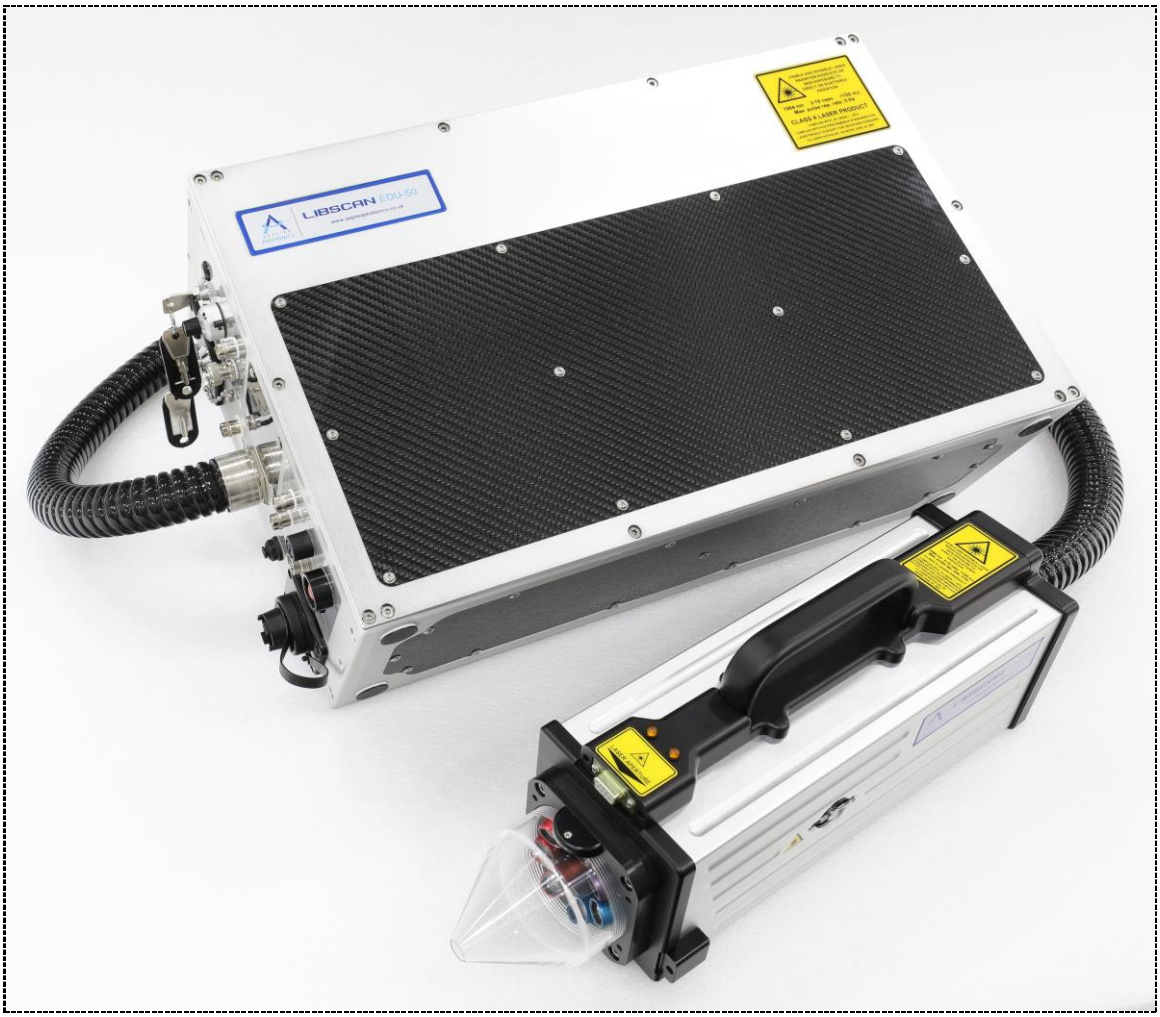
LIBSCAN EDU-50™

Portable, Modular LIBS Instrument For Educational Establishments



User's Manual

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APPLIED PHOTONICS

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1 Introduction

LIBSCAN EDU-50 is a competitively priced, full-feature modular LIBS instrument with an integrated compact Q-switched Nd:YAG laser operating at 1064 nm. It is designed primarily for use by educational establishments with the aim of helping to introduce students to Laser-Induced Breakdown Spectroscopy (LIBS). ***LIBSCAN EDU-50*** shares many of the design features incorporated in our fully portable ***LIBSCAN 25+*** product, including portability and the modular design principles used in our entire ***LIBSCAN*** range of products. ***LIBSCAN EDU-50*** is designed primarily for classroom or laboratory use but can also be used for field applications such as analysing geological or environmental samples at site where it can be operated for up to 4 hrs from a single charge using its integral Li-Ion battery. Recharging is achieved using a mains plug-in adaptor Li-Ion charger which is supplied with the instrument. The six-channel design of ***LIBSCAN EDU-50*** allows for up to six compact spectrometers to be installed (approx. 185 – 910 nm), depending upon the requirements of the intended application and budget limitations. ***LIBSCAN EDU-50*** can be supplied with an optional imaging camera for recording close-up video / still images of the sample. So that ***LIBSCAN EDU-50*** may be used by persons who may not be trained and experienced in the use of high-power lasers, it has been designed as a Class 1 laser product (i.e. intrinsically laser safe under all reasonably foreseeable conditions – no requirement for the user to don laser protective eyewear) when used with one of our modular sample chambers. In order to meet the international standards for a Class 1 laser product, ***LIBSCAN EDU-50*** includes an interlock system which prevents activation of the laser unless a modular sample chamber is fitted and the sample chamber door is closed. The safety aspects of ***LIBSCAN EDU-50*** are discussed in detail in Section 2.

IMPORTANT NOTE:
LIBSCAN EDU-50 is labelled as a **Class 4 laser product** since it may be used without a sample chamber when the laser safety interlock circuit is overridden using the Interlock Override keyswitch (full details of this are provided later in this User's Manual). To maintain Class 1 laser product status, it is imperative that the Laser Interlock key is removed from the keyswitch (located on the control panel of the instrument) and kept in a secure place by the nominated responsible person (e.g. the Laser Safety Officer). Without this key, it is impossible to activate the laser without the ***LIBSCAN EDU-50*** head being fitted to one of our modular sample chambers and so the equipment meets the requirements of a Class 1 laser product.

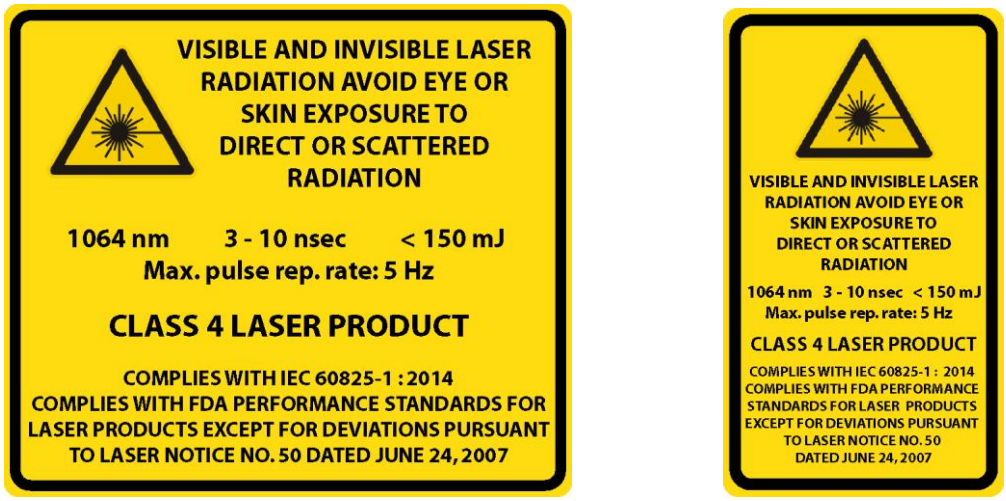
The ***LIBSCAN EDU-50*** is a modular design LIBS system which offers a highly versatile, adaptable and upgradeable product suitable for use either in a laboratory environment or in the field. The modular design is also particularly well-suited to research and development work and hence ***LIBSCAN EDU-50*** will be of value to organisations who wish to conduct their own LIBS R&D program and who may wish, for example, to integrate a LIBS instrument with an industrial process control application. ***LIBSCAN EDU-50*** is available with six plasma light collection channels and so therefore may be used with up to six fully-integrated individual spectrometers. Various types of modular sample chamber are available for ***LIBSCAN EDU-50*** including ones equipped with computer-controlled, multi-axis sample stages.

This User's Manual provides the necessary information needed to configure the integrated ***LIBSCAN EDU-50*** instrument and use it safely. It is assumed that the user will be familiar with the safety issues arising from the use of high-power lasers and will have preferably been trained in the safe use of laser products. Ideally, your organisation will have an appointed Laser Safety Officer, in which case this person should be consulted before operating ***LIBSCAN EDU-50***.

2 Safety

2.1 Laser radiation

LIBSCAN EDU-50 contains a high-power Q-switched Nd:YAG laser (Class 4, nominally 50 mJ @ 1064 nm, 3 - 10 ns pulse length, 1 Hz pulse repetition rate). In view of this, it is imperative the person(s) responsible for the use and maintenance of the equipment is / are suitably trained and experienced and are fully aware of the hazards inherent to this type of high-power laser equipment. It is imperative also that, prior to using the equipment, an appropriate risk assessment is conducted in such a way as to take account of the skill level of the operator, the proposed use of the equipment, the environment in which the equipment is to be operated, and how its use may affect people who are not directly involved with the proposed use of the equipment. Additionally, it is important that the ***LIBSCAN EDU-50*** is checked regularly for damage or incorrect functioning by a person who is suitably experienced in laser safety (e.g. a nominated Laser Safety Officer). The laser safety interlock circuit should be tested each day the ***LIBSCAN EDU-50*** is used. The procedure for this test is explained later in this User's Manual.



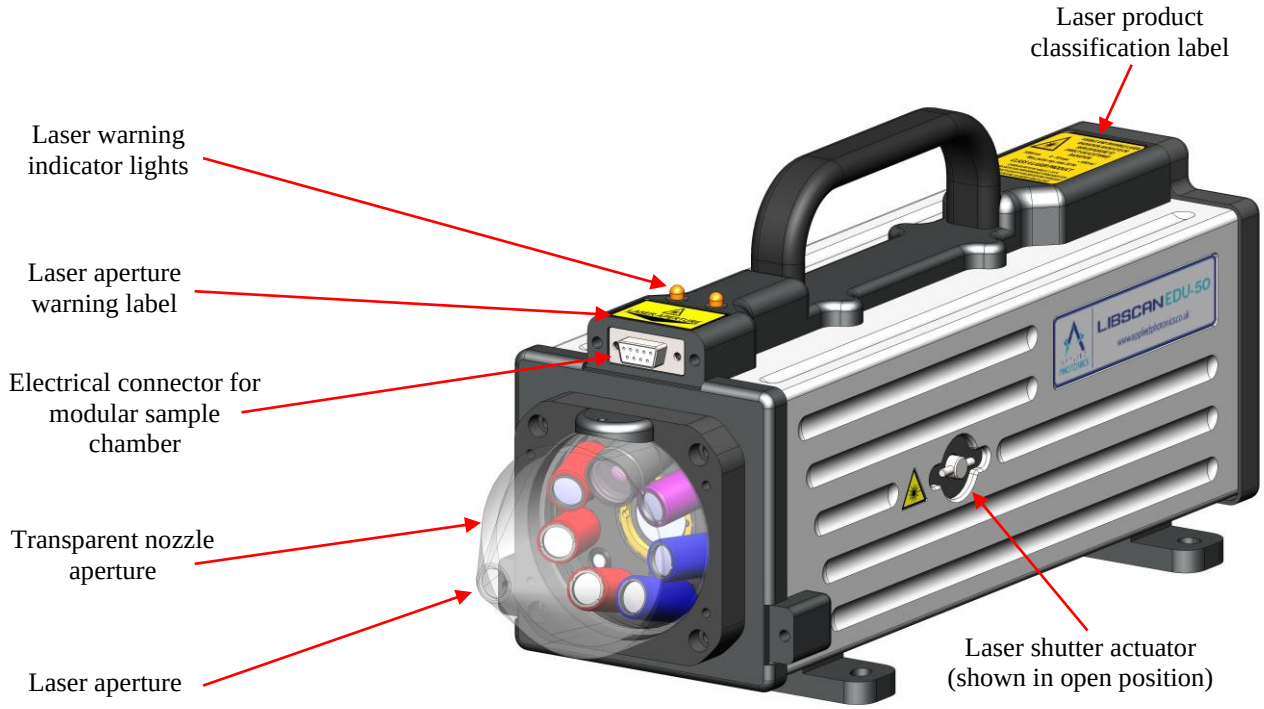
Examples of laser product classification labels used on ***LIBSCAN EDU-50***

LIBSCAN EDU-50 is designed to meet the laser safety requirements of the relevant European standards (BS EN 60825) and USA standards (ANSI Z136.1). Although LIBSCAN EDU-50 is designed to meet Class 1 laser product standards, personal exposure to hazardous levels of laser radiation could occur if the safety interlock is deliberately defeated and/or if any of the safety covers and windows are dismantled and removed. Accordingly, the following warning should be heeded as to the hazards which would exist if the safety features of LIBSCAN EDU-50 are disabled in any way.

The most significant hazard relating to exposure of persons to the laser radiation is eye injury since direct or scattered laser radiation produced by the laser used in LIBSCAN EDU-50 can cause serious and permanent injury to the eyes including blindness - such injury may be instantaneous. All users of LIBSCAN EDU-50 should be made aware of the need not to interfere with the safety features and the risks to personal safety that would exist should the safety features be disabled.

IMPORTANT

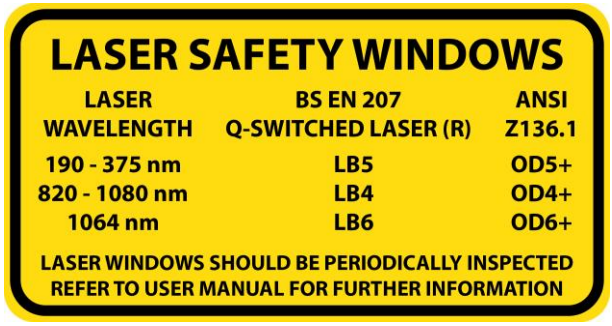
- READ and UNDERSTAND this User's Manual before operating the LIBS equipment.
- ENSURE that an appropriate risk assessment has been conducted to establish whether or not the laser safety windows fitted to the modular sample chambers provide adequate protection against exposure to laser radiation **for the specific laser you intend to use with the LIBS equipment**. For advice on this matter, consult your Laser Safety Officer and/or Applied Photonics Ltd.
- ONLY suitably qualified and authorised persons should activate the Interlock Override keyswitch. The key should be removed from the keyswitch and held by the Laser Safety Officer when this feature is not required.
- ALWAYS use appropriate laser safety protective eyewear when operating the LIBS equipment in "open-beam" configuration – you should seek advice from your Laser Safety Officer on this matter.
- ALWAYS switch the laser off when not in use and remove the key from the keyswitch of the laser power supply to prevent unauthorised activation.
- ALWAYS thoroughly inspect the LIBS equipment for damage prior to use. Particular attention should be given to the laser safety windows and the laser safety interlock system, which should be tested each time the equipment is used.
- NEVER allow unauthorised and/or untrained persons to operate the LIBS equipment.
- NEVER operate the LIBS equipment in areas where explosive gas mixtures may be present.
- NEVER operate the LIBS equipment with any access cover, panel, or protective window removed.
- NEVER place inside the sample chamber flammable liquids or any other material which may give rise to flammable / explosive gas mixtures. Activation of the laser under these conditions could result in an explosion leading to severe personal injury and/or fire hazard. Remember that the laser-induced plasma is a source of ignition.
- NEVER point the LIBS laser beam at a person (even with laser switched off), especially towards the eyes, even if the person is wearing laser safety eyewear. **The laser should be considered "active" unless the laser key switch is switched off and the safety shutter fitted to the LIBSCAN EDU-50 head is switched to the CLOSED position**.
- NOTE that the transparent acrylic nozzle aperture of the LIBSCAN EDU-50 head does not provide any protection to the user against exposure to direct or scattered laser radiation. The function of the nozzle aperture is described later in this User's Manual.



CAD image of LIBSCAN EDU-50 head showing location of laser warning indicator light, laser aperture, laser warning labels, laser shutter actuator and the electrical connector interface for the modular sample chamber

2.2 Note on the laser safety window material used in the modular sample chambers

The laser safety window material fitted to the modular sample chambers is rated as follows:



R LB6 at 1064 nm indicates a protection level of maximum spectral transmittance of 10^{-6} at 1064 nm for a pulsed laser of pulse length 10^{-9} – 10^{-7} seconds (ie. a Q-switched laser). The laser safety windows used in Applied Photonics Ltd's range of modular sample chambers provide adequate protection against reflected and/or scattered laser light of wavelength 1064 nm, 355 nm and 266 nm such that Class 1 Accessible Emission Limits are met if the sample chamber is fitted and used correctly.

If in any doubt, you should consult your Laser Safety Officer and/or Applied Photonics Ltd for advice on this matter.

Warning – the Applied Photonics Ltd modular sample chambers are designed specifically for use with our LIBSCAN (and our LIBS-6 / LIBS-8 integrated LIBS modules) range of products and should not be used with any other laser device or product. Additionally, LIBSCAN EDU-50 must only be used with one of Applied Photonics Ltd's range of modular sample chambers. If in doubt, seek advice from the manufacturer, Applied Photonics Ltd.

2.3 Electrical

The majority of internal electrical components within the ***LIBSCAN EDU-50*** instrument operate at a nominal voltage of 12 VDC at a maximum current of approximately 3.0 Amp. The integrated laser and associated power supply operate at voltages of up to 1000 VDC. Accordingly, there exists an electric shock risk should the equipment be dismantled. There are no user serviceable components within the ***LIBSCAN EDU-50*** instrument and so the equipment should not be dismantled (doing so will void the warranty and expose the user to an electrical and/or laser radiation hazard). For servicing and repairs, the equipment should be returned to the manufacturer or an authorised agent.

3 General description

3.1 Overview

The main components of ***LIBSCAN EDU-50*** with an SC-2L modular sample chamber are illustrated in the following figure.

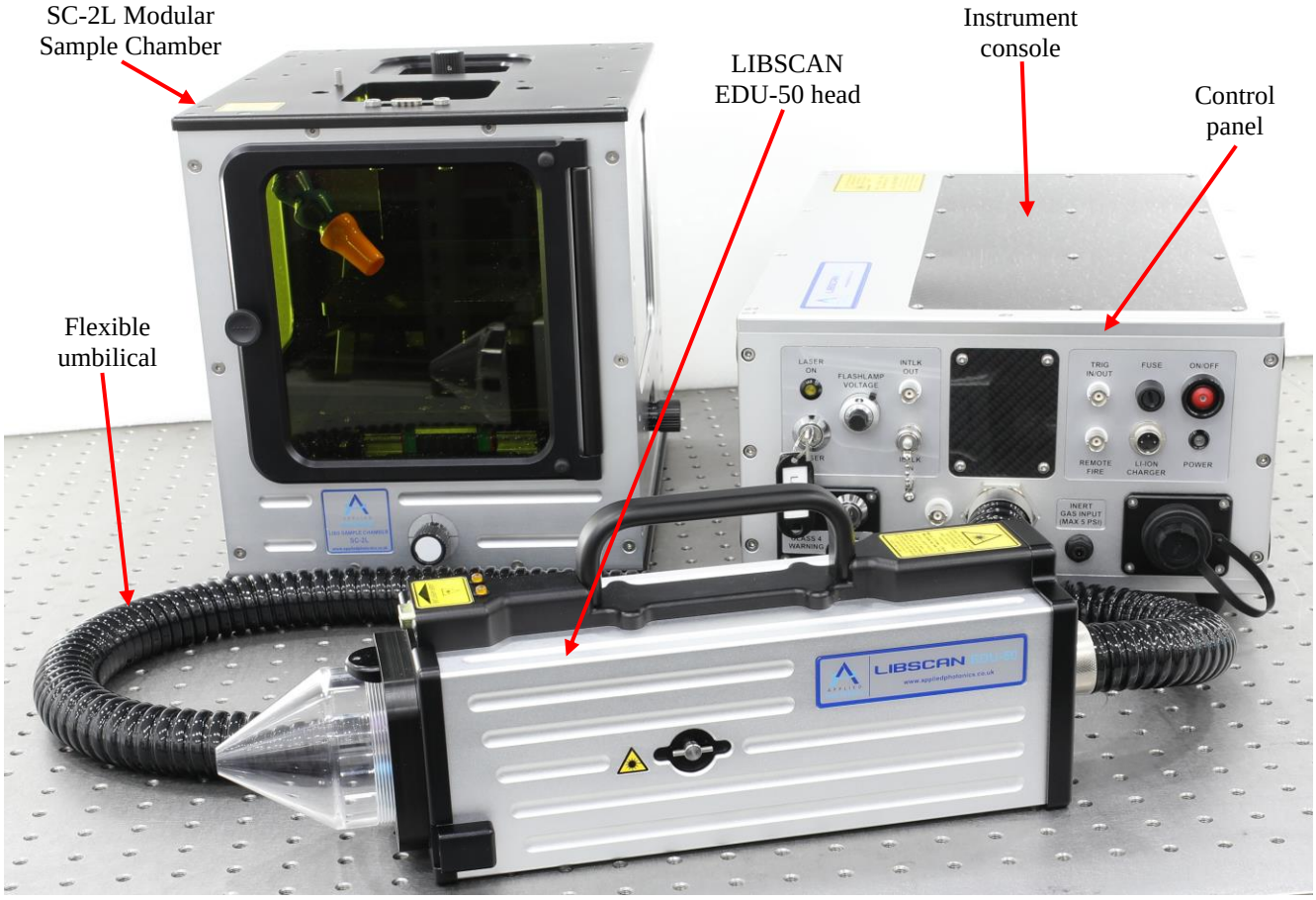
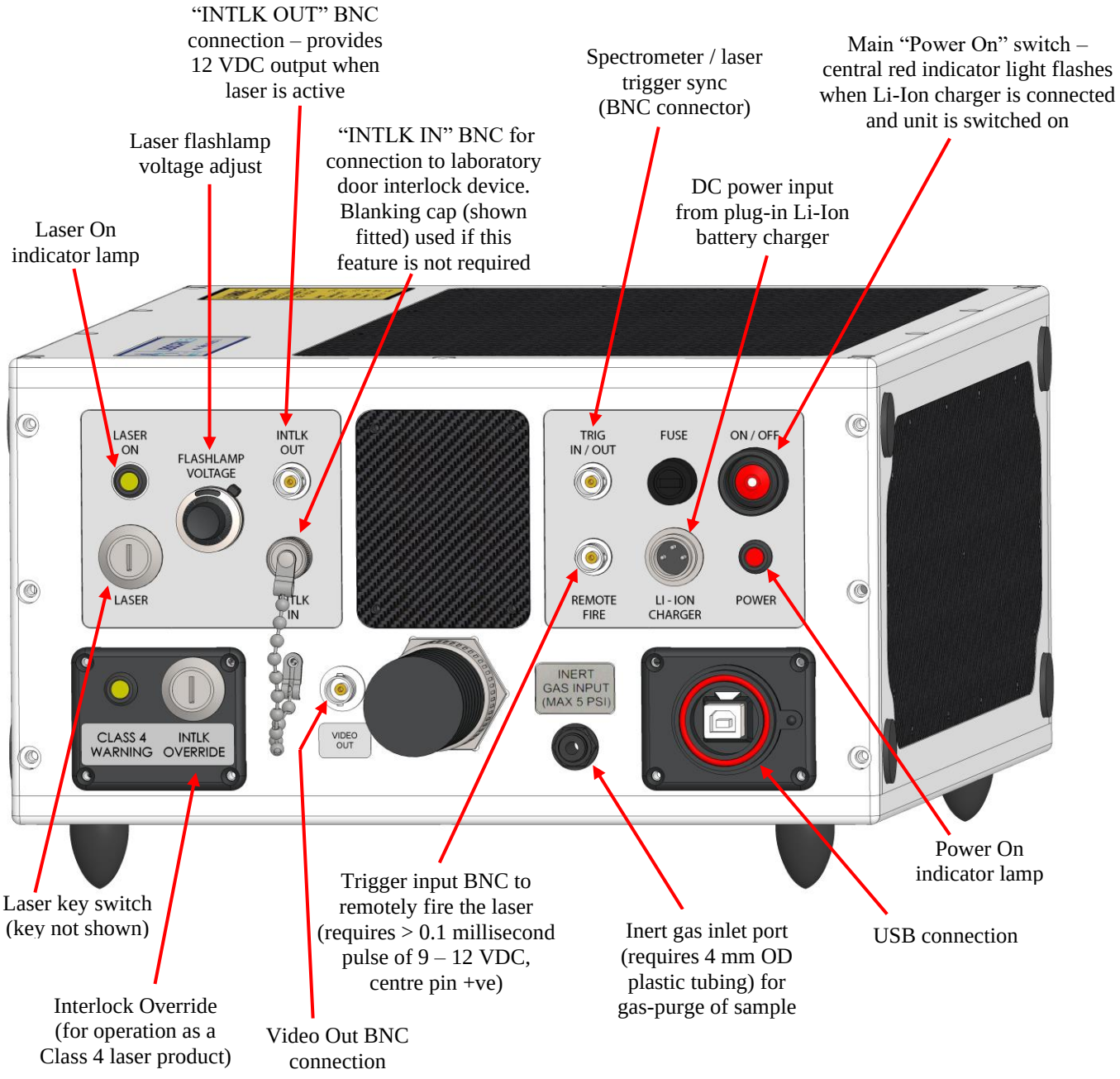


Image illustrating the main components of the ***LIBSCAN EDU-50*** instrument with SC-2L modular sample chamber

The instrument console contains the optical spectrometers (up to six spectrometers may be installed), the laser power supply, the Li-Ion battery, and various electrical / electronic components. The ***LIBSCAN EDU-50*** head contains the laser, the laser beam expander optics, the plasma light collection optics, a miniature colour video camera (optional item) and various other components associated with the safe operation of the equipment. The ***LIBSCAN EDU-50*** head is permanently connected to the instrument console via a flexible umbilical of length ~1.3 metres. The umbilical contains the optical fibres used to transmit the plasma light to the spectrometers, and the electrical cabling for the laser and other electrical components within the head. The control panel provides the various switches and electrical connections associated with the operation of the instrument.

3.2 Instrument console and control panel



Interlock Override

The Interlock Override keyswitch located on the control panel of the ***LIBSCAN EDU-50*** console is used to override or disable the laser safety interlock when the ***LIBSCAN EDU-50*** is required to be used in an "open beam" configuration (i.e. without a sample chamber). This is a specialised use for the LIBS equipment where it becomes a **Class 4 laser product** and so must be used in a suitably controlled environment such as a laser laboratory and only by persons trained in the use of Class 4 lasers. Appropriate Personal Protective Equipment (PPE) such as laser protective eyewear will be required when using ***LIBSCAN EDU-50*** with the laser safety interlock circuit disabled by the Interlock Override keyswitch. To override the laser safety interlock, the keyswitch should be turned "on" by turning clock-wise. The orange / yellow LED indicator to the left of the keyswitch (labelled Class 4 Warning) will flash continuously when the interlock override keyswitch is activated. When the keyswitch is set to "off), the LED will be extinguished indicating that the laser safety interlock is operating. The key should be removed from the Interlock Override keyswitch to prevent unauthorised activation of the interlock

override. Consult your Laser Safety Officer regarding where this key should be stored. If you are in any doubt over the safe use of the Interlock Override, you should remove the key and store it in a secure place so that operators of the LIBS equipment cannot access it. Further guidance on this and other laser safety matters can be obtained by contacting Applied Photonics Ltd.

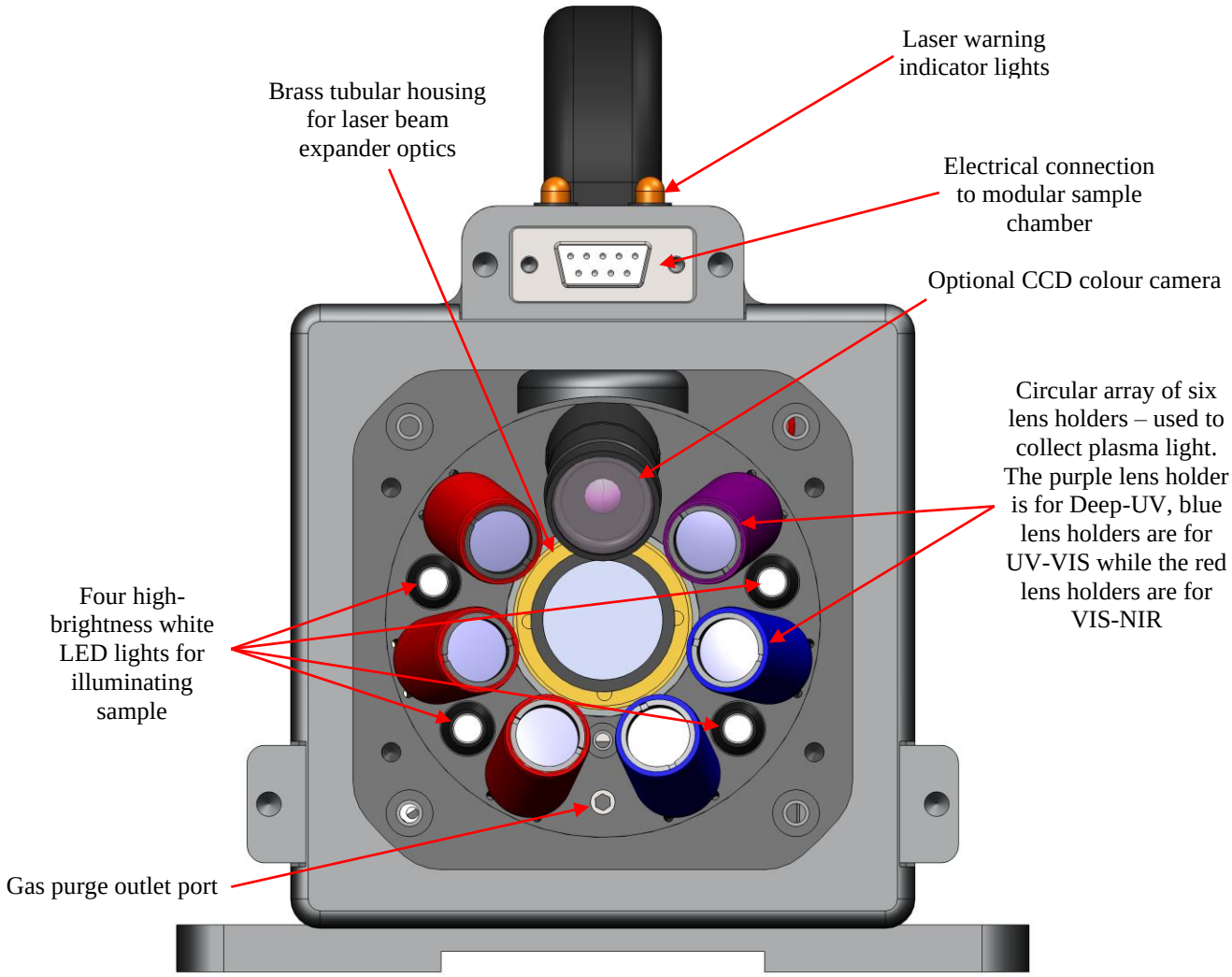
3.3 LIBSCAN EDU-50 head

The ***LIBSCAN EDU-50*** head contains the laser and associated optics required to focus the laser beam on to a sample and collect the plasma light for transmission to the spectrometers located within the spectrometer console. The head is also designed to accommodate a miniature CCD camera and associated components used with the optional imaging kit. The main features of the ***LIBSCAN EDU-50*** head fitted with the optional imaging kit are illustrated in the following figures. Use of the transparent nozzle aperture allows the operator to view the laser plasma even when a sample is placed up against the aperture.

It is not necessary to have an nozzle aperture fitted to the ***LIBSCAN EDU-50*** head although it is beneficial to do so as it provides the following functions: i) facilitates correct positioning of the sample being analysed, ii) helps to direct the purge gas (if used) to the region in space where the laser plasma will be formed, and iii) provides protection for the optics etc against accidental mechanical damage.

LIBSCAN EDU-50 head with nozzle aperture removed

LIBSCAN EDU-50 head with nozzle aperture fitted



Front view of ***LIBSCAN EDU-50*** head showing six-channel plasma light collection lens array, optional CCD camera, LED lights, laser aperture and gas purge outlet port

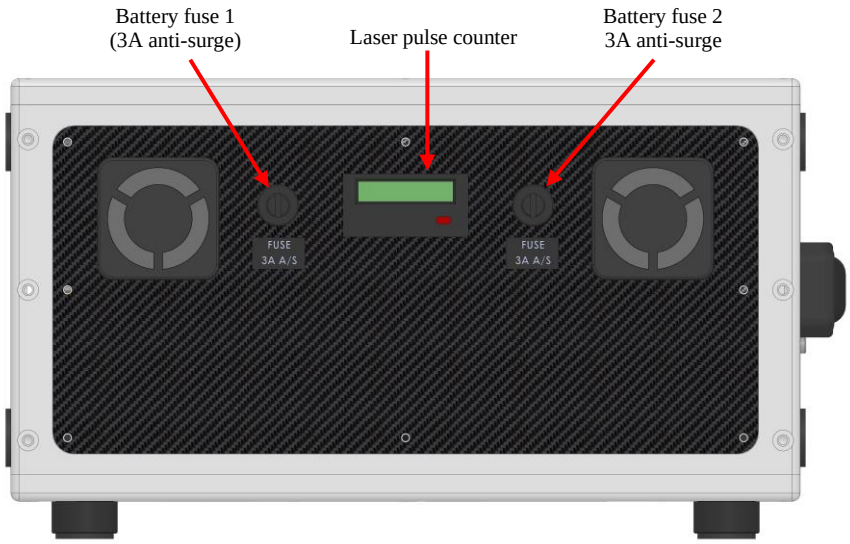
3.4 The integrated pulsed laser

The integrated laser is a passively Q-switch Nd:YAG operating at 1064 nm with a nominal output pulse energy of 50 mJ. The actual output pulse energy will vary from laser to laser and may be as high as 70 mJ – the test report supplied with each ***LIBSCAN EDU-50*** will specify the actual laser pulse energy. The shot-to-shot variation in pulse energy is typically better than 10% (stability measurements are detailed in the Test Report supplied with the ***LIBSCAN EDU-50***). Note that it is not possible to adjust the laser pulse energy due to the design of the laser. Provision has been made for the user to adjust the flashlamp voltage (10-turn potentiometer with dial indicator located on control panel of instrument console) so that the voltage may be increased if necessary as the flashlamp degrades with use. If the flashlamp voltage is too low, the laser will not fire even if the flashlamp fires. If the voltage is too high, the laser may start to operate in double-pulse mode in which case each "fire" of the laser will generate two pulses each of nominally 50 mJ and with a variable inter-pulse separation of some tens of microseconds. If measured using an appropriate energy meter, the double pulse output will appear to be a single pulse of energy approaching twice that obtained in single pulse operation. Hence the laser classification label affixed to the LIBSCAN EDU-50 instrument console states a maximum energy of 150 mJ.

IMPORTANT NOTE:
The laser should not be used in double-pulse mode as the lifetime of the laser will be reduced significantly. The flashlamp voltage should not be adjusted from the factory set value (as detailed in the Test Report supplied with the LIBS equipment) without first contacting the equipment manufacturer (Applied Photonics Ltd) or their nominated agent. Failure to adhere to this will void the warranty.

Although the laser is able to fire at a pulse repetition rate of approximately 1 Hz, it is recommended that the laser is operated at not more than approx. 0.5 Hz in order to prolong the life of the flashlamp. If the laser is operated at above 0.5 Hz, it must not be operated for more than approximately 60 pulses without allowing a cool down period of at least 1 minute. Failure to adhere to this procedure will result in the laser overheating which will degrade performance and will reduce the life expectancy of the flashlamp. If operated within these limits, the flashlamp can be expected to have a lifetime of at least 300,000 pulses. Replacing the flashlamp requires the ***LIBSCAN EDU-50*** instrument to be returned to the manufacturer or authorised local agent.

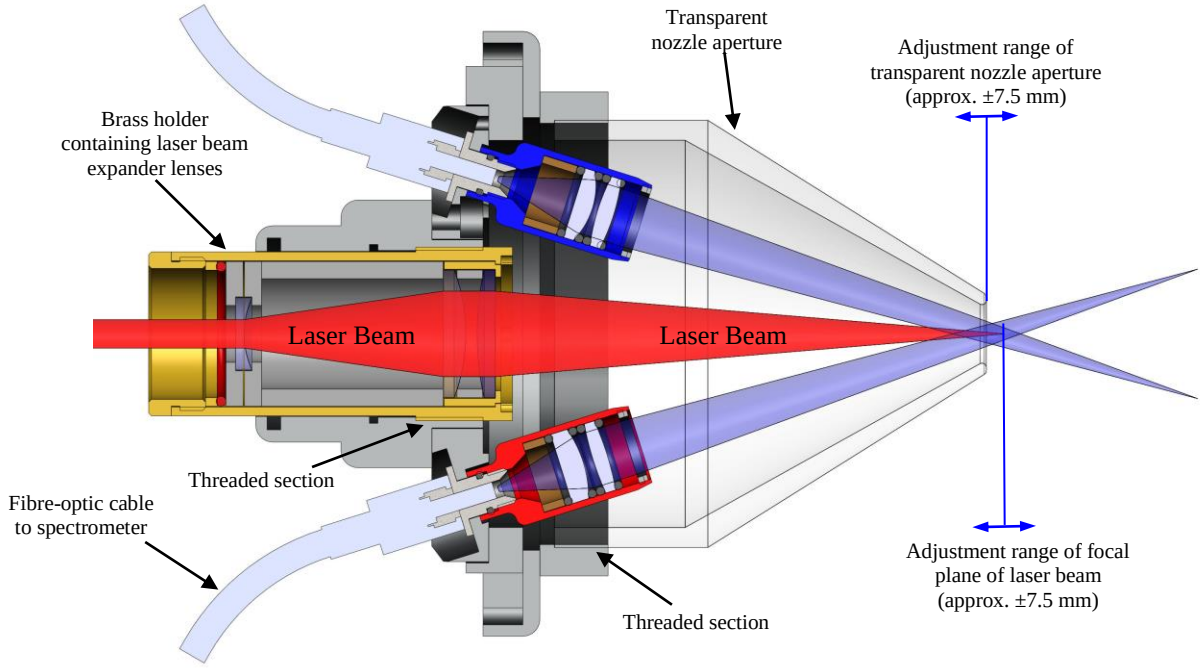
The pulse counter on the rear panel of the LIBSCAN EDU-50 console (see CAD image below) is used to record the total number of laser pulses that have been fired. The red button on the counter display is used to reset the counter but has been disabled so that the true total number of laser pulses is recorded. The two fuses (3 Amp anti-surge) are used to protect the internal electronics from an over-current situation (e.g. caused by an internal short circuit). The internal Li-Ion battery is capable of delivering some tens of amps so it is essential that these fuses are replaced only with the same rating and type of fuse as originally fitted.

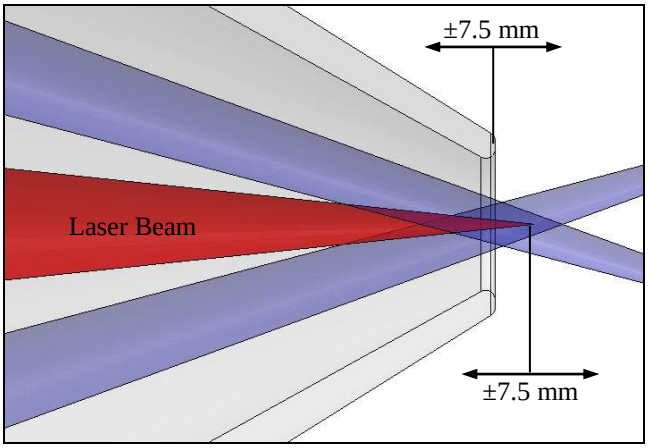


Rear panel of ***LIBSCAN EDU-50*** console showing laser pulse counter and Li-Ion battery fuses 1 and 2

3.5 Laser beam expander and plasma light collection optics

The optical configuration used in the ***LIBSCAN EDU-50*** instrument is illustrated schematically in the following diagram. The laser beam expander consists of three lenses and is used to provide a tightly focussed laser beam at nominally 100 mm from the aperture of the beam expander. The brass tubular piece which houses the beam expander lenses is threaded so that rotating it causes the focal plane of the laser beam to move. A special tool is used to rotate the brass tubular piece after first removing the nozzle aperture for access – the laser focus is factory set and should not require adjustment by the user. The design allows for approximately ±7.5 mm of adjustment, as illustrated in the following diagrams. The plasma light collection optics are angled such that the convergence point of the field of view of each collection lens coincides with the focal plane of the laser beam, as illustrated in the following schematic diagrams. The transparent nozzle aperture is threaded so that rotation causes it to move along the optic axis of the laser beam – range of travel is approximately ±7.5 mm (it may be removed from the body of the ***LIBSCAN EDU-50*** head by unscrewing further). The main purpose of the transparent aperture nozzle is to provide a convenient means of setting the distance to the sample surface. The nozzle aperture also provides containment of the purge gas to ensure the sample surface and laser-induced plasma region are effectively purged of atmospheric air and provides physical protection for the laser and plasma light collection optics (and imaging camera if fitted).





Close-up view of laser beam focus and field-of-view of plasma light collection optics

3.6 Imaging camera and associated components

The imaging camera is offered as an optional feature for ***LIBSCAN EDU-50***. A miniature colour CCD camera is installed inside the ***LIBSCAN EDU-50*** head and is located within the black tubular holder at the 12 o'clock position at the front of the head. The tubular holder is fitted with an optical filter to protect the CCD camera from damage due to possible high levels of stray laser light (1064 nm). The video output of the camera is connected to an external USB frame grabber (Magewell) – refer to diagram on page 15.

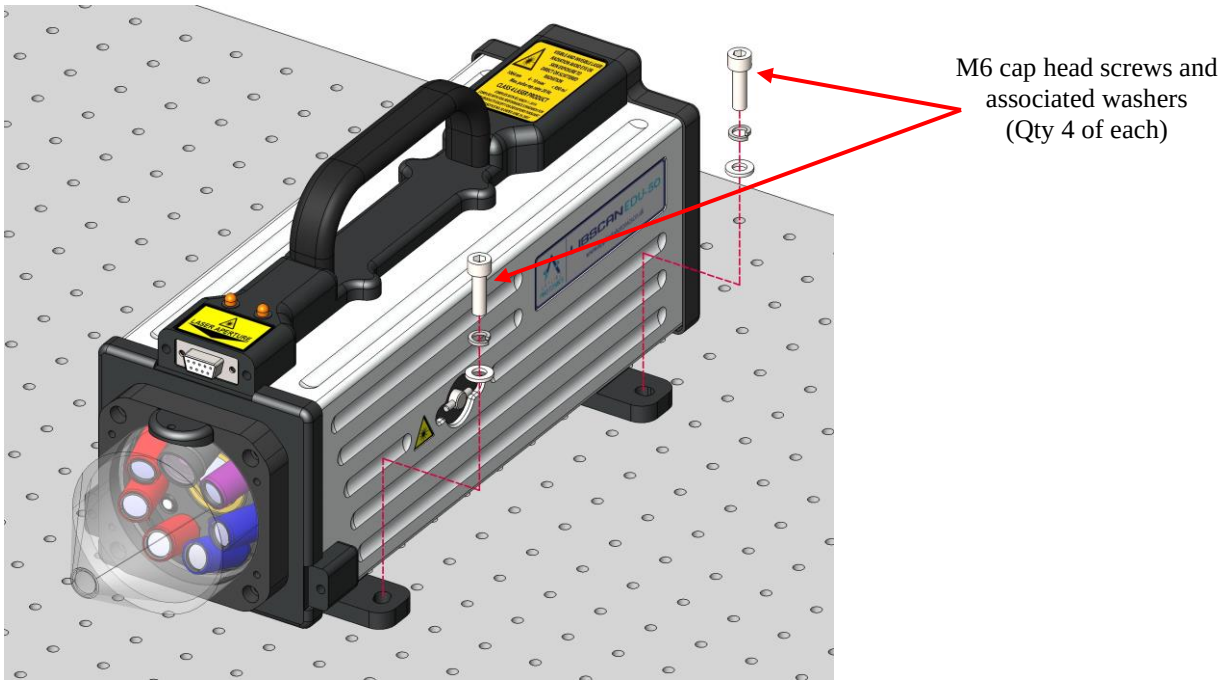
The specifications for the miniature CCD camera are:

- 1/3-inch CMOS colour sensor 2.5 MP (1956 x 1266)
- Adjustable focus (approx. 20 mm to infinity) – factory set by Applied Photonics Ltd
- Lens: f = 12 mm, f/1.8
- 12 VDC @ 1 A

Information on how to set up and use the imaging camera is provided in the LIBSoft User's Manual.

3.7 Attachment of the *LIBSCAN EDU-50* head to an optical table

LIBSCAN EDU-50 head is fitted with feet which may be used to secure the head to an optical table or breadboard (metric or imperial) using appropriate fixing screws (not supplied). The method of attachment is illustrated in the CAD image below.



3.8 Modular sample chambers

A range of modular sample chambers is available for use with the LIBSCAN range of LIBS instruments (see table below). These sample chambers are also suitable for use with our LIBS-6 and LIBS-8 integrated LIBS modules. ***LIBSCAN EDU-50*** requires an adaptor which provides a mechanical and electrical interface between the ***LIBSCAN EDU-50*** head and the modular sample chamber.

			
SC-1	SC-2C	SC-2M	SC-2L
Single axis translation stage, 20 mm travel per stage (manual control). Approx. overall dimensions: 110 x 120 x 210 mm, approx. 2.0 kg	2-axis translation stage, 20 mm travel per stage (manual control). Approx. overall dimensions: 110 x 120 x 260 mm, approx. 2.5 kg	2-axis translation stage, 20 mm travel per stage (manual control) Fume extract port. Internal LED light. Approx. overall dimensions: 160 x 160 x 260 mm, approx. 4.0 kg	3-axis translation stage, 50 mm travel per stage (manual control). Fume extract port. Internal LED light. Approx. overall dimensions: 280 x 250 x 330 mm, 15 kg
			
SC-2XL	XYZ-750	XYZ-2500	SC-LQ2
3-axis translation stage, 50 mm travel per stage (manual control). Fume extract port. Internal LED light. Approx. overall dimensions: 330 x 360 x 430 mm, approx. 20 kg	3-axis translation stage, 75 mm travel per stage (computer-controlled). Fume extract port. Internal LED light. Approx. overall dimensions: 330 x 360 x 480 mm, approx. 24 kg	3-axis translation stage, X & Y travel = 250 mm, Z travel = 100 mm (computer-controlled). Fume extract port. Internal LED light. Approx. overall dimensions: 470 x 770 x 730 mm, approx. 50 kg	Modular sample chamber designed to analyse liquids. Can be used to analyse a sample (typically 50 to 100 mL) or may be configured for "flow through" operation.

Current range of modular sample chambers manufactured by Applied Photonics Ltd

WARNING

The modular sample chambers described above are designed specifically for use with our LIBSCAN range of modular LIBS systems and our LIBS-6 / LIBS-8 integrated LIBS modules. The specifications for the laser safety windows are as follows:

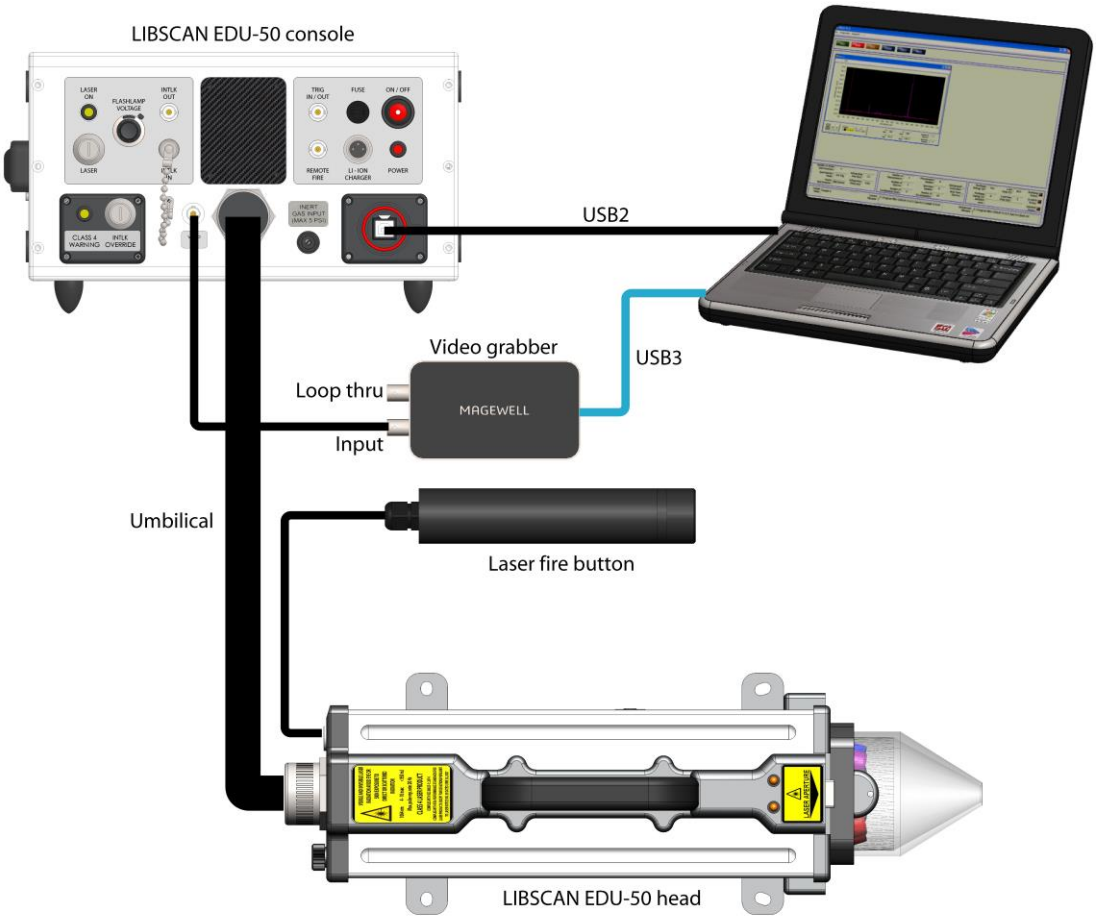
Laser Wavelength (nm)	**USA Standard ANSI Z 136.1 – 2014**	**UK & European Standard BS EN 207:2017**
	Optical Density	**Protection Level R (Q-switched laser)**
1064	OD 6	LB6
355	OD 5	LB5
266	OD 5	LB5

R LB6 at 1064 nm indicates a protection level of maximum spectral transmittance of 10^{-6} at 1064 nm for a pulsed laser of pulse length 10^{-9} – 10^{-7} seconds (i.e. a Q-switched laser).

Other laser safety windows are available for applications using a 532 nm laser. Contact Applied Photonics Ltd for further information.

3.9 Electrical connections

The following schematic diagram illustrates the various electrical connections between the various parts of the ***LIBSCAN EDU-50*** instrument.



4. General operating procedure

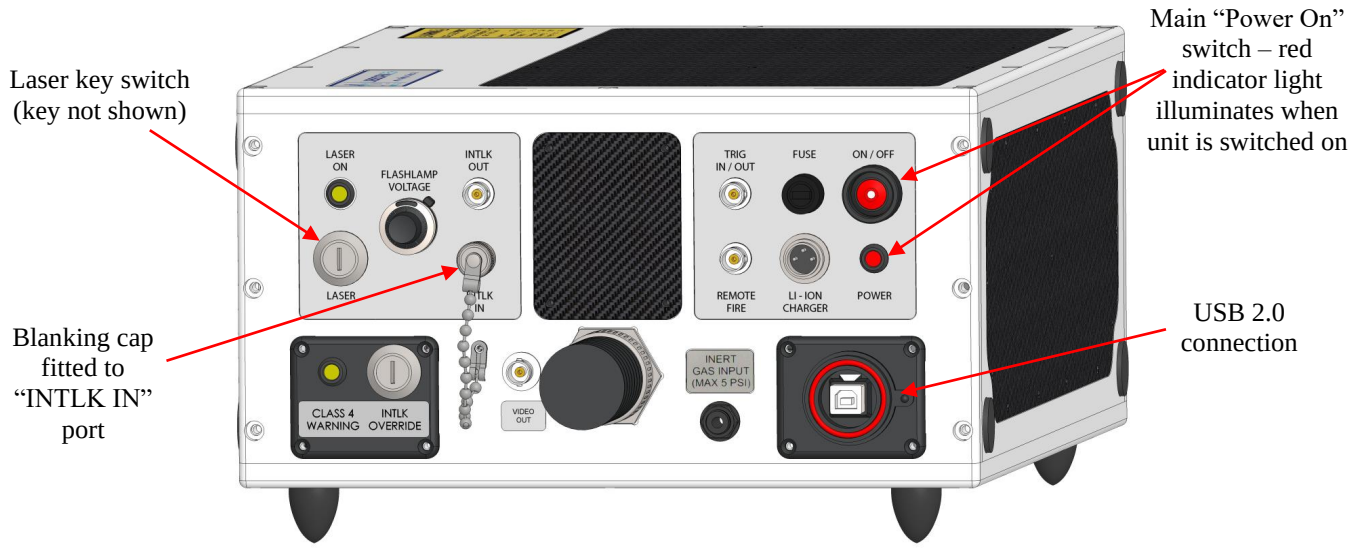
Step 1

Refer to the LIBSoft User's Manual supplied with the LIBS equipment. Install ***LIBSoft*** on a suitable computer (if a computer was supplied with the LIBS equipment, ***LIBSoft*** will be pre-installed on the computer). Once the software is installed, connect the computer to the USB 2.0 port located on the control panel of the ***LIBSCAN EDU-50*** instrument console (see illustration below). The remainder of this operating procedure relates to the ***LIBSCAN EDU-50*** hardware and not the ***LIBSoft*** software. ***LIBSoft*** has a comprehensive Help File accessible via the software.

Step 2

The Li-Ion battery (12 VDC, 8 Ah) is fitted to the ***LIBSCAN EDU-50*** instrument console and so the unit is ready to power up. The main power on switch on the instrument console (see illustration below) is used to activate the instrument. Before switching the instrument on, the laser key switch should be switched to the OFF position (i.e. key in vertical position - key can only be removed when in the OFF position). The use of a separate switch for the laser allows the user to activate the spectrometers without having to activate the laser. **IMPORTANT:** The Interlock Override key must be removed from the keyswitch (located on the front panel of the console) in order to maintain Class 1 laser product status. Your nominated Laser Safety Officer should keep this key in a safe place so as to prevent unauthorised use of the Interlock Override feature.

If you have a laser laboratory door interlock system, you may wish to connect the ***LIBSCAN EDU-50*** instrument to your interlock system using a BNC lead which connects to the "INTLK IN" port on the console (see following illustration). You will first need to remove the blanking cap which is fitted to the "INTLK IN" port. Note that ***LIBSCAN EDU-50*** is a Class 1 Laser Product when it is used with one of our modular sample chambers so it is not necessary to connect the instrument to a laboratory door interlock system although some users may prefer to do this in order to comply with any special local rules they may have on laser safety.

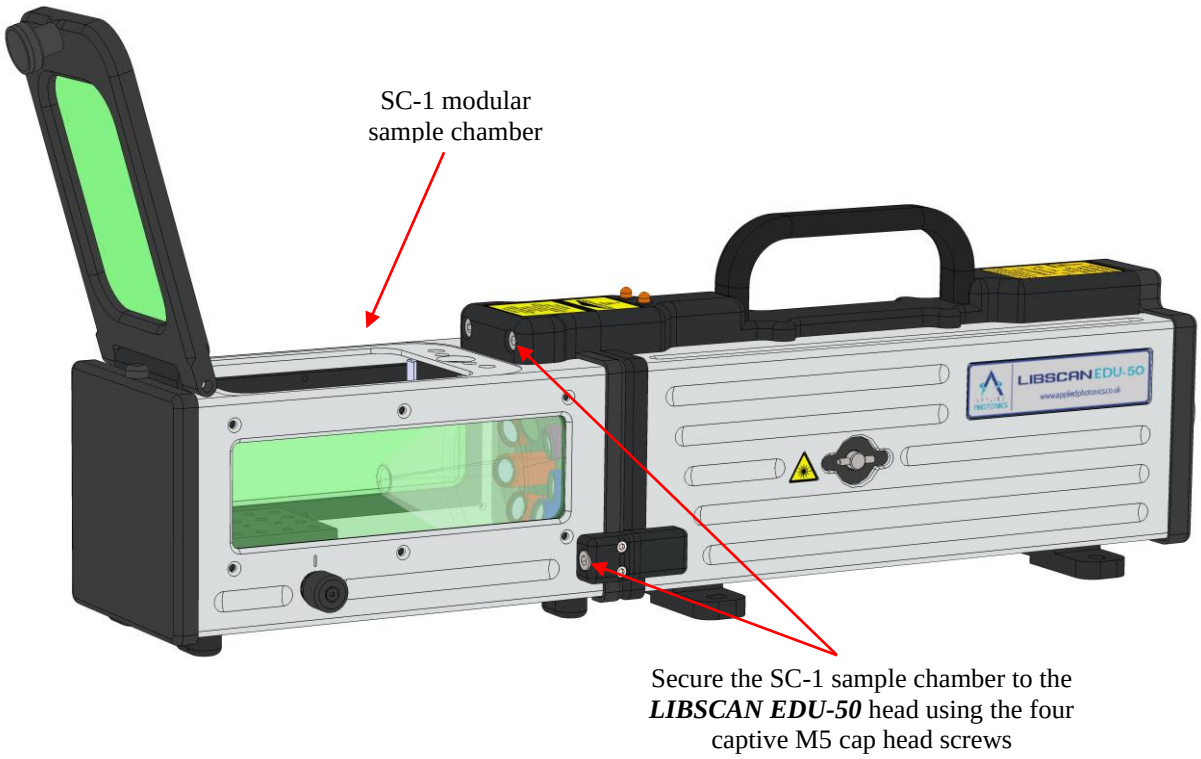


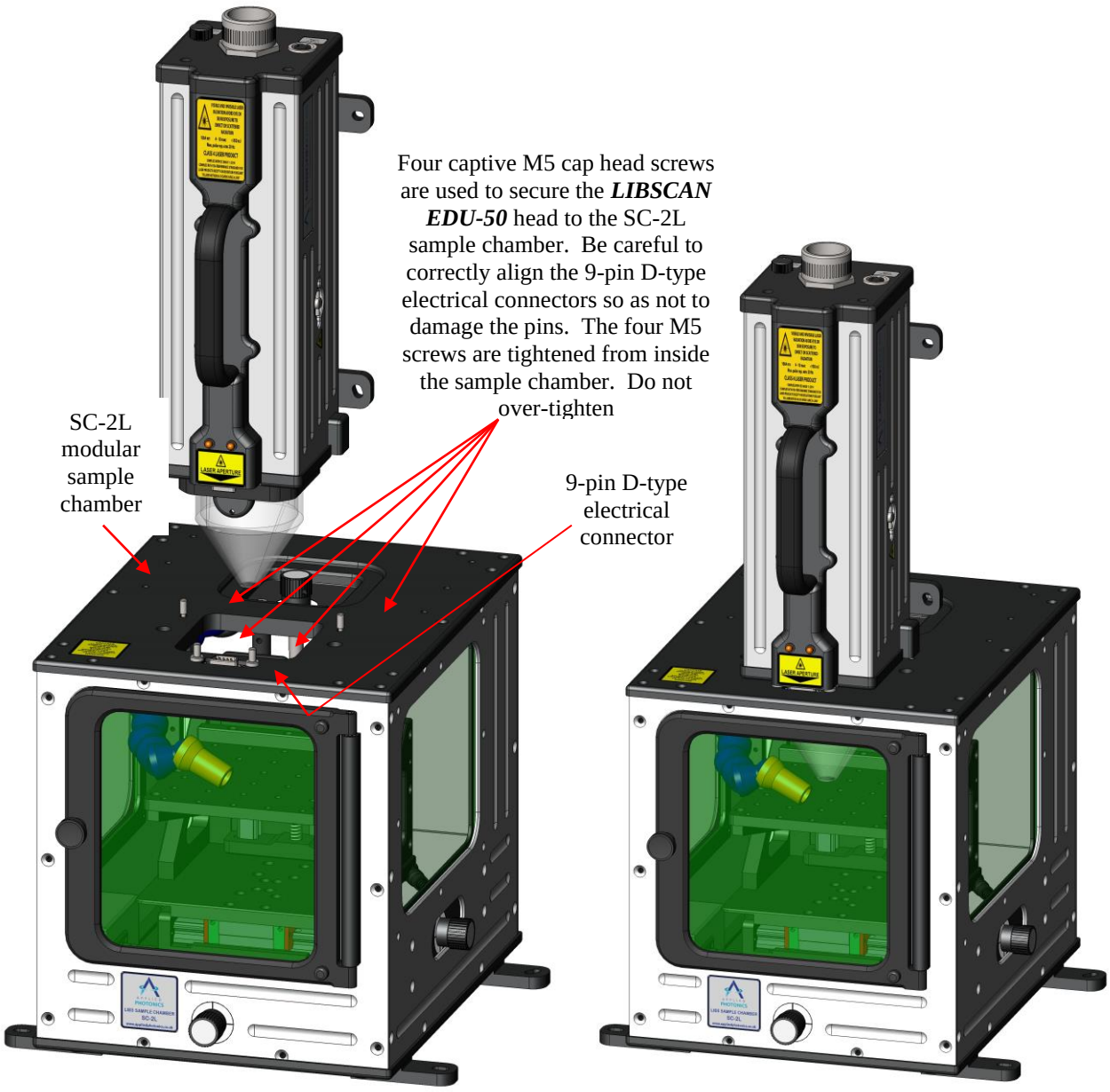
Note 1: The "INTLK IN" port needs to be in a closed circuit (ie. shorted) condition before activation of the laser is possible. The blanking cap is used to achieve this condition when the ***LIBSCAN EDU-50*** instrument is not connected to an external laser safety interlock system. The "INTLK OUT" port provides a 12 VDC output (centre pin +ve) whenever the laser is switched on via the key switch. This port may therefore be used to illuminate an appropriate warning light or drive a relay. Current drain from this port should be limited to less than approx. 250 mA – the current is ultimately limited by the main fuse (3 Amp Anti-Surge) fitted to the ***LIBSCAN EDU-50*** instrument console.

Note 2: The "FLASHLAMP VOLTAGE" control is factory set to a scale reading of typically 750 to 850, the actual value for each instrument being stated in the associated test report. Note that the scale reading (ie. 0 to 1000) does not equate to actual voltage (the adjustable voltage range is approximately 500 to 1000 Volts DC). Decreasing the flashlamp voltage will eventually result in the laser not firing while increasing the flashlamp voltage will eventually result in the laser operating in "double-pulse" mode (i.e. 2 pulses of approx. 50 mJ each, separated in time by some tens of microseconds). Note that this type of "double-pulse" operation is not usually suitable for LIBS measurements. **IMPORTANT: The flashlamp voltage should not be adjusted unless there is a good reason to do so. Contact Applied Photonics Ltd for advice on this. If the flashlamp voltage is increased above its factory set value, the repetition rate / duty cycle of the laser should be reduced accordingly.**

Note 3: The BNC port labelled "REMOTE FIRE" provides the user with the option of remotely firing the laser as opposed to normal method of firing the laser using the "Laser Fire" trigger button which connects to the rear of the ***LIBSCAN EDU-50*** head. The "REMOTE FIRE" BNC port may be activated by a voltage pulse of approx 0.1 milliseconds or longer and of amplitude 9 to 12 VDC (centre pin +ve). Note that the absolute maximum voltage applied to this port must be limited to 12 VDC. The port labelled "TRIG IN/OUT" may be used in two ways as follows. When the laser is not used, the spectrometers may be triggered from an external source by connecting a TTL compatible trigger to the "TRIG IN/OUT" port. When the laser is being used, the "TRIG IN/OUT" port provides a TTL pulse which is synchronised with the laser pulse (it is the same pulse that is used to trigger the spectrometers located within the LIBSCAN EDU-50 instrument console).
Note that in normal use, the "REMOTE FIRE" BNC port and the "TRIG IN/OUT" BNC port are not used. They are provided for special applications of the equipment.

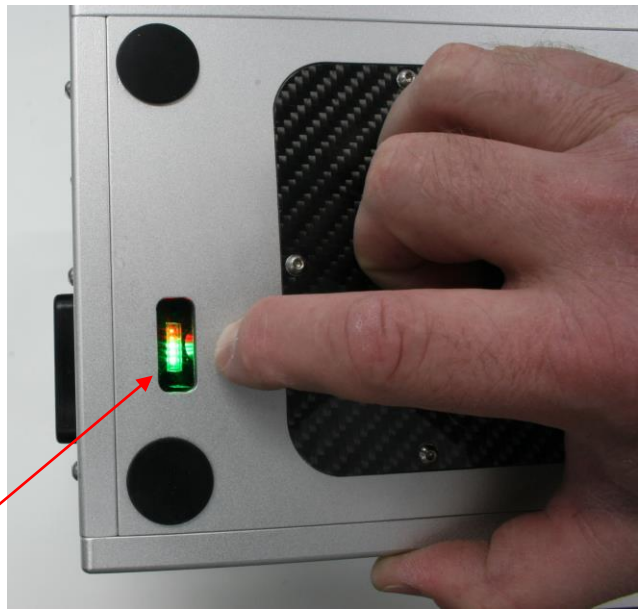
Step 3
Fit the modular sample chamber to the ***LIBSCAN EDU-50*** head using the four attachment screws as illustrated in the following diagrams which illustrate two types of modular sample chamber (SC-1 and SC-2L).





Step 4

As ***LIBSCAN EDU-50*** may be operated using its internal Li-Ion battery, it is not necessary to connect the unit to an electrical power source unless the battery is depleted. For laboratory use, however, it is recommended that the plug-in Li-Ion battery charger is connected to the instrument so as to keep the Li-Ion battery in a fully-charged state, however, to avoid the possibility of over-charging the Li-Ion battery the charger should not be left connected to the ***LIBSCAN EDU-50*** instrument for longer than approx. 8 hrs when the instrument is not in use (i.e. switched off). The charge status of the internal Li-Ion battery may be checked by depressing the button located on the side panel of the instrument console and viewing the indicator lights via the window, as illustrated in the following images.



Li-Ion battery charge status indicator

Press black button to activate status indicator lights

2 Reds + 3 Greens:		75 - 100% capacity
2 Reds + 2 Greens:		50 - 75% capacity
2 Reds + 1 Green:		20 - 50% capacity
2 Reds*	:	10 - 20% capacity
1 Red**	:	Less than 10% capacity
No lights***:		Empty

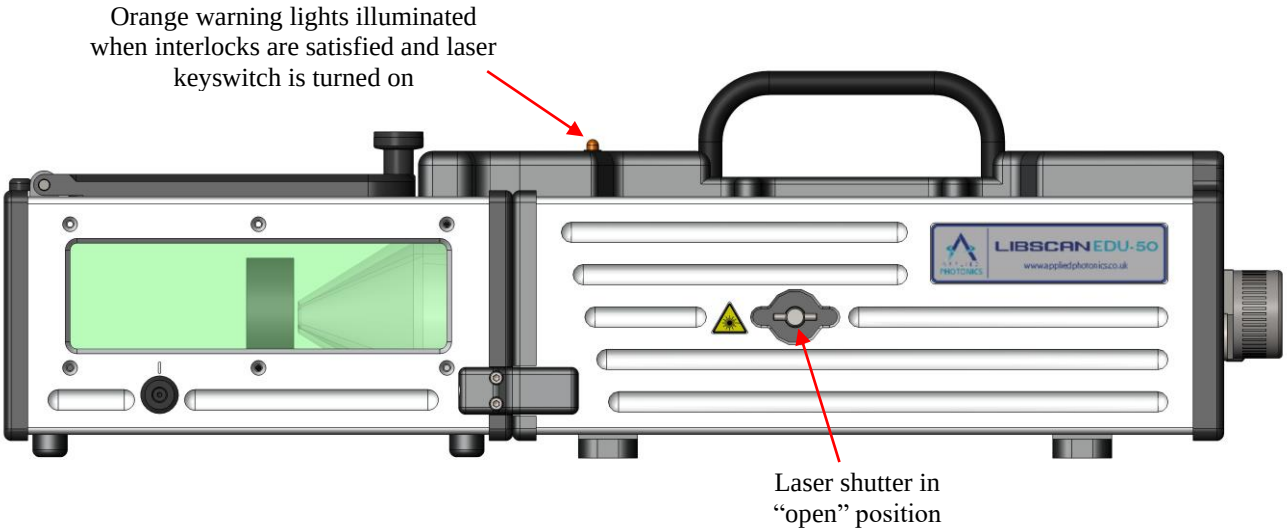
* Recharge as soon as possible

** Battery is about to electronically switch off to prevent over-discharge

*** Recharge within 12 hours

Step 5

Make sure that the laser shutter on the ***LIBSCAN EDU-50*** head is in the open position as shown in the following illustration.



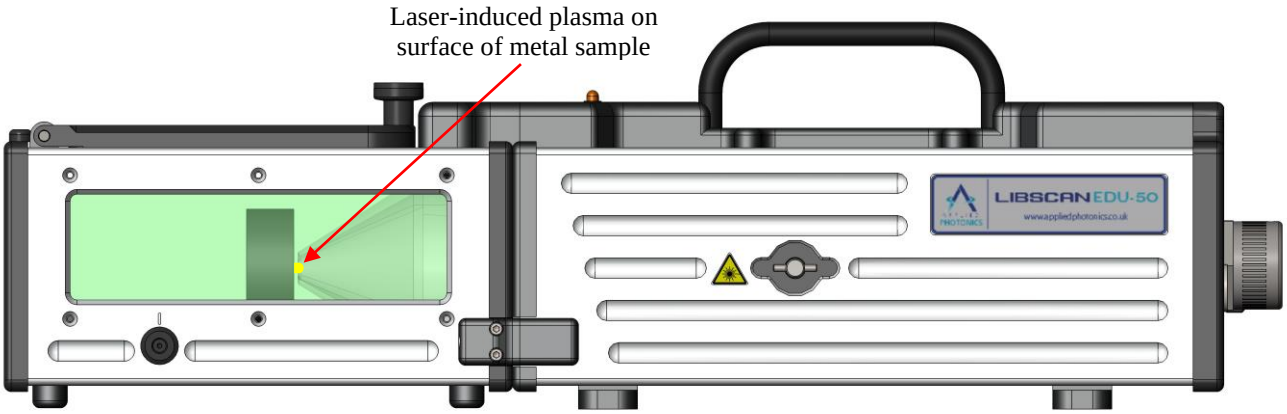
Step 6

Switch the laser key switch to the ON position. The LASER ON light on the instrument console should now be illuminated. If the laser safety interlock circuit is satisfied, the orange warning indicator light next to the laser aperture label on the ***LIBSCAN EDU-50*** head should be illuminated, indicating that the laser is in a "ready to fire" state. Note that the orange warning indicator lamps will only be illuminated if all of the following conditions are met:

- The sample chamber is correctly fitted to the LIBSCAN EDU-50 head
- The sample chamber door is fully closed
- The laser shutter is in the "open" position
- The blanking cap is fitted to the "INTLK IN" BNC port, or it is connected to an external interlock circuit which is providing a short-circuit across the BNC connector electrical terminals.
- The ***LIBSCAN EDU-50*** is switched on
- The laser keyswitch is switched on
- At least 1 second has elapsed since the previous firing of the laser (this is explained in more detail below).

Step 7

Check operation of the laser by placing a sample (e.g. a metallic object) inside the sample chamber and directly in front of the acrylic nozzle aperture and then activating a single pulse of the laser by pressing the trigger button located on the rear of the ***LIBSCAN EDU-50*** head. A laser plasma should be produced on the surface of the sample.



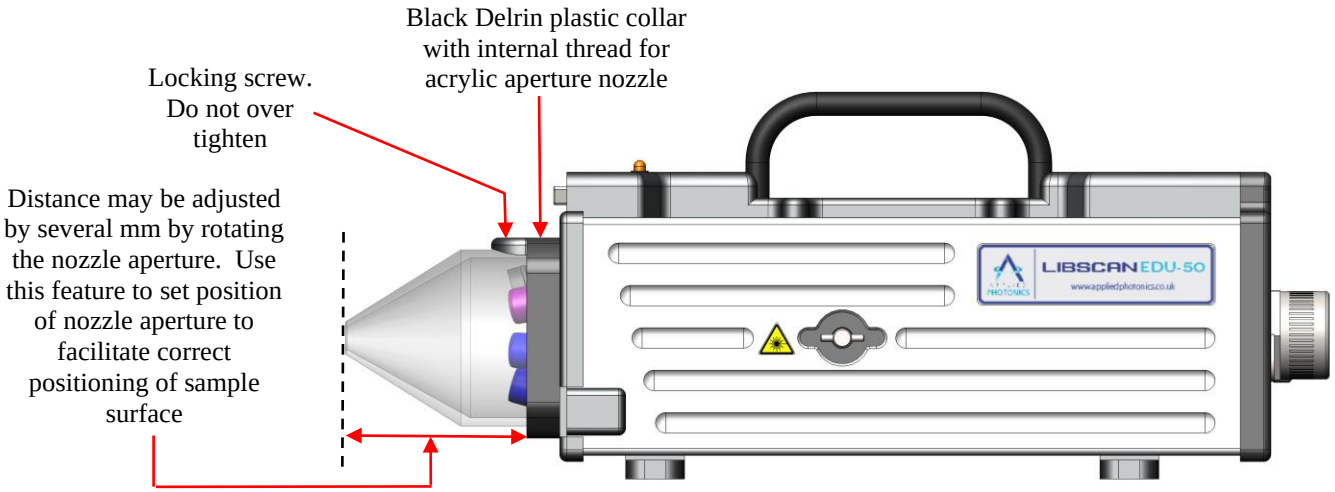
Note that on firing the laser, the orange warning light will go out for approx 1 second. During this time the laser is inhibited and so pressing the "Fire Laser" button will not activate the laser. An internal time delay circuit ensures that the repetition rate of the laser is limited to less than approx. 1 Hz. It is necessary to wait until the orange warning light is illuminated before firing the laser.

Step 8

Check for correct operation of the sample chamber door interlock – opening the door should result in the laser warning light on the LIBSCAN EDU-50 head being turned off. If it does not, cease using the equipment immediately and contact the manufacturer or their authorised local agent for advice before continuing to operate the equipment. If the interlock functions correctly, you may continue to use the equipment as normal. Switch the laser off by switching the laser keyswitch on the control panel to the off position.

Step 9

In order to obtain best performance from the LIBSCAN EDU-50 instrument, it is recommended that an argon gas purge is used. The pressure must be limited to less than 5 psi and flow-rate is typically 1 to 5 litres per minute. If argon gas is not available, it is recommended that either nitrogen or air purge is used. Note that if no gas purge is used, particulates arising from laser ablation of the sample will accumulate within the transparent acrylic nozzle aperture and may result in a deterioration of quality of the recorded spectra due to attenuation of the laser beam and/or obstruction / absorption of plasma light. Accordingly, we strongly recommend that the gas purge feature is used during operation of the LIBSCAN EDU-50 instrument.



CAD view of ***LIBSCAN EDU-50*** head showing method for adjusting position of nozzle aperture. Note that the position of the aperture nozzle has been correctly set by the manufacturer so should not need adjustment by the user.

5. Shut-down procedure

Step 1 Switch off the laser safety keyswitch, remove key and store in a safe place to prevent unauthorised use of the equipment.

Step 2 After closing down the LIBSoft application on the computer, switch off the main power on switch on the ***LIBSCAN EDU-50*** console.

Step 3 Disconnect purge gas supply if connected.

Step 4 The Li-Ion plug-in battery charger may be left connected to the ***LIBSCAN EDU-50*** instrument in order to fully charge the integrated Li-Ion battery. The battery will be fully charged after about 8 hrs charging time. Do not charge for longer periods as damage to the battery may result.

6. Maintenance and inspection

LIBSCAN EDU-50 should be periodically inspected for signs of damage or wear and tear. Of particular importance are the safety features including the sample chamber door and associated interlock circuit, the laser safety windows and the laser safety shutter on the ***LIBSCAN EDU-50*** head, all of which should be inspected / tested prior to each use of the equipment. If any damage to the laser safety windows or other safety components is observed or suspected, or the sample chamber door interlock switch is not functioning correctly, ***LIBSCAN EDU-50*** should be temporarily removed from service (remove laser

keyswitch to prevent operation of the equipment) until the fault is rectified. If in any doubt, contact the manufacturer, Applied Photonics Ltd, for further advice on maintenance and inspection of the product.

It may be necessary to occasionally clean the external surfaces of the optics located in the ***LIBSCAN EDU-50*** head. Dust / particulates may accumulate on the optics, especially if the ***LIBSCAN EDU-50*** instrument has been operated without using gas purge. An air duster is the best way of cleaning the optics. Access to the optics is best achieved by firstly removing the sample chamber from the ***LIBSCAN EDU-50*** head, then removing the acrylic nozzle aperture assembly by unscrewing the four M4 cap head screws used to secure the black Delrin plastic collar to the ***LIBSCAN EDU-50*** head.

The laser flashlamp has a limited life expectancy and so will need periodic replacement depending on the use of the equipment. The flashlamp is not a user serviceable component and so it is necessary to return the ***LIBSCAN EDU-50*** instrument to Applied Photonics Ltd or an authorised local agent for replacement of the flashlamp.

7. Shipping and storage

The ***LIBSCAN EDU-50*** instrument should be kept in a clean, dry environment which is free from extremes of temperature. The equipment contains sensitive optical and electro-optical components and so should be protected from excessive vibration or shock. During transport, the ***LIBSCAN EDU-50*** instrument and associated components should be packed in such a way as to prevent damage from shock or vibration (particularly the ***LIBSCAN EDU-50*** head) and protected from ingress of dust. The laser used in ***LIBSCAN EDU-50*** is air cooled rather than liquid cooled and so no special precautions are necessary prior to shipping / storage (e.g. draining of liquid coolant is not required). Note that ***LIBSCAN EDU-50*** contains a Li-Ion battery (12 VDC, 8Ahr) and that these types of battery are classed as dangerous goods (hazardous goods classification UN 3481). Check with the shipping agent prior to shipping the equipment.

8. Trouble-shooting / fault finding

Laser does not activate:

1. Is the ***LIBSCAN EDU-50*** instrument switched on and the laser keyswitch activated?
2. Is the internal Li-Ion battery sufficiently charged?
3. Are all the conditions met for satisfying the laser safety interlock circuit? See Step 6 of Section 4.
4. If the sample chamber is fitted with an "Emergency Off" button, check that it has not been activated.
5. Is a sample placed directly in front of the acrylic nozzle aperture?
6. If the sample is weakly absorbing to the laser beam (e.g. plastic, glass, etc), try using a metallic sample (such samples are provided with the LIBS equipment),
7. If the laser warning lights on the ***LIBSCAN EDU-50*** head are illuminated and the laser still does not fire even though the warning light goes out for approx. 1 second after activating the "Laser Fire" button, try increasing the flashlamp voltage using the Flashlamp Voltage control – increase the voltage in steps of approx. 25 at a time. If the laser does not fire after reaching a dial indicator setting of 900, cease using the equipment and contact the manufacturer or their authorised local agent for advice.

Laser-induced plasma appears to be adequately intense although a poor signal is observed on some or all of the spectrometer channels:

1. Are the data acquisition settings on the LIBSoft software set up correctly?
2. Is the composition of the sample such that emission lines are not expected to be seen on some or all of the spectrometer channels? If yes, then use an alternative sample which has numerous emission lines (e.g. copper, zinc or an iron-containing material such as steel) to check for correct operation of the ***LIBSCAN EDU-50*** instrument.
3. Is the sample positioned correctly relative to the laser beam focus? It may be necessary to adjust the position of the nozzle aperture if it has previously been adjusted from the factory set position.

Recorded spectra show some emission lines which are saturating the detector ("flat top" appearance to the emission line):

1. Increase spectrometer integration delay via the LIBSoft software. The minimum value is 0.9 μs but it may be necessary to increase this value so as to prevent saturation of the spectrometer detectors when the emission line(s) are particularly intense. For some materials it may be necessary to increase this value to as much as 20 μs. A degree of experimentation will be necessary to establish optimum settings for laser spot size and spectrometer integration delay.
2. Increase spot size of laser beam on sample by adjusting the position of the sample relative to the focal plane of the laser beam (it is usual to set focus to be approximately 1 to 3 millimetres "into" the sample surface).

Recorded spectra show some emission lines suffering from "self-reversal" (i.e. a "dip" in the centre of the emission line):

1. Follow same procedure as for saturated detector

Air-breakdown is observed in the path of the laser beam just in front of the sample surface:

1. The focal plane of the laser beam is set incorrectly (ie. it is set to be in front of the sample) – adjust position of sample so that the focal plane of the laser beam is coincident, or preferably just "into", the sample surface.

2. On irradiation by the laser beam, the sample is creating considerable quantities of particulates in the path of the laser beam. Try cleaning the surface of the sample if loose material (e.g. oxide, surface contamination etc) is present. Increasing laser beam spot size on the surface of the sample may also help. Use the fume extraction feature of the sample chamber if available (the outlet of the flexible fume extraction tube inside the SC-2L sample chamber will need connection to a suitable fume extraction device such as an electrical solder fume extractor / filtration unit).

Appendix A1

Certificate of Conformity

Applied Photonics Limited
Unit 8 Carleton Business Park
Skipton North Yorkshire
BD23 2DE United Kingdom

EC
Declaration of Conformity

Applied Photonics Ltd declares that the product listed below has been designed and manufactured in compliance with the relevant standards as follows:

Product name: **LIBSCAN EDU-50 Modular LIBS instrument for educational establishments**

Model Number: **LIBSCAN EDU-50**

Laser product safety
This device conforms with the principal objectives of safety of laser products by application of the following standards: **BS EN 60825-1:2014 and BS EN 207:2017 and ANSI Z136.1 2014**

Electrical Safety
This device conforms with the principal safety objectives of the **European Directive 73/23/EEC as amended by 2014/35/EU**, as implemented by the Electrical Equipment (Safety) Regulations 1994, by application of the following standard: **BS EN 61010-1:2010.**

Electro-Magnetic Compatibility
This device conforms with the principal objectives of the European Directive (89/336/EEC) as amended by 91/31/EEC and 93/68/EEC and 2014/30/EU, as implemented by The EMC Regulations (SI 1992 No. 2372 and amendments SI 1994 No. 3080 and SI 2006/3418), by application of the following standard: **BS EN 61326-1:2013**

Year of affixation of the CE Marking: 2020

Signed: 

Name: Andrew I. Whitehouse

Title: Managing Director

Place: Applied Photonics Ltd, Unit 8 Carleton Business Park, Skipton, North Yorkshire BD23 2DE, United Kingdom

Date: March 2020