; if either LED is illuminated "solid" (not flashing), that indicates a fault condition and the unit should be referred to the manufacturer for investigation and repair.

2.5.1. Laser Armed LED (Yellow)

The yellow "Laser Armed" LED flashes when both laser interlock systems (Key-Switch and Remote Interlock ("Continuity Circuit"), both described below) are "closed" (configured to allow the laser to fire).

When this LED flashes, it indicates that power is being supplied to the laser driver circuit, and it is physically (electrically) possible for the laser to fire if given the appropriate signal through software or signaling electronics.

When this LED flashes, it does not mean the laser is currently firing; it means it can fire, when you instruct it to.

If this LED is not flashing, it typically means one of these things:

- the spectrometer is not plugged in to mains
- the spectrometer is not switched on using the side power switch
- the laser key is not inserted
- the laser key is not turned to the "firing" position
- the remote interlock plug is not inserted
- an external circuit wired to the remote interlock plug is "open" (not "closed")

2.5.2. Laser Firing LED (Red)

The red "Laser Firing" LED flashes when the laser is armed (the yellow LED is flashing) and the laser has been commanded to fire. It indicates that the laser is actively preparing or attempting to fire.

The red LED does not indicate that the laser is "currently" firing at that instant in time. However, it does urgently suggest that the laser may fire at any moment, and for safety reasons should be treated as though it were firing.

Reasons why the LED may be flashing, even though the laser may not be actively firing:

- The Laser Firing Delay may not have completed (see section 2.6, below)
- The laser may have been configured to fire at less than full-power, and as a result is set to pulse at a specific duty cycle using PWM (Pulse-Width Modulation). In this state, the laser will rapidly toggle between firing and not-firing in order to adjust the total laser energy being directed at the sample. The "Laser Firing" LED does not deactivate during times when the laser is momentarily off due to the instantaneous state of the PWM duty-cycle.

2.6. Laser Firing Delay

There is a regulatory requirement that the "laser firing" LED should illuminate for a short period of time before the laser actually begins emitting hazardous radiation. This is so that the operator and bystanders have an opportunity to visually observe the LED illumination and take appropriate defensive action if this circumstance was unexpected (e.g., close their eyes, look away, disable the laser through software, hit an "emergency stop" wall-box linked to the remote interlock, turn the key-switch, etc).

2.7. Laser Interlock Key-Switch

Wasatch Photonics Raman spectrometers with integrated lasers include a laser interlock key-switch on the back face of the spectrometer (opposite the collection / excitation optics). This key is removable, and must be turned to a "firing" position before the laser can be armed and fired.

If the key is not inserted and turned to the "firing" position, neither the yellow "Armed" nor the red "Firing" LED can illuminate, nor can the laser fire.

If the key is inserted and turned to the "firing" position, the yellow "Armed" LED may illuminate, but the red "Firing" LED should not illuminate until the laser is instructed to fire through software.

If the key is turned "off" or removed while the laser is firing, the laser will immediately cease firing. Re-inserting and turning the key back to the "firing" position will not automatically cause the laser to resume firing: a fresh software command must be sent to re-instruct the laser to resume firing.

2.8. Remote Laser Interlock

Wasatch Photonics Raman spectrometers with integrated lasers include a remote laser interlock jack on the back face of the spectrometer (adjacent to the key-switch). This jack uses a standard stereo audio plug connector (SP-3540A, DigiKey 102-4779-ND), simplifying development of compatible plugs for your laboratory or OEM requirements.

If the jack is left empty (no plug inserted), the laser interlock circuit will be broken ("open") and the laser will not fire. This will likewise prevent the yellow "Laser Armed" LED from illuminating.

The microphone plug should be wired to your laboratory's remote door-entry / remote interlock system. Such interlock circuits are varied, and can include one or multiple nodes such as the following:

- Door interlocks which open (disarm) when the magnetic seal is broken, and close (arm) when the magnets connect, such that arrival of an unexpected visitor causes the laser to immediately disable.
- "Emergency Stop" buttons which allow users to quickly deactivate the laser by depressing or signaling a conveniently large and accessible physical switch.
- "Exit Override" buttons which temporarily disable "downstream" interlocks by forcibly closing the circuit (typically only for a few seconds and accompanied by an audible siren).
- "Entry Override" keypads allowing the door override to be temporarily disabled with a passcode.
- Interlocked power strips, such that opening of the interlock circuit cuts power to connected devices.

For additional guidance on recommended use of the remote interlock to support your laser laboratory's safety systems, see Appendix F, Remote Interlock Sample Configurations.

> For temporary desktop use without a permanent remote interlock system installed, the remote interlock can be defeated using the provided "loopback" microphone plug, which closes the continuity circuit and allows the laser to fire (subject to key-switch and other safety systems).

2.9. Laser Software Control

Software also plays a part in laser safety, as there is no way to fire the laser without a deliberate sequence of events triggered through software on a connected computer.

That is to say, even with the spectrometer powered through mains, with the power switch on, the interlock key inserted and in the "Fire" position, and the remote interlock continuity circuit closed, there is no way to induce the laser to fire without a software command via USB. The spectrometer does not contain any physical "fire" or "measure" buttons, and has no ability to independently fire the laser save through software control.

For this purpose, Wasatch provides ENLIGHTEN™ as a cross-platform open-source desktop application, as well as a variety of software drivers and libraries which customers can use to design their own software. ENLIGHTEN™ is covered in section 8, and also on our website.

3. Unboxing Your X series Raman Spectrometer

Your Wasatch Photonics X series Raman spectrometer should come boxed with the following items:

- Spectrometer
- 12V power supply with mains cable for appropriate regional outlet
- USB cable (standard-A plug to standard-B plug)
- Thumbdrive containing calibration reports and ENLIGHTEN™ installer

If you ordered your spectrometer as part of a bundle, it may include any or all of the following additional accouterments:

- SMA-905 collection fiber (if ILC or IC coupling)
- FC/PC excitation fiber (if ILC coupling)
- Raman Probe (if ILC or IC coupling)
- External laser (if IC coupling)
- Sampling accessories (vial holders etc)

WP 532X-ILC in shipping box

Cable tray in shipping box bottom

For additional information on setting up your X series Raman spectrometer, please see the appropriate QuickStart guide found on the Technical Documents & Resources page on our website:

https://wasatchphotonics.com/technical-resources/

4. Optical Coupling

Wasatch Photonics X series Raman spectrometers support four different optical coupling designs which allow different type of system setups:

- ILP (Spectrometer with Integrated Laser and Probe) for creation of a fully integrated system
- ILC (Spectrometer with Integrated Laser and Interchangeable Coupling) for creation of a semi-integrated system
- IC (Spectrometer with Interchangeable Coupling) for creation of a fully modular system
- IP (Spectrometer with Integrated Probe) for creation of a system with the user's laser (available only to OEMs)

These are each discussed in the following sections.

4.1. ILP (Integrated Laser and Probe)

These spectrometers contain both an integrated laser and an integrated Raman probe, to support epi-illuminated (co-axial) excitation and collection in a single package with focused free space optics. No additional optical fibers or external Raman probes are required — everything you need is inside the enclosed housing, accessed through a single focused lens.

X series Raman spectrometer with ILP coupling

Distinguishing features of the ILP design include an absence of any fiber connectors, whether SMA (collection) or FC/PC (excitation). The only aperture on the front face is a cylindrical objective lens converging both the outbound laser and inbound Raman scatter signal into a single focused point at a fixed stand-off working distance.

4.2. ILC (Integrated Laser and Interchangeable Coupling)

These spectrometers contain an integrated multi-mode laser, but do not contain an integrated Raman probe. Therefore, these models must be used in conjunction with an external Raman probe of the appropriate wavelength.

These units have two optical fiber connectors on the front face: an FC/PC connector to transmit outbound excitation laser light, and an SMA-905 connector to collect Raman scatter from the sample.

X series Raman spectrometer with ILC coupling

Typically both fibers are joined in an external Raman probe like the Wasatch RP 785. It is important to use a probe built for the correct laser wavelength, as that determines the filter within the probe.

Wasatch Photonics Raman Probes

4.3. IC (Interchangeable Coupling)

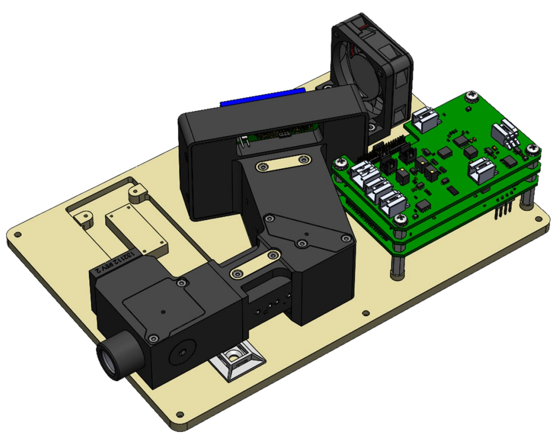
These spectrometers contain neither an integrated laser nor an integrated probe. The user is expected to provide, power and control their laser through other means, connecting the spectrometer to that laser through an external Raman probe as described previously in section 4.2, ILC (Integrated Laser and interchangeable Coupling).

X series Raman spectrometer with IC coupling

Besides having only the single SMA-905 fiber connector, these units are also visually distinguished by lacking any LEDs on the front face, as they have no integrated laser requiring warning signals. Likewise, the back face of these spectrometers lack other laser-safety interfaces such as the interlock key-switch or remote interlock socket.

4.4. IP (Integrated Probe)

These spectrometers provide an integrated Raman Probe with free space coaxial optics, but do *not* provide an integrated laser. Therefore, it is incumbent on the user to provide their own laser and couple it to the integrated probe's FC/PC connector.



X series Raman spectrometer with IP coupling

Because the user will need access to the integrated probe to connect their laser fiber, and because it would cause unnecessary signal loss to couple such a laser through a secondary fiber leading to a housing connector, the IP coupling is only available in OEM (lidless) configurations.

5. Measurement Setup

5.1. Fiber Connections

Note it is very important to not touch the fiber ends with your fingers, as this can leave oil deposits on the exposed optics. Fiber end caps have been provided to protect the fiber ends when not in use.

785X-ILC showing FC/PC excitation fiber port (left) and SMA collection port (right)

5.1.1. Fiber Specifications

	Collection (Measurement)	Excitation (Laser)
	Applies to ILC and IC models	*Applies to ILC models*
Connector	SMA-905	FC/PC
Numeric Aperture (NA)	0.39	0.22
Core Diameter (µm)	400 (≤ 600 µm)	105 typical
Recommended Jacketing	metal or plastic	metal

5.1.2. Jacketing

Wasatch recommends metal-jacketed fibers when possible to minimize the possibility of laser light leaking into the environment, or conversely ambient light leaking into the measurement.

5.1.3. Polarization

Polarization-maintaining fibers are supported but do not add value for typical measurements. Polarization-maintaining fibers are a type of small-core, single-mode fiber that is used to prevent light from changing polarization direction during propagation. However, Wasatch gratings and spectrometers are designed with low polarization dependence to ensure throughput remains consistent regardless of the input polarization state. Thus, as Raman scattering is inherently unpolarized, and given that it is a low-light measurement, we recommend use of multimode fiber to capture and couple as much light as possible into the Raman spectrometer.

5.2. Sampling Accessories

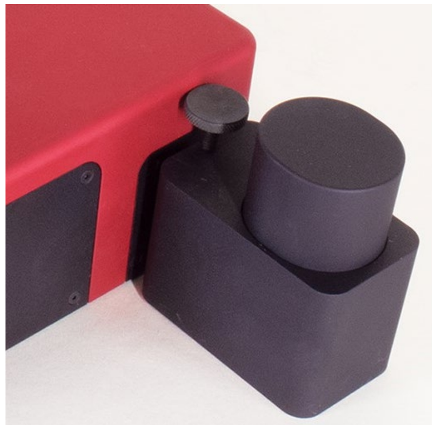
5.2.1. RP series Raman Probes (ILC)

Note that the same probes can be used interchangeably between ƒ/1.3 and ƒ/1.8 ILC models, however, Wasatch Photonics RP series Raman probes are designed with an f/1.3 input aperture, and will thus match most efficiently with our f/1.3 spectrometer models.

5.2.2. Cuvette Holder / Vial Accessory (for use with IC and ILC models)

Wasatch Photonics offers a cuvette holder / vial accessory designed specifically for use with our RP series probes (WP-CUV-RP). It can accommodate small vials, large vials, square cuvettes, and microscope slides. It features a thumb screw which can be used to lock the position of the probe relative to the sample once optimal focusing/signal has been achieved.

5.2.3. Vial Accessory (ILP)



Wasatch Photonics offers a cuvette holder / vial accessory designed specifically for use with our fully integrated X series Raman systems (ILP models). It can accommodate small vials, large vials, and square cuvettes. It features a thumb screw which can be used to lock the position of the probe relative to the freespace front optic/lens once optimal focusing/signal has been achieved.

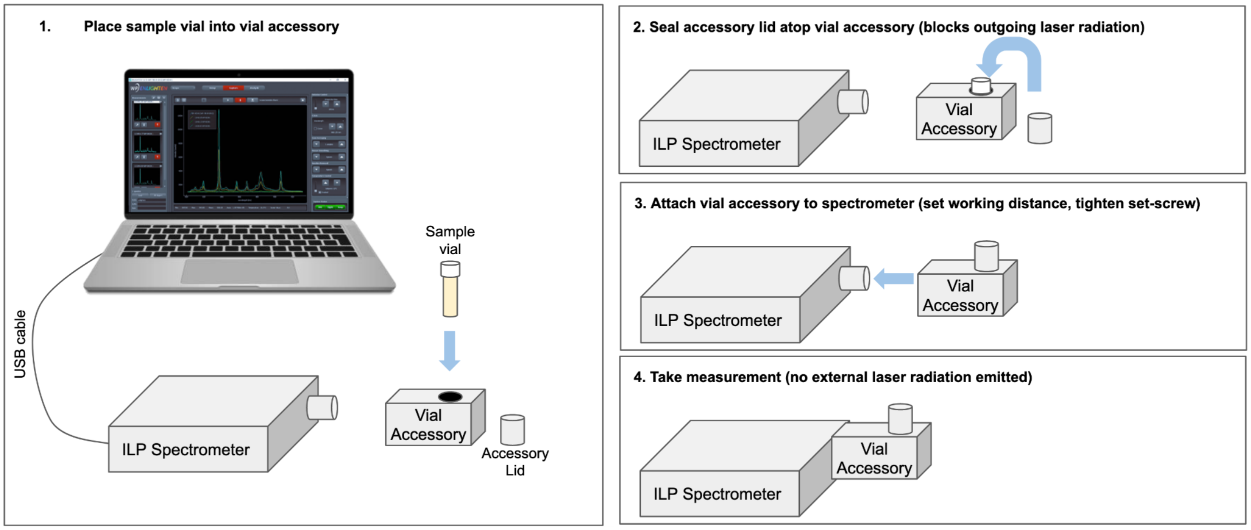
5.3. Sampling Operations / System Setup

5.3.1. ILP Models / Fully Integrated Systems

An X series spectrometer with integrated laser and probe (ILP coupling) can be used as a fully integrated Raman system, typically with an additional cuvette holder/vial assembly, as shown below:

To complete setup of the system, slide the cuvette holder/vial accessory over the freespace front optic/lens, then tighten down the thumb-screw on the vial accessory such that it can't inadvertently be disconnected from the spectrometer or change the working distance.

Place the sample vial inside the accessory, then place the accessory lid securely over the vial to ensure no laser light can escape (nor ambient light intrude). Note that the position of the cuvette holder/vial accessory relative to the spectrometer (i.e., the working distance) may need to be adjusted in and out to achieve maximum signal from the sample and minimum background fluorescence from the sample vessel.



5.3.2. ILC Models / Semi-integrated Systems

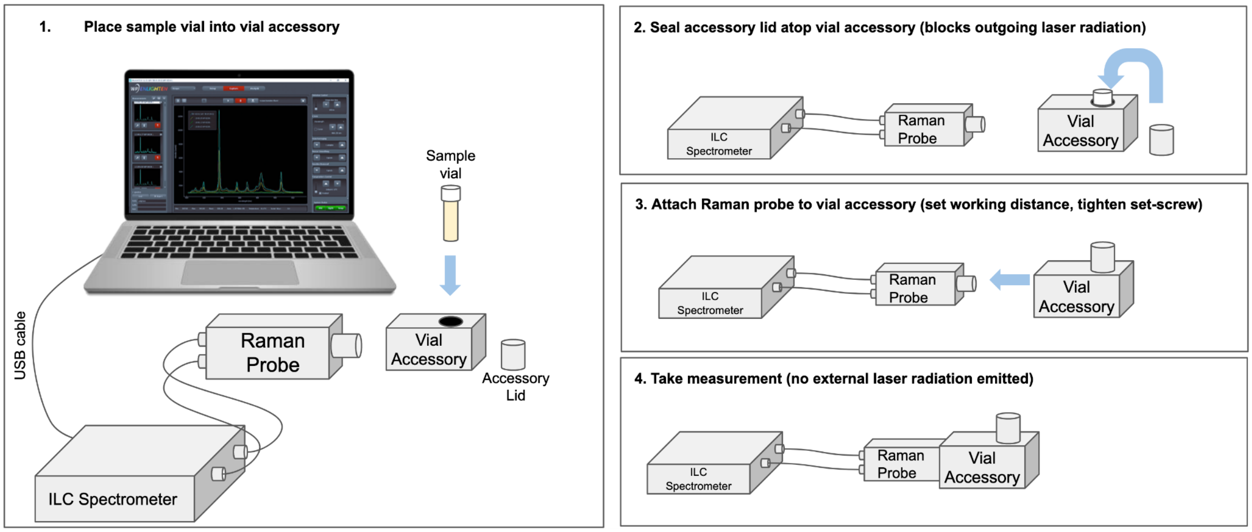
An X series spectrometer with integrated laser (ILC coupling) allows creation of a semi-integrated Raman system, which can be completed by adding an external Raman probe and corresponding cuvette holder/vial assembly, as shown below:

To complete setup of the system, attach the Raman probe to the spectrometer with fibers:

1) Connect the excitation fiber (keyed FC/PC connectors) to the spectrometer's laser port on the LED panel (left), and to the Raman probe (lower input, as shown)
2) Connect the collection fiber (SMA connectors) to the spectrometer's input port on the smaller front panel (right), and to the Raman probe (upper input, as shown)

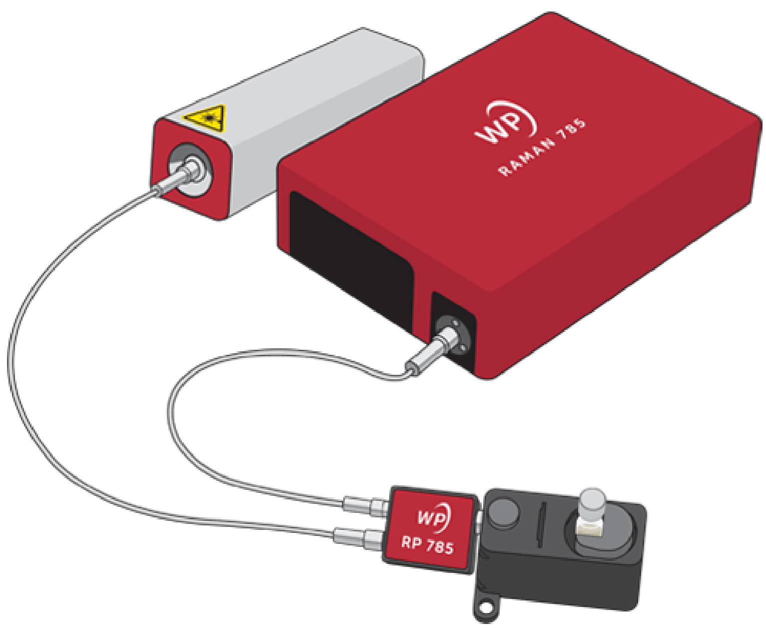
Slide the cuvette holder/vial accessory over the end of the Raman probe, then tighten down the thumb-screw on the vial accessory such that it can't inadvertently disconnect from the probe or change in working distance.

Place the sample vial inside the accessory, then place the accessory lid securely over the vial to ensure no laser light can escape (nor ambient light intrude). Note that the position of the cuvette holder/vial accessory relative to the probe (i.e., the working distance) may need to be adjusted in and out to achieve maximum signal from the sample and minimum background fluorescence from the sample vessel.



5.3.3. IC Models / Fully Modular Systems

An X series spectrometer (IC coupling) allows creation of a fully modular Raman system, which can be completed by adding a standalone laser, an external Raman probe, and the corresponding cuvette holder/vial assembly, as shown below:



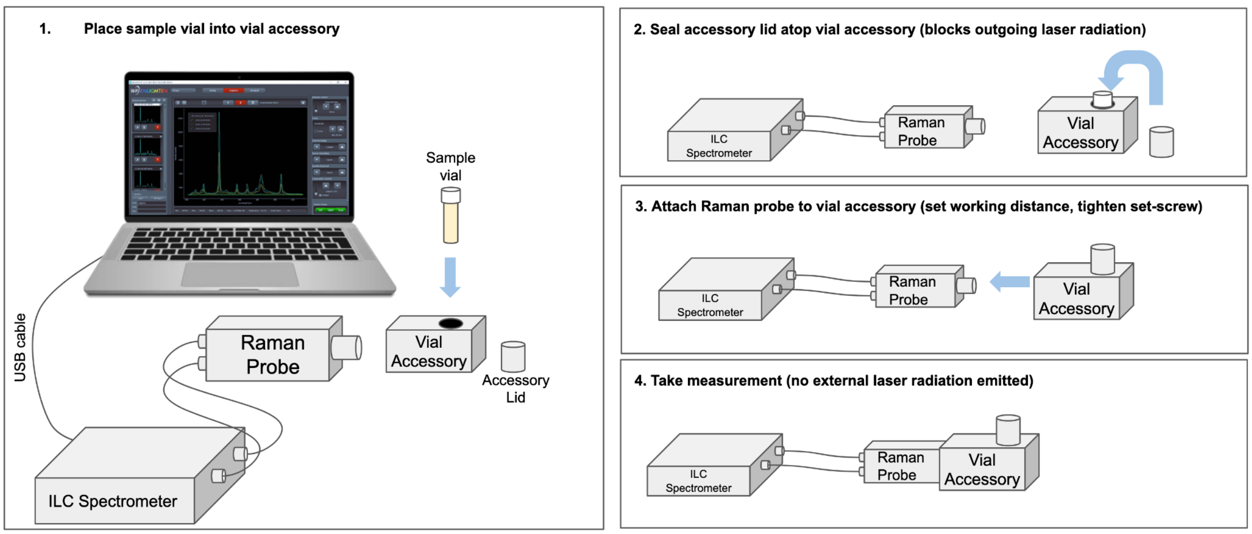
To complete setup of the system, attach the Raman probe to the laser and spectrometer with fibers:

3) Connect the excitation fiber (keyed FC/PC connectors) to the laser's output port as per the manufacturer's instructions, and to the Raman probe (lower input, as shown)

4) Connect the collection fiber (SMA connectors) to the spectrometer's input port, and to the Raman probe (upper input, as shown).

Slide the cuvette holder/vial accessory over the end of the Raman probe, then tighten down the thumb-screw on the vial accessory such that it can't inadvertently disconnect from the probe or change in working distance.

Place the sample vial inside the accessory, then place the accessory lid securely over the vial to ensure no laser light can escape (nor ambient light intrude). Note that the position of the cuvette holder/vial accessory relative to the probe (i.e., the working distance) may need to be adjusted in and out to achieve maximum signal from the sample and minimum background fluorescence from the sample vessel.



6. Power

All X series spectrometers are powered by mains through an included external AC/DC transformer. The transformer accepts 50-60Hz at 100-240VAC, and outputs 12VDC at 5A, providing up to 60W of power.

Per-model operational power requirements including empirically measured current draw can be found in ENG-0157 Empirical Power Draw and Power Supply Guidance. This document is available through your sales representative or distributor.

7. Communications

All X series spectrometers communicate with their host controller through USB 2.0. They currently support USB 2.0 High-Speed communications (480 Mbps).

7.1. USB Communications

The USB communications interface is detailed in our public engineering document ENG-0001 USB API, available on our website's Technical References section.

The USB devices all use the Vendor ID (VID) 0x24aa, and one of the following Product ID (PID):

Product ID	Models
`0x1000`	Silicon-based detectors (532X, 638X, 785X, 830X)
`0x2000`	InGaAs-based detectors (1064X)

The spectrometers use a "vendor" device class, as opposed to one of the "standard" USB classes such as "HID" (keyboards and mice), "printer" etc. As such they require control through a USB driver such as libusb. Any USB driver could be used for this purpose (e.g. WinUSB.sys), but we have provided libraries and installer files for Windows, Linux and MacOS based on the libusb and libusb-win32 packages.

For Windows, the simplest way to obtain these is to install our free ENLIGHTEN™ application, available on the website here: https://wasatchphotonics.com/product-category/software/

For other platforms, and for libraries allowing you to control your spectrometer over USB from a variety of languages including Python, C#, C/C++, MATLAB, LabVIEW and others, see our Software Drivers and Libraries website.

8. ENLIGHTEN™ Quick Start

Following are some basic instructions to collect a spectrum. This section is intended for new users and will only cover the most basic features. For additional information, please see the full ENLIGHTEN™ Manual available here on the website.

8.1. Installation

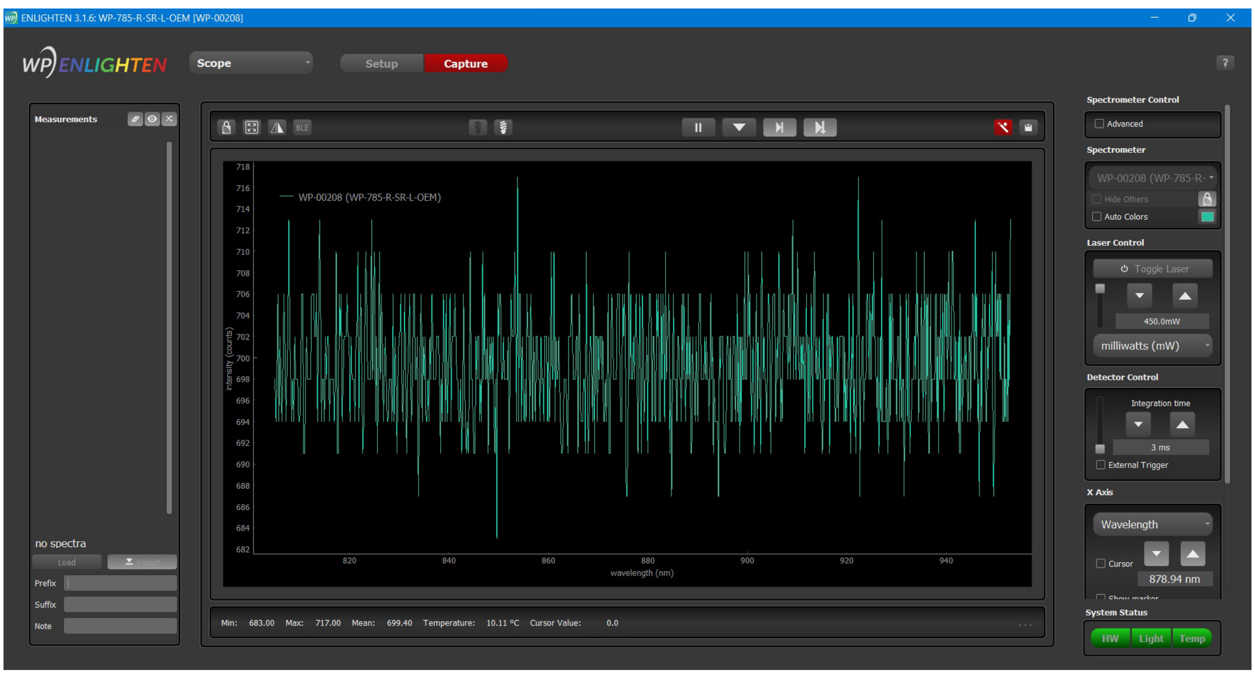
Installers for ENLIGHTEN can be found on the Wasatch website:

https://wasatchphotonics.com/ENLIGHTEN/

Windows installation is a simple affair, while Linux, MacOS and Raspberry Pi installations can involve slightly more steps. See the ENLIGHTEN™ Manual for additional information on obtaining and installing ENLIGHTEN™.

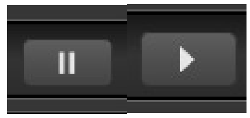
8.2. Scope Mode

In order to collect a spectrum, first launch the ENLIGHTEN™ software. The default screen, showing Capture Tab of Scope Mode, will look like this:



In the image above, you can see an overall flat (though zoomed-in) baseline spectrum with a level intensity around 700 counts. This spectrometer has its front optics completely capped such that no light can enter the unit. If your spectrometer is not capped you could see resultant free-running spectra from any ambient light entering the unit.

By default, the Spectrum Chart displays free-running spectra; if you wish to pause this feature, simply click the Pause button above the chart, then resume with “Play”:



8.3. Set Measurement Parameters

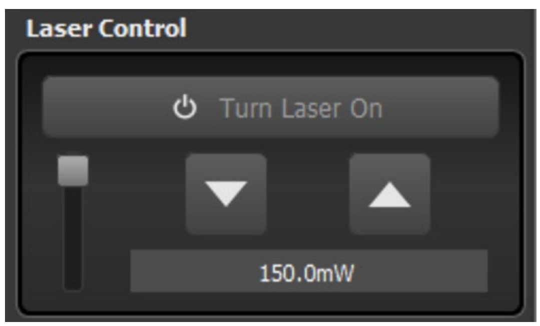
In this section, we describe how to set the sampling parameters of your experimental setup based on the light source being used (integrated or external laser).

8.3.1. Laser Control

Before firing the laser, please review the Laser Safety steps outlined in Section 5, and ensure that the output laser path is fully enclosed and shielded against inadvertent leakage of laser radiation into the environment.

8.3.1.1. Integrated Laser

If your system contains an integrated laser, laser control is enabled within the ENLIGHTEN™ software. The laser can be enabled by pressing ctrl-L or clicking the Turn On Laser button under Laser Control on the right side of the screen.



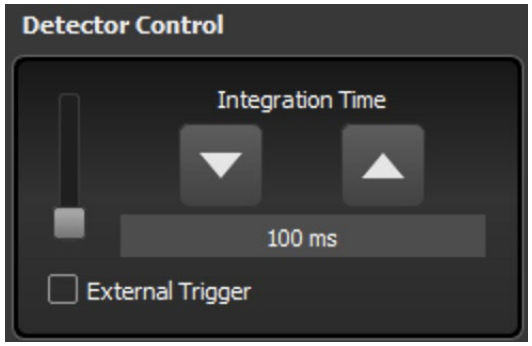
8.3.1.2. External Laser

If you require an external laser to excite your sample, all laser control is performed using the laser's own control interface. Please refer to the laser manufacturer operating instructions regarding laser control.

Connect the laser via a fiber optic cable to either the spectrometer (IP Integrated Probe models) or Raman probe (IC Interchangeable Coupling models) prior to firing the laser.

8.3.2. Integration Time

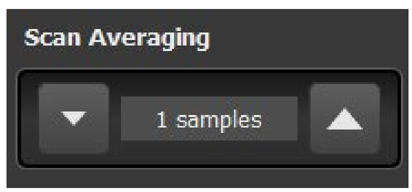
Adjust integration time as needed to achieve your desired Raman signal intensity, using the on-screen arrows or pressing ctrl-T (Time). As you increase or decrease integration time, monitor the signal intensity with respect to the y-axis (signal counts) to achieve the desired signal level.



It is recommended to increase integration time until the Raman signal reaches about 40,000 counts on the Y-axis.

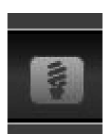
8.3.3. Scan Averaging

If your experimental setup allows for increased sampling time, you also have the option to increase the number of scan averages. Increasing the scan averaging will decrease the noise in your spectrum but will increase sampling time.



8.3.4. Dark Subtraction

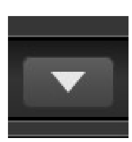
Next, toggle the laser off and allow the dark baseline spectrum to normalize. After ensuring the front optics are completely covered, store a dark measurement by pressing ctrl-D or clicking the black light bulb button (Store Dark button) above the Spectrum Chart. Do not adjust any sampling parameters between turning the laser off and storing the dark measurements. Now you are ready to collect Raman spectra!



After the dark has been stored, toggle the laser back on and check to make sure your Raman spectrum intensity (as well as profile) is as expected.

8.3.5. Save Measurements

You can then save a spectrum by pressing ctrl-S or clicking the Save button above the spectrum chart.



On Windows computers, measurements will be saved to your hard drive in the following location:

- Documents
  - EnlightenSpectra
    - YYYY-MM-DD (per-day folders to group measurements by date)

Click “Export” to re-save all spectra from the “clipboard” at the left of the screen to a single wide, multi-measurement CSV file. This file can be found directly inside the “EnlightenSpectra” folder.

9. Troubleshooting

9.1. Electrical Transients

Although Wasatch continually strives to make our electronics as fault-tolerant as possible to power spikes and drains (electrical fast transients) over both the 5V USB and 12V mains connections, these are sensitive instruments and may enter a failure mode in which the spectrometer ceases to respond over USB.

In this event, the spectrometer should be fully power-cycled (switched off, if it has a power switch, else unplugged for 10 seconds) and the software restarted. The spectrometer should then resume normal operations.

10. Maintenance and Servicing

Wasatch Photonics spectrometers have no user-serviceable parts other than the optional interchangeable coupling assembly.

DO NOT MAKE ADJUSTMENTS TO THE SPECTROMETER OR LASER CONTROL SYSTEMS OTHER THAN THOSE RECOMMENDED IN THIS MANUAL. DOING SO COULD VOID YOUR WARRANTY AND COMPROMISE OPERATOR SAFETY.

Removing the housing or disassembling the spectrometer risks damage to the instrument, invalidates factory calibrations, invalidates the warranty and risks operator injury if laser systems are operated in an uncertified state.

If your product is deemed in need of service or repair, please contact the manufacturer to arrange an RMA (Return Material Authorization) for factory maintenance.

10.1. Cleaning

Fingerprints and other smudges can be removed from exposed optics using KimTech KimWipes or similar glass wipes, in conjunction with isopropyl alcohol (IPA) and cotton swabs.

In the event of a chemical spill or opened sample vial, please refer to the SDS (MSDS) Safety Data Sheet for the compounds in question. In the event that chemicals are released into the interior of the spectrometer, please schedule an RMA for factory service.

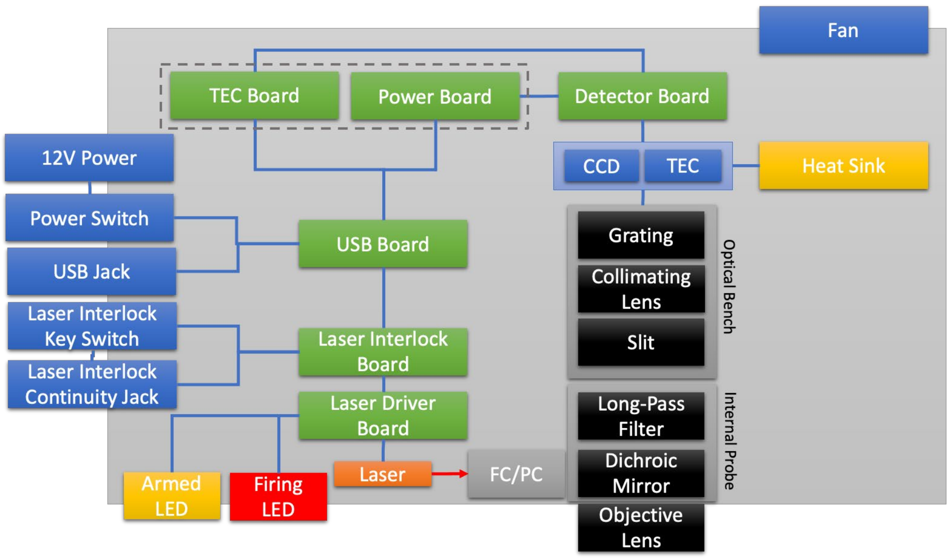
10.2. Replacement Power Transformer

Wasatch Photonics X series spectrometers ship with a 12V “wall-wart” power brick (AC/DC transformer). If yours is damaged or lost you can obtain a replacement from Wasatch (EDAC EA10683N-120).

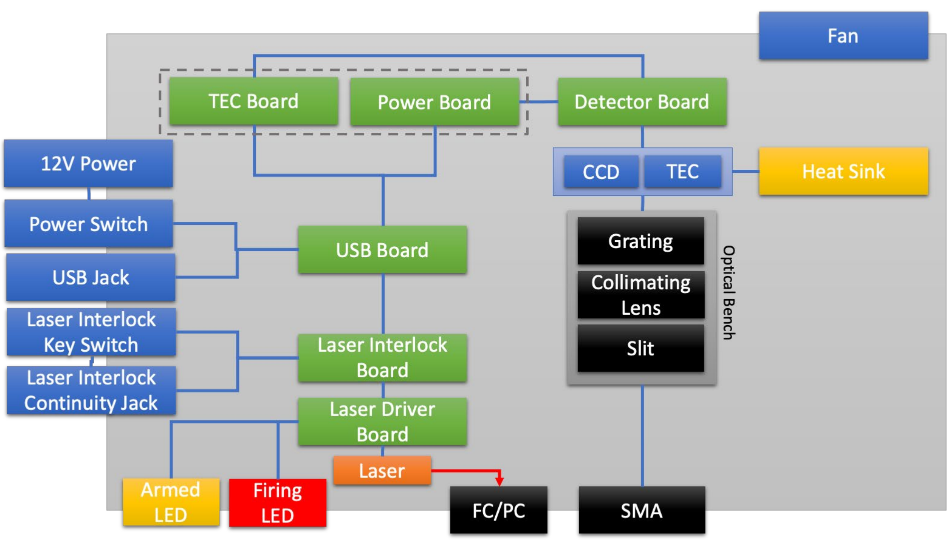
A. Appendix: Block Diagrams

a. Internal Block Diagrams

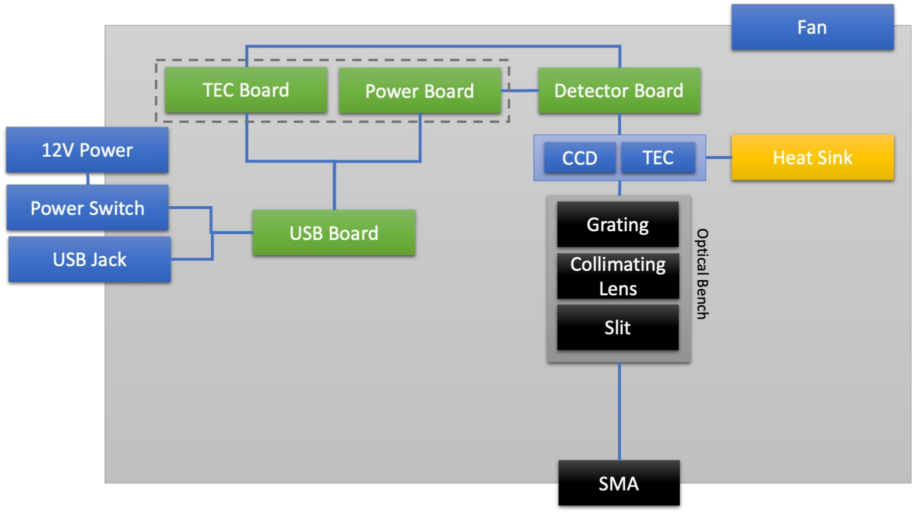
i. ILP (Integrated Laser and Probe)



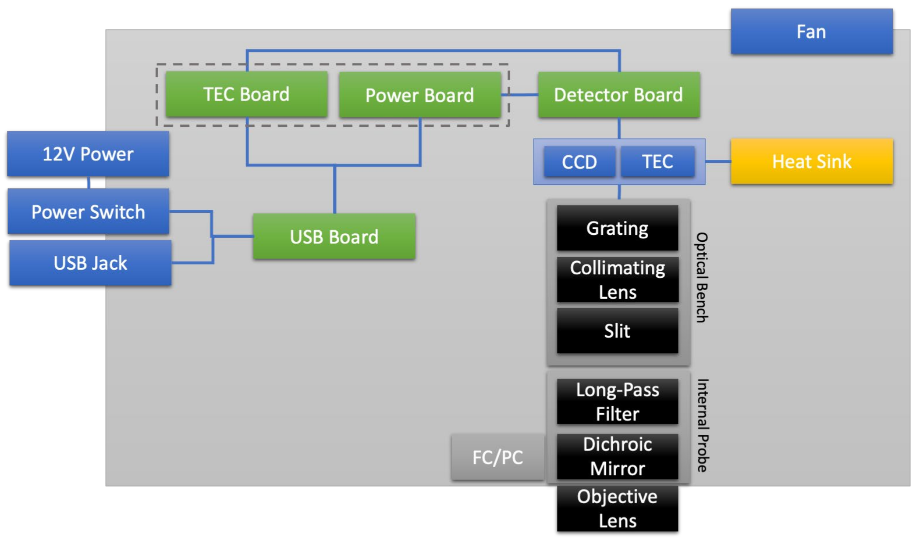
ii. ILC (Integrated Laser and interchangeable Coupling)



iii. IC (Interchangeable Coupling)

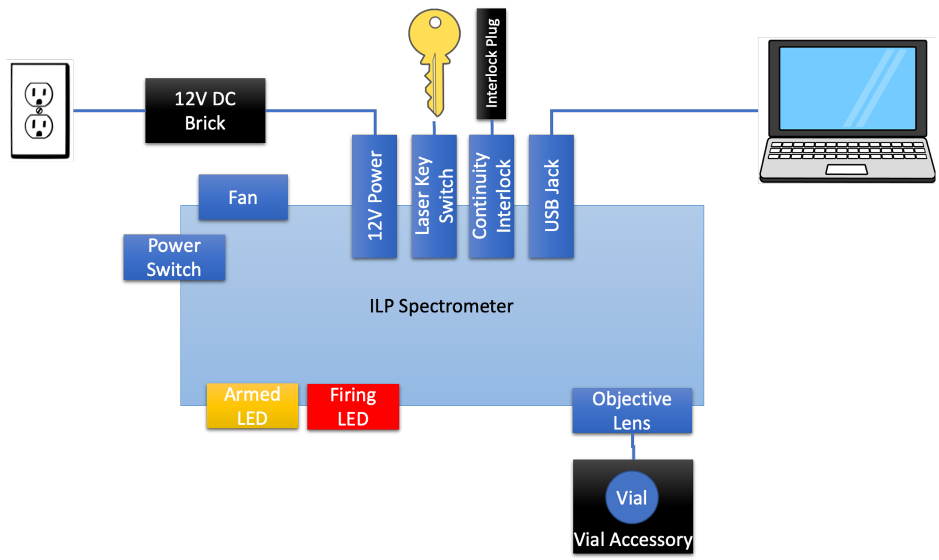


iv. IP (Integrated Probe)

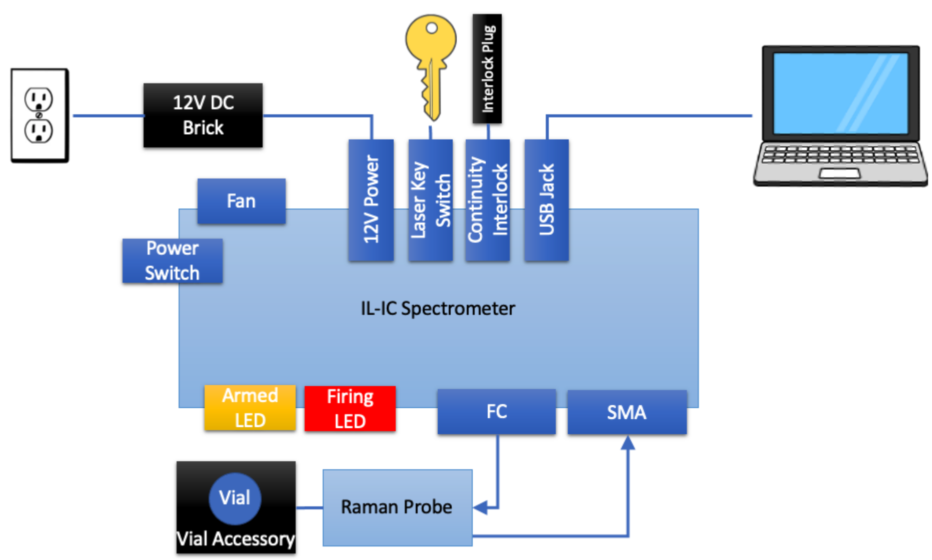


b. External Block Diagrams

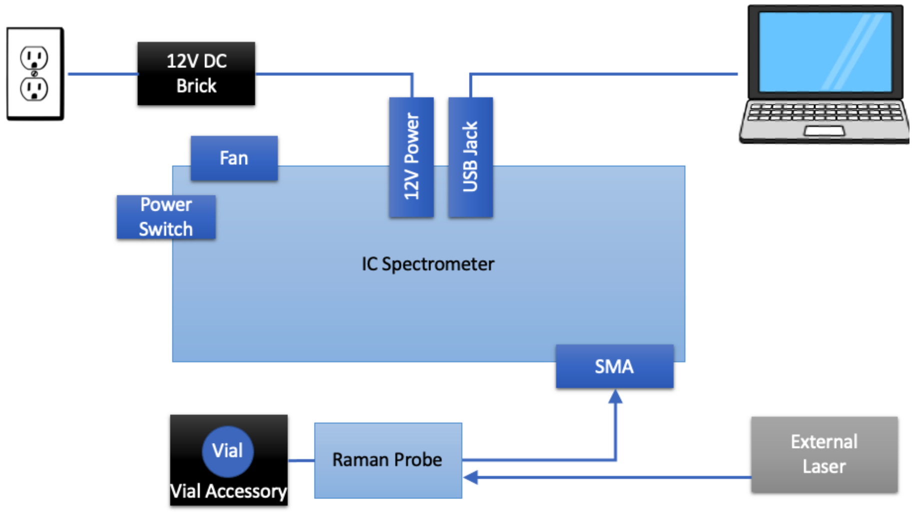
i. ILP (Integrated Laser and Probe)



ii. ILC (Integrated Laser and interchangeable Coupling)



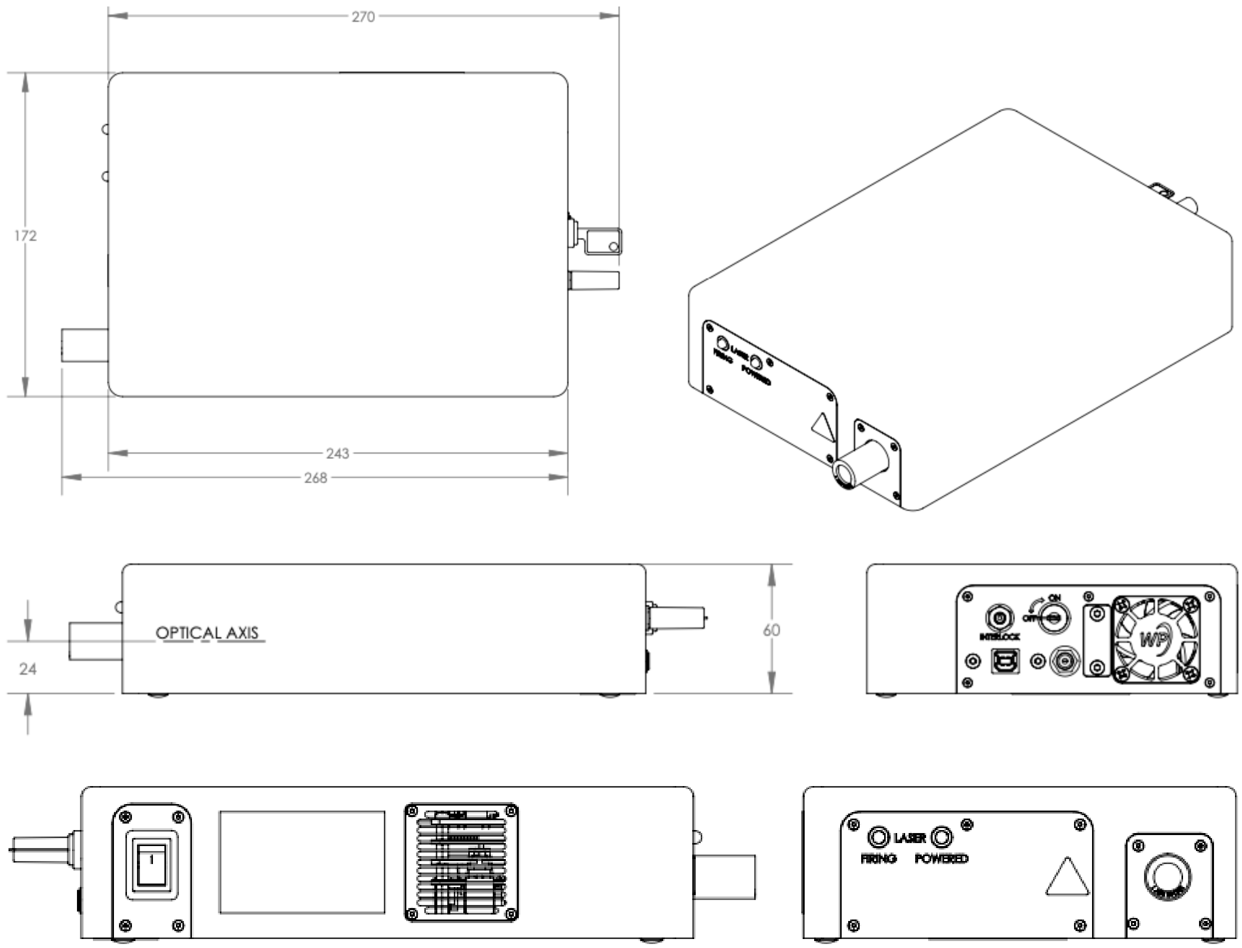
iii. IC (Interchangeable Coupling)

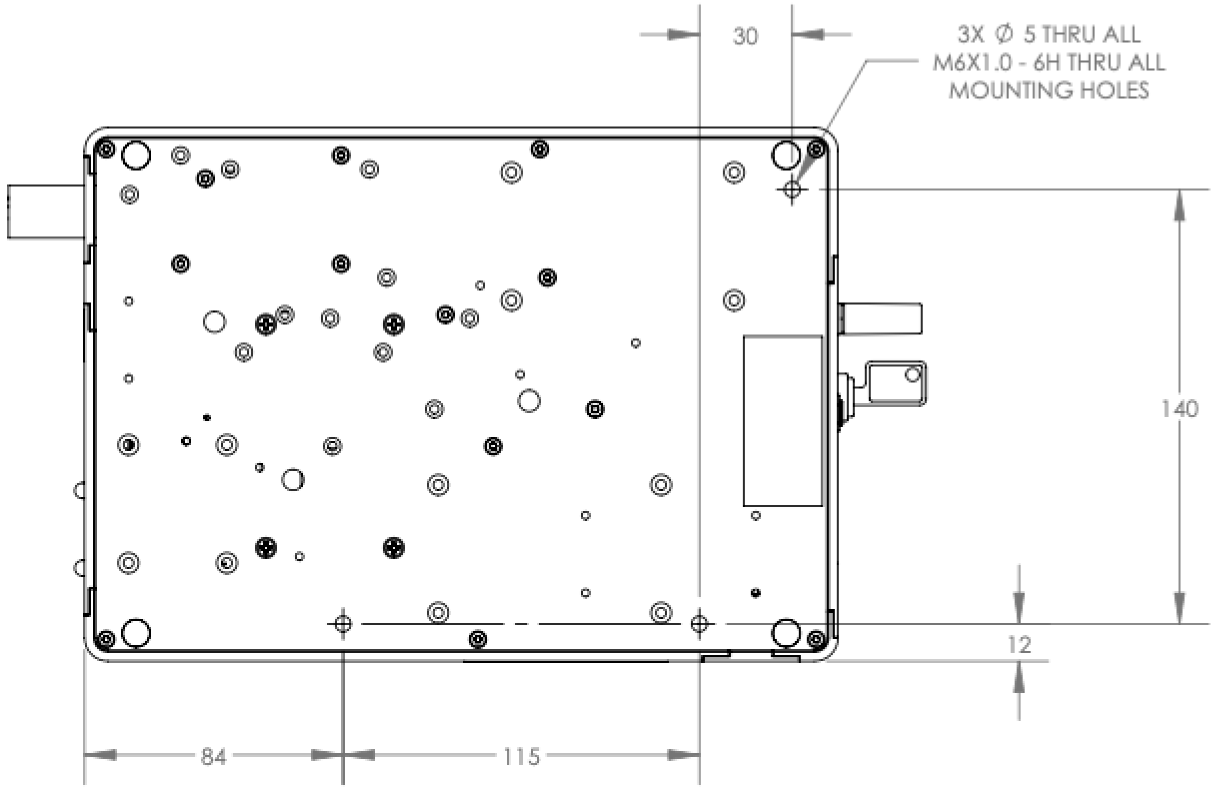


B. Appendix: Mechanical Drawings

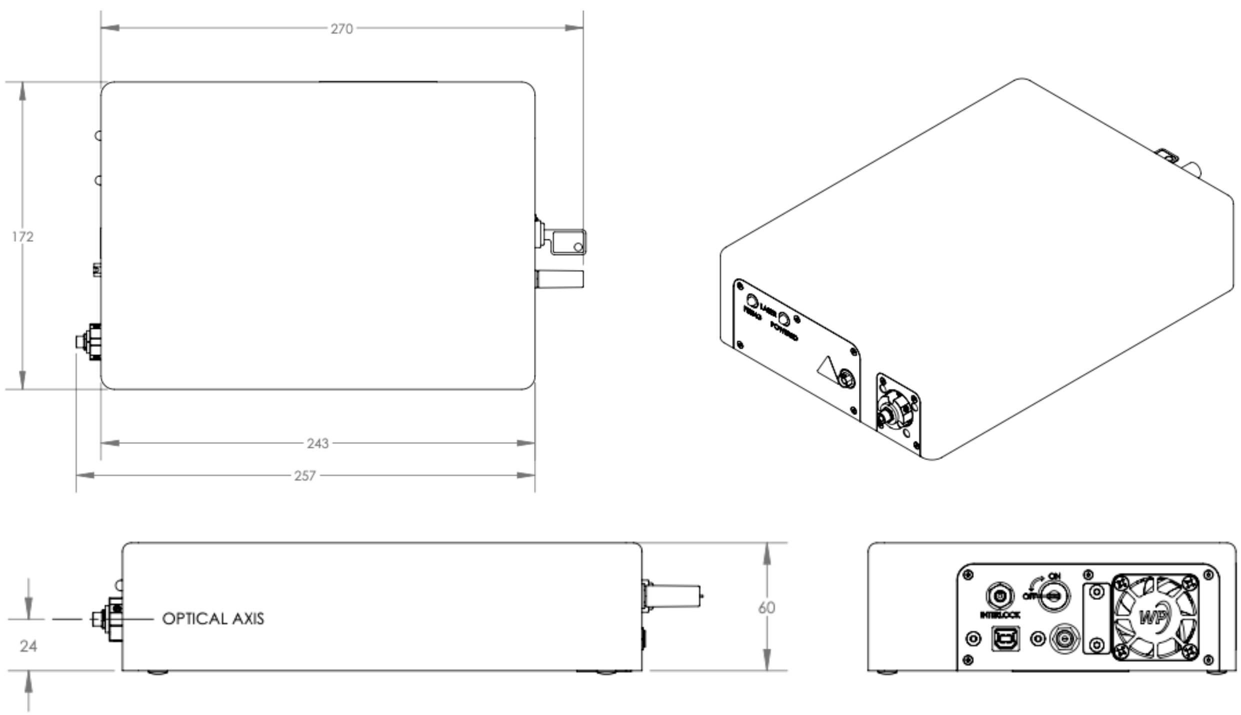
All dimensions are in millimeters (mm).

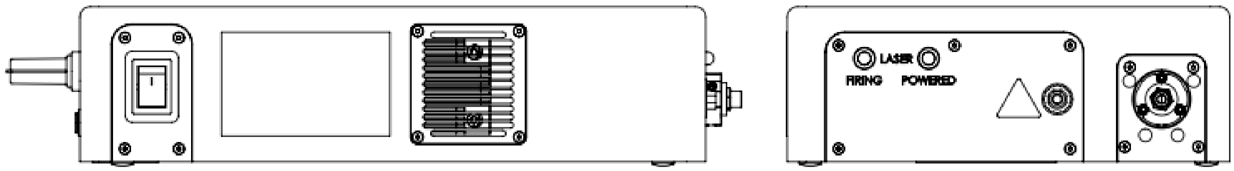
a. ILP (Integrated Laser and Probe)

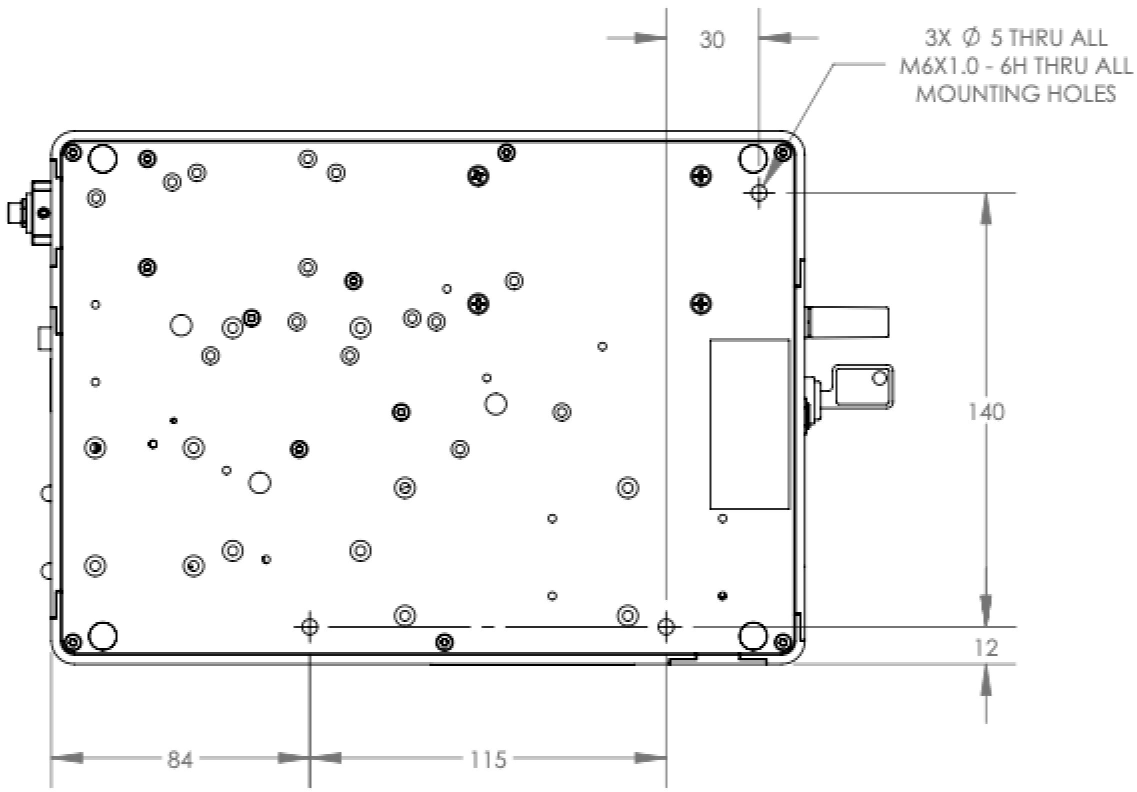




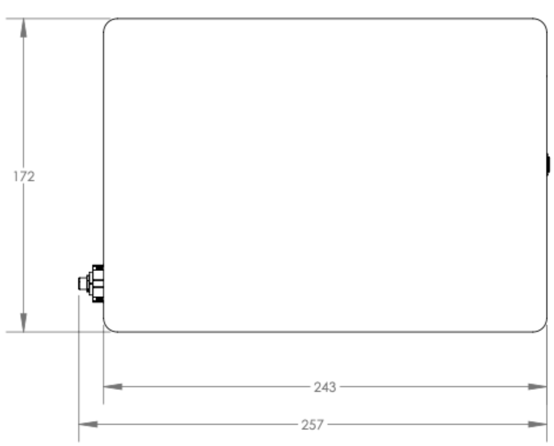
b. ILC (Integrated Laser and interchangeable Coupling)

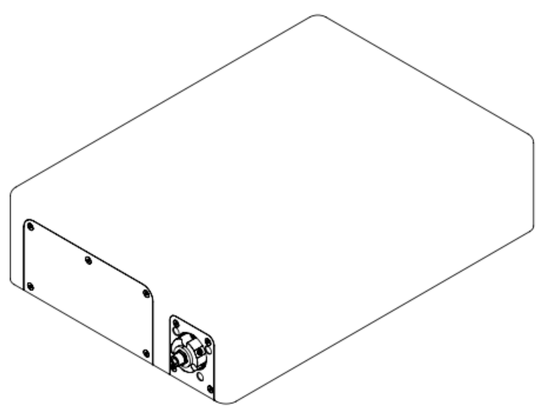


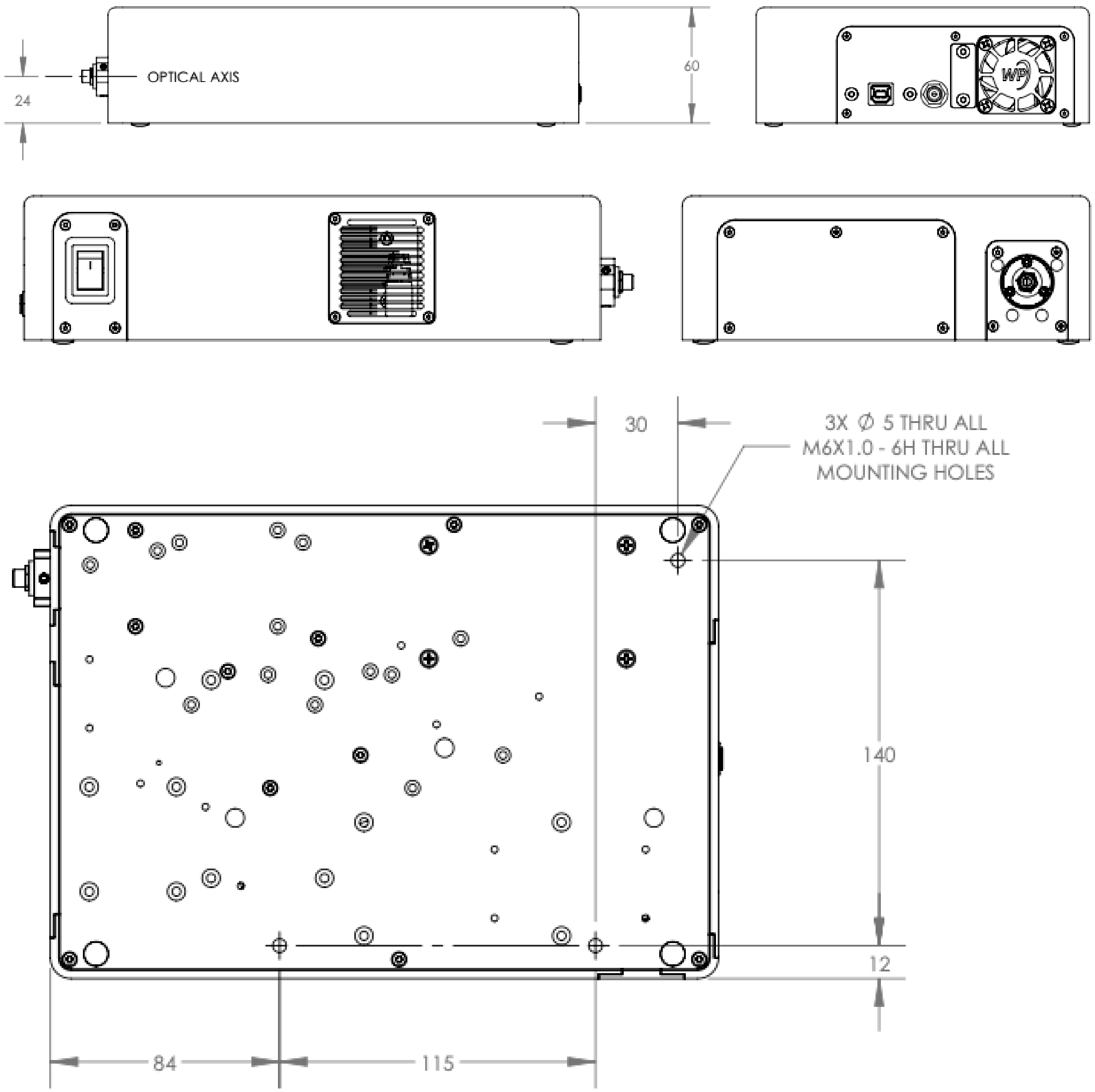




c. IC (Interchangeable Coupling)







d. IP (Interchangeable Probe)

Model available in OEM configuration only. Dimensioned drawings and models available through your sales channel or distributor.

C. Appendix: Housing Labels

Following are reproductions of the labels affixed to the spectrometer housing, should any become worn or unclear.

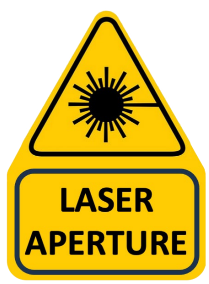
a. Product Identification Label

This label specifies the place and date of manufacture, the unique serial number for your device, the model of your spectrometer (including excitation wavelength, focal ratio, cooling, coupling and slit width).

The template also clarifies the input voltage (12VDC) and current (5A) provided by the DC transformer.

This label is typically applied to the underside of the unit (bottom of the baseplate).

b. Laser Aperture Label



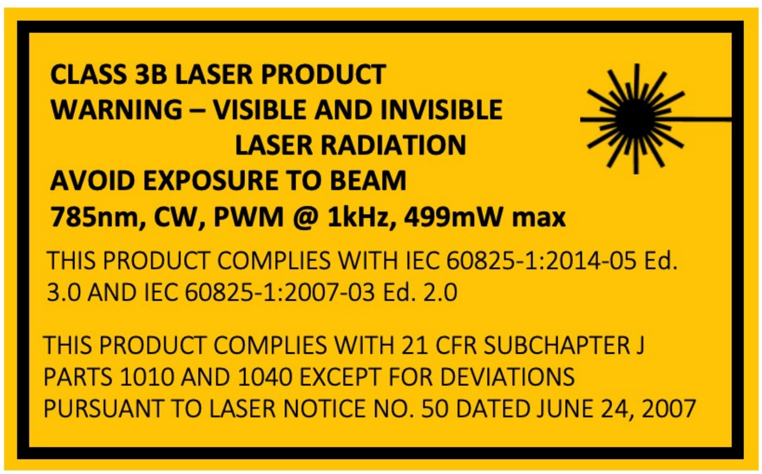
On models containing an integrated laser, this label is placed next to the aperture from which laser radiation is emitted (the objective lens on ILP models, or the FC/PC fiber connector on ILC models).

c. Class 3B Warning Logotype

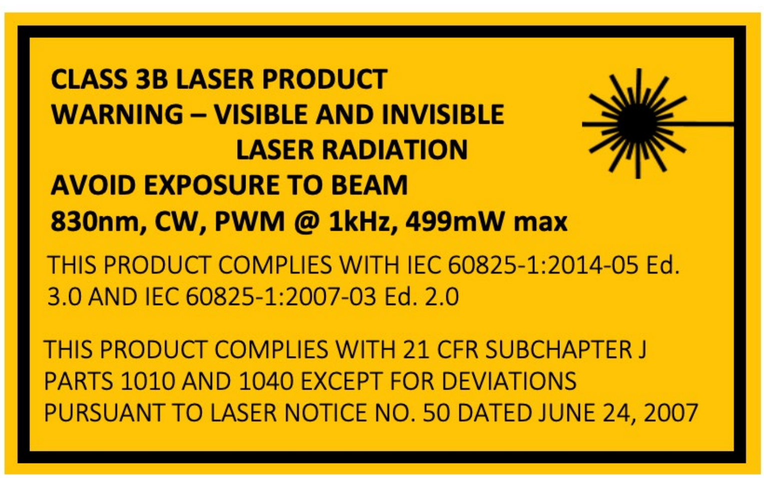
On models containing an integrated laser, this label is placed on the side of the spectrometer's housing. It contains important safety and regulatory information about the spectrometer. Text of the label varies for different excitation wavelengths as shown below.

i. 638nm (ILP and ILC)

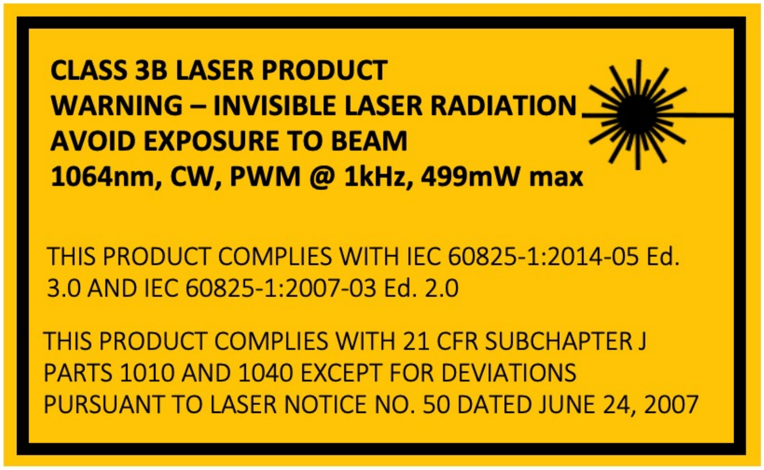
ii. 785nm (ILP and ILC)



iii. 830nm (ILP and ILC)



iv. 1064 (ILP and ILC)



D. Appendix: MPE, NOHD and NHZ

Laser safety makes frequent use of Maximum Permissible Exposure (MPE), Nominal Ocular Hazard Distance (NOHD) and Nominal Hazard Zone (NHZ) metrics. The source tables and equations for these calculations are drawn from IEC 60825-1 Ed. 3.0 2014-05, especially Annex A. This standard can be obtained from various regulatory agencies, including:

- IEC (International Electrotechnical Commission) IEC 60825-1:2014
- ANSI (American National Standards Institute) IEC 60825-1 Ed. 1.2 en:2001

Tip: Although not a regulatory authority, new LSOs (Laser Safety Officers) learning to navigate these equations may wish to utilize the University of Chicago's Laser Safety Calculation Guide (referenced below as UC), which helps "bridge the gap" between MPE (as defined by IEC 60825-1) and NOHD / NHZ.

The following tables contain inputs and computed results for X series Raman Spectrometers (638/785/830X) based on optical design specifications and vendor datasheets.

For source equations in Excel, please submit a request through Wasatch Photonics Product Support. Note that UC equations for NOHD and NHZ are intended for visible lasers, and are not necessarily representative in SWIR.

Note that while these equations, coefficients and beam properties have been drawn from published sources and the results computed per regulatory guidance, operator safety cannot be so easily quantified or amortized.

Due to the criticality of human health and wellbeing, and the variability inherent in both components and the individuals using them, **Wasatch Photonics recommends adding significant margin to these values**, and does not recommend looking directly into an emitted laser beam or direct reflection without appropriate protective gear (goggles) at any range.

a. ILP Models

The following table is applicable for Wasatch Photonics X series ILP spectrometers with integrated laser probes (laser radiation is being emitted from the spectrometer's objective lens).

Parameter (unit)	785X	830X	638X	Reference
Excitation λ (nm)	785	830	638	WP datasheets
Laser Power (mW)	450	450	250	datasheets + power meters
beam divergence (α, full ∠, deg)	12	12	12	6° half-angle
lens focal length (f_0, mm)	25	25	25	Zemax model
beam dia. at lens (b_0, mm)	8.8	8.8	8.8	Zemax model
60825-1 A.1 MPE for C_6 = 1 at the cornea expressed as irradiance or radiant exposure				
Exposure Time (sec)	10.00	10.00	0.25	UC Table 1
C_4	1.48	1.82	1.00	60825-1 Table 9
MPE (J / m²)	1.50E+02	1.84E+02	6.36E+00	60825-1 Table A.1
MPE (W / m²)	1.50E+01	1.84E+01	2.55E+01	unit conversion
MPE (mW / m²)	1.50E+04	1.84E+04	2.55E+04	unit conversion
MPE (mW / cm²)	1.50E+00	1.84E+00	2.55E+00	unit conversion
60825-1 A.2 MPE at the cornea for extended sources in the range (400, 1400nm) (retinal hazard region) expressed as irradiance or radiant exposure				
α (mrad)	209.44	209.44	209.44	unit conversion
α min (mrad)	1.5	1.5	1.5	60825-1 Table 9
α max (mrad)	100.00	100.00	100.00	60825-1 Table 9
C_6	66.67	66.67	66.67	60825-1 Table 9
MPE (J / m²)	9.98E+03	1.23E+04	4.24E+02	60825-1 Table A.2
MPE (W / m²)	9.98E+02	1.23E+03	1.70E+03	unit conversion
MPE (mW / m²)	9.98E+05	1.23E+06	1.70E+06	unit conversion
60825-1 A.3 MPE of A.1 (C_6=1) for λ (400, 1400nm) expressed as power or energy				
MPE Energy (J)	5.82E-03	7.16E-03	2.47E-04	60825-1 Table A.3
60825-1 A.4 MPE of A.1 (extended range) for λ (400, 1400nm) expressed as power or energy				
MPE Energy (J)	3.88E-01	4.78E-01	1.65E-02	60825-1 Table A.4
60825-1 A.5 MPE of the skin to laser radiation				
MPE (J / m²)	2.89E+04	3.56E+04	7.78E+03	60825-1 Table A.5
NOHD for a lens on laser				
NOHD (m)	0.56	0.50	0.32	UC NOHD for lens on laser
NOHD extended (m)	0.07	0.06	0.04	unit conversion
NHZ for laser reflections (0° viewing angle θ, 100% specular reflectance ρ_λ)				
Diffuse Radius (cm)	9.78	8.82	5.59	UC NHZ
Specular Radius (m)	93.29	84.10	53.32	UC NHZ

b. ILC Models (FC/PC Connector)

The following table applies to X series ILC units in which no Raman probe has been connected (laser energy is being measured directly out of the FC/PC spectrometer port).

Parameter (unit)	785X	830X	638X	Reference
Excitation λ (nm)	785	830	638	WP datasheets
Laser Power (mW)	450	450	250	datasheets + power meters
beam divergence (α, full ∠, deg)	12	12	12	6° half-angle
60825-1 A.1 MPE for C_6 = 1 at the cornea expressed as irradiance or radiant exposure				
Exposure Time (sec)	10.00	10.00	0.25	UC Table 1
C_4	1.48	1.82	1.00	60825-1 Table 9
MPE (J / m²)	1.50E+02	1.84E+02	6.36E+00	60825-1 Table A.1
MPE (W / m²)	1.50E+01	1.84E+01	2.55E+01	unit conversion
MPE (mW / m²)	1.50E+04	1.84E+04	2.55E+04	unit conversion
60825-1 A.2 MPE at the cornea for extended sources in the range (400, 1400nm) (retinal hazard region) expressed as irradiance or radiant exposure				
α (mrad)	209.44	209.44	209.44	unit conversion
α min (mrad)	1.5	1.5	1.5	60825-1 Table 9
α max (mrad)	100.00	100.00	100.00	60825-1 Table 9
C_6	66.67	66.67	66.67	60825-1 Table 9
MPE (J / m²)	9.98E+03	1.23E+04	4.24E+02	60825-1 Table A.2
MPE (W / m²)	9.98E+02	1.23E+03	1.70E+03	unit conversion
MPE (mW / m²)	9.98E+05	1.23E+06	1.70E+06	unit conversion
60825-1 A.3 MPE of A.1 (C_6=1) for λ (400, 1400nm) expressed as power or energy				
MPE Energy (J)	5.82E-03	7.16E-03	2.47E-04	60825-1 Table A.3
60825-1 A.4 MPE of A.1 (extended range) for λ (400, 1400nm) expressed as power or energy				
MPE Energy (J)	3.88E-01	4.78E-01	1.65E-02	60825-1 Table A.4
60825-1 A.5 MPE of the skin to laser radiation				
MPE (J / m²)	2.89E+04	3.56E+04	7.78E+03	60825-1 Table A.5
NOHD for visible laser with no lens or fibers				
NOHD (m)	0.93	0.84	0.53	UC Determination of NOHD
NOHD extended (m)	0.11	0.10	0.07	unit conversion
NHZ for laser reflections (0° viewing angle θ, 100% specular reflectance ρ_λ)				
Diffuse Radius (cm)	9.78	8.82	5.59	UC NHZ
Specular Radius (m)	93.29	84.10	53.32	UC NHZ

c. ILC Models (Raman Probe)

The following table applies to X series ILC units fiber-coupled to an external Raman probe, where laser radiation is being emitted through the external probe's objective lens.

Parameter (unit)	**785X**	**830X**	**638X**	**Reference**
Excitation λ (nm)	785	830	638	WP datasheets
Laser Power (mW)	300	300	150	datasheets + power meters
beam divergence (α, full ∠, deg)	37.26	37.26	37.26	6° half-angle
lens focal length (f_0, mm)	11.44	11.44	11.44	Zemax model
beam dia. at lens (b_0, mm)	5	5	5	Zemax model
60825-1 A.1 MPE for C_6 = 1 at the cornea expressed as irradiance or radiant exposure				
Exposure Time (sec)	10.00	10.00	0.25	UC Table 1
C_4	1.48	1.82	1.00	60825-1 Table 9
MPE (J / m²)	1.50E+02	1.84E+02	6.36E+00	60825-1 Table A.1
MPE (W / m²)	1.50E+01	1.84E+01	2.55E+01	unit conversion
MPE (mW / m²)	1.50E+04	1.84E+04	2.55E+04	unit conversion
60825-1 A.2 MPE at the cornea for extended sources in the range (400, 1400nm) (retinal hazard region) expressed as irradiance or radiant exposure				
α (mrad)	209.44	209.44	209.44	unit conversion
α min (mrad)	1.5	1.5	1.5	60825-1 Table 9
α max (mrad)	100.00	100.00	100.00	60825-1 Table 9
C_6	66.67	66.67	66.67	60825-1 Table 9
MPE (J / m²)	9.98E+03	1.23E+04	4.24E+02	60825-1 Table A.2
MPE (W / m²)	9.98E+02	1.23E+03	1.70E+03	unit conversion
MPE (mW / m²)	9.98E+05	1.23E+06	1.70E+06	unit conversion
60825-1 A.3 MPE of A.1 (C_6=1) for λ (400, 1400nm) expressed as power or energy				
MPE Energy (J)	5.82E-03	7.16E-03	2.47E-04	60825-1 Table A.3
60825-1 A.4 MPE of A.1 (extended range) for λ (400, 1400nm) expressed as power or energy				
MPE Energy (J)	3.88E-01	4.78E-01	1.65E-02	60825-1 Table A.4
60825-1 A.5 MPE of the skin to laser radiation				
MPE (J / m²)	2.89E+04	3.56E+04	7.78E+03	60825-1 Table A.5
NOHD for a lens on laser				
NOHD (m)	0.37	0.33	0.20	UC NOHD for lens on laser
NOHD extended (m)	0.04	0.04	0.02	unit conversion
NHZ for laser reflections (0° viewing angle θ, 100% specular reflectance ρ_λ)				
Diffuse Radius (cm)	7.99	7.20	4.33	UC NHZ
Specular Radius (m)	24.53	22.12	13.30	UC NHZ

d. Continuous Wave PWM vs "Pulsed"

When computing laser safety parameters, it is important to distinguish between Continuous Wave (CW) lasers and "pulsed" lasers. All Wasatch Photonics integrated lasers are Continuous Wave (CW) solid-state diode lasers.

Pulsed lasers use an excitation medium which must be pulsed (pumped) at some rate to build up photons within a sealed resonance chamber, and then an optical switch (typically a Q-switch such as a Pockels cell) is used to briefly open the chamber and release the photons in a single high-energy pulse. This is significant in laser safety because, although the "average power" of a pulsed laser may seem moderate when measured over time, the "instantaneous power" of an individual (though brief) pulse can be quite intense.

In contrast, continuous wave diode lasers generate photons continuously in an open resonance chamber such that, while energized, laser energy is emitted from the chamber in an unbroken stream. While Wasatch spectrometers do allow CW laser power to be attenuated via Pulsed-Width Modulation (PWM), that is not the same as a pulsed laser. Unlike a pulsed laser which seals the resonance chamber between pulses, and deliberately builds up a brief but intense charge of photons for spontaneous release, PWM literally unpowers the diode between bursts. Therefore, the power output of an individual burst does not exceed "average power" (within standard inrush / stabilization noise).

E. Appendix: Electrical Connectors and Pin-outs

a. 12VDC Power

The 12V power connector on the back face of the spectrometer is a CUI Devices PJ-064B 2.5x5.5mm barrel jack (DigiKey CP-064B-ND).

Users are *strongly* recommended to use the included 12V transformer, as it has been rigorously tested to ensure it satisfactorily protects the spectrometer from electrical aberrations arriving through mains, and in turn protects the mains circuit from electrical disturbances coupled through the spectrometer or USB cable.

b. USB

USB communications are supported through a standard-B USB socket on the rear of the spectrometer. Any standard-B USB cable should work for communications, but all electrical testing was performed with cables of 2m length or less (longer cables may allow additional noise to couple into the system).

c. Remote Laser Interlock

This jack uses a standard stereo audio plug connector (CUI Devices SP-3540A, DigiKey 102-4779-ND).

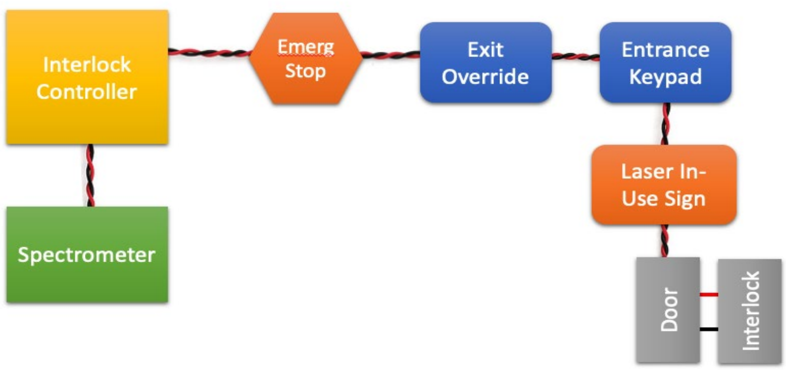
F. Appendix: Remote Interlock Sample Configurations

The Remote Interlock is a two-wire "continuity circuit" that can be wired into your laser lab's existing safety features. Two sample configurations are described below; work with your facility's Laser Safety Officer to design a safety system appropriate to your equipment and measurement.

In each configuration, an interlock controller is used as the central hub of the laser safety system. It connects the continuity circuit, in series, to an "Emergency Stop" button, an "Exit Override" timer, a door interlock, and an "Entry Override" keypad. In the External Laser configuration, the interlock circuit also connects to an interlocked power strip. If any of the elements in this chain cause the circuit to be "open," the laser will be prevented from firing.

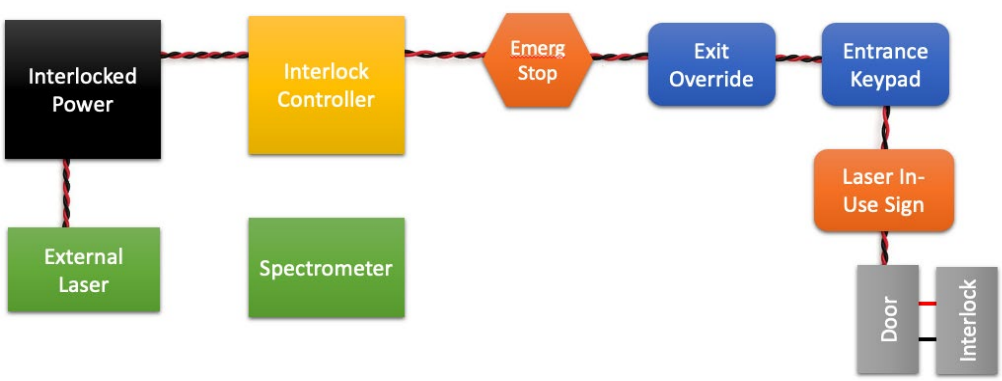
Photos of tested vendor products for each node are included at the end of the appendix.

a. Configuration 1: Integrated Laser (Remote Interlock)



For Wasatch Raman spectrometers with an integrated laser (ILP or ILC models), the remote interlock can be wired directly to the Interlock Controller.

b. Configuration Two: External Laser



If your external laser has a continuity interlock connector, you can wire that directly to the Interlock Controller. Alternatively, you can use an interlocked power switch to control power to any external light source, as shown above.

c. Tested Vendor Products

[LaserMet ICS-6-24 ELISe Interlock Controller]()

LaserMet ICS-KP14 Entry Keypad

LaserMet IS-MDC-12 Door Interlock

LaserMet Door Signs

LaserMet ICS-OR-PB Exit Override

Digital Loggers IoT Power Relay