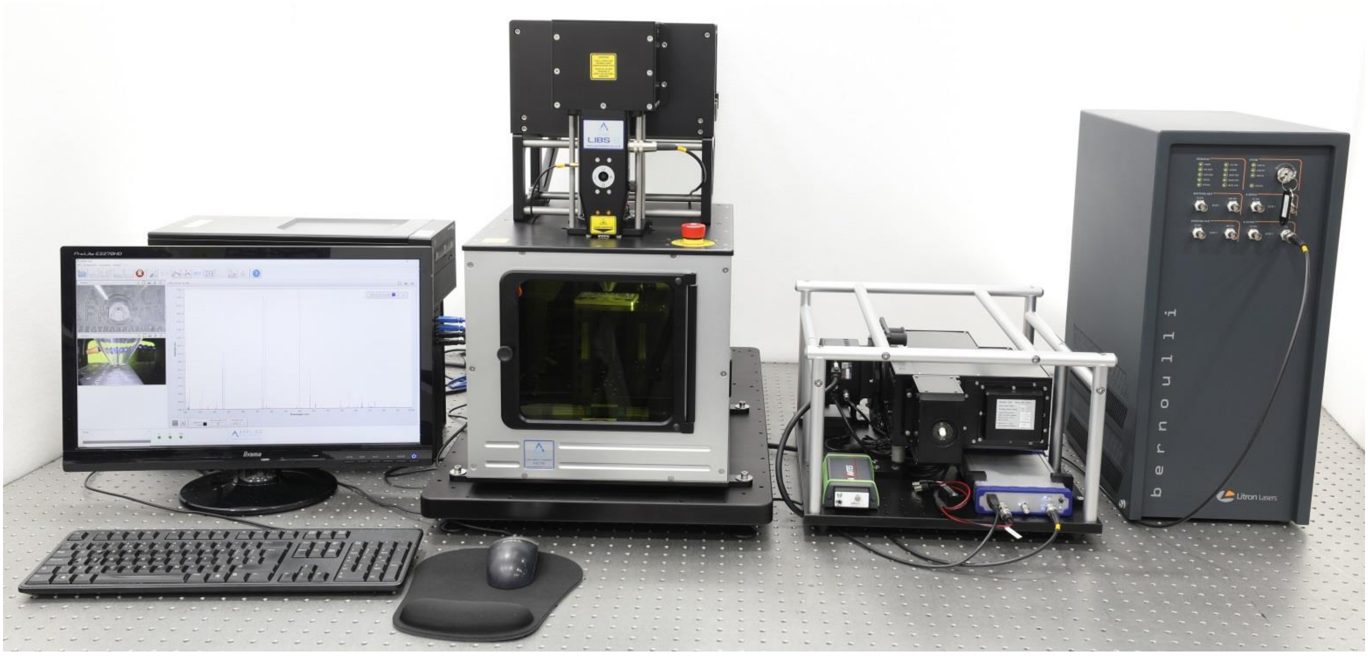
LIBS-6™ & LIBS-8™

Modular Laser-Induced Breakdown Spectroscopy (LIBS) System

Double-pulse, dual wavelength laser (1064 & 266 nm)
High-resolution, broad-band (190 – 1100 nm) echelle spectrograph



User's Manual for Example Configuration 2

June 2022

APPLIED PHOTONICS
LASER SPECTROSCOPY SOLUTIONS

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1 Introduction

The modular Laser-Induced Breakdown Spectroscopy (LIBS) system described in this User's Manual is designed to be a highly versatile product for use by research scientists, application engineers and OEMs. Essentially a "LIBS system building block", the LIBS-6 and LIBS-8 modules may be used together with a variety of Q-switched Nd:YAG lasers and optical spectrometers to form a customised, modular LIBS system tailored to suit the requirements of a specific application or experimental research project. The LIBS modules remove the need for the research scientist or application engineer to design and construct their own laser focussing optics and plasma light collection optics by combining these features into a compact, integrated and easy to use device. An optional imaging kit may be added to the LIBS module, increasing further its functionality and versatility.

The modular LIBS system described in this User's Manual comprises the following main components: a LIBS-6 module, two AP-Bernoulli adaptor platforms (one for 1064 nm laser configuration and one for 266 nm laser configuration), a Litron Bernoulli double-pulse dual wavelength (1064 nm and 266 nm) pulsed Nd:YAG laser, an XYZ-750 modular sample chamber with computer-controlled 3-axis translation stage, and a Catalina Scientific EMU-120/65 echelle spectrograph equipped with a Raptor Photonics EMCCD camera.

This User's Manual provides the necessary information needed to configure the LIBS equipment and operate the equipment 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 high-power (Class 4) laser products.

2 Safety

2.1 Laser radiation

The modular LIBS system utilises a high-power Q-switched Nd:YAG laser (Class 4) and so it is imperative the equipment is operated only by suitably trained and experienced persons who 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 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 use of the equipment.

Example of a laser warning product label

The modular LIBS system is designed to meet the laser safety requirements of the relevant European standards (BS EN 60825) and USA standards (ANSI Z136.1). Although the modular LIBS system is supplied with a sample chamber which provides adequate containment of the laser radiation to Class 1 Accessible Emission Limits, it is possible for the user to operate the LIBS equipment without the sample chamber (ie. operation in "open beam" mode as may be required for certain types of experiment). Accordingly, it is necessary to consider the modular LIBS system to be **Class 4 Laser Products** and so, by definition, the equipment poses a risk of personal injury (eye, skin injury) and poses a fire risk. As with all Class 4 laser products, appropriate safety precautions must be taken as identified via a suitable risk assessment conducted by the user in consultation with a suitably qualified and experienced Laser Safety Officer.

The most significant hazard relating to exposure of personnel to the laser radiation is eye injury since direct or scattered laser radiation produced by the equipment can cause serious and permanent injury to the eyes including blindness - such injury may be instantaneous. Precautions must be taken to avoid exposure of personnel to hazardous levels of laser radiation. Such precautions may include the setting up of a temporary or permanent laser controlled area (e.g. a laser laboratory). Other measures may also be necessary, as determined by appropriate and thorough assessment of the risks (ie. a risk assessment) conducted by the personnel responsible for the safe use of the laser equipment. Consult the User's Manual supplied with the laser for further guidance on the safe use of the laser.

The door of the sample chamber is equipped with a dual electrical interlock switch which is designed to prevent activation of the laser unless the door is fully closed. The door interlock switch is electrically connected to the "Interlock In/Out" port on the LIBS module via the 9-pin connector located directly above the laser aperture. The "Interlock In/Out" port connects with the Interlock Interface Unit (using the supplied lead) which in turn is connected to the interlock circuits of the laser power supply. This is discussed in more detail later in this User's Manual.

Interlock Interface Unit

Removal of the sample chamber from the LIBS-6 module, or disconnection of the Interlock In/Out lead, will also activate the interlock (ie. prevent activation of the laser). The Interlock Interface Unit is equipped with an Interlock Override facility (a keyswitch) which allows the interlock to be disabled so that the LIBS system may be used without a sample chamber (ie. "open beam" mode). In view of this, the modular LIBS system **must be categorised as a Class 4 laser product** since, by design, the product may be used in such a way that the laser beam is not contained (ie. "open beam" mode of operation). If, however, the sample chamber is correctly fitted to the LIBS-6 module and the Interlock Override keyswitch is switched off and the key removed, then the laser radiation is adequately contained to Class 1 Accessible Emission Limits by the design of the hardware.

IMPORTANT

- READ and UNDERSTAND both this User's Manual and the instructions provided by the manufacturer of the laser 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 power supply is deactivated.**
- NOTE that the transparent acrylic nozzle aperture of the LIBS-6 module 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.

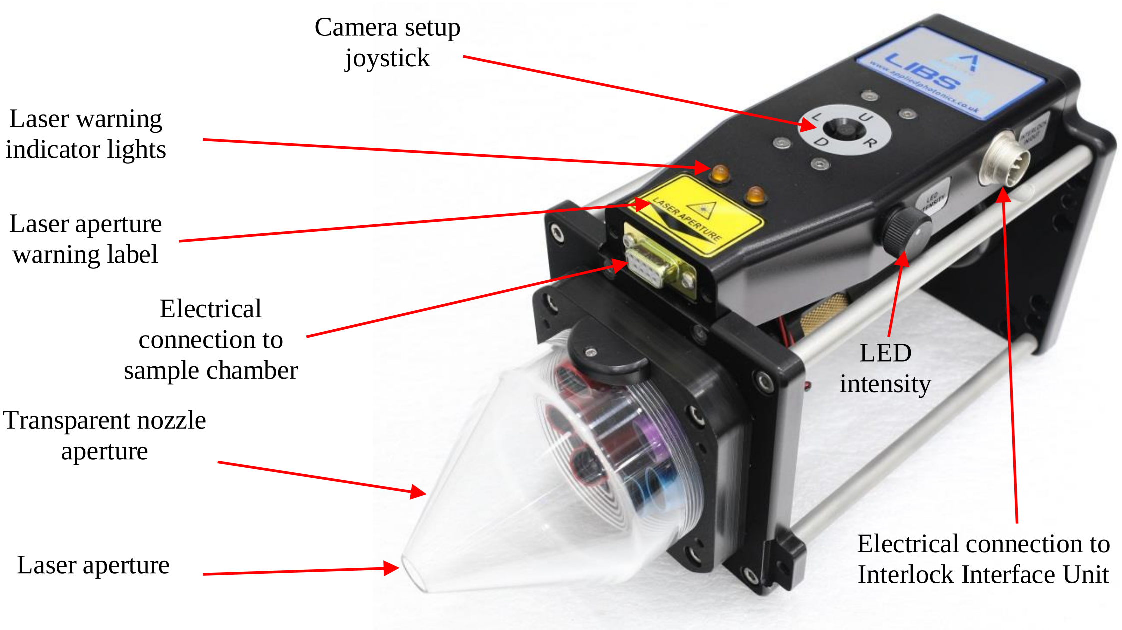


Image of LIBS-6 module showing location of laser warning indicator lights, laser aperture and warning label

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

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

Laser Wavelength (nm)	USA Standard ANSI Z 136.1 – 2014 Optical Density	UK & European Standard BS EN 207:2009 Protection Level R (Q-switched laser)
1064	OD 6	L6
355	OD 5	L5
266	OD 3	L3

R L6 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).

The laser safety windows used in Applied Photonics Ltd's range of modular sample chambers provide adequate protection against 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 used correctly and laser pulse energies are not excessively high (i.e. typically less than 300 mJ with a 5 - 10 ns pulse length). Note that the protective windows are NOT suitable for use with a 532 nm laser. Given that the LIBS-6 (and LIBS-8) modules may be used with a variety of lasers, it is the responsibility of the user to conduct a risk assessment to establish whether or not the laser safety windows provide adequate protection for the particular laser being used. 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 LIBS-6 / LIBS-8 integrated LIBS modules and our LIBSCAN range of products and should not be used with any other laser device or product. If in doubt, seek advice from the manufacturer, Applied Photonics Ltd.

2.3 Electrical

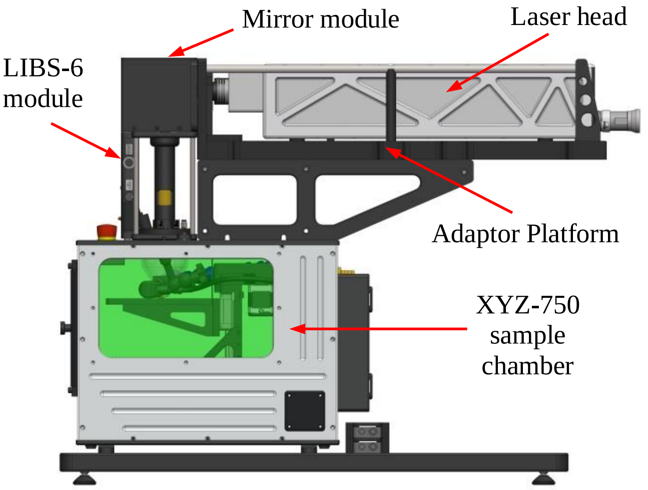
The LIBS-6 integrated LIBS module, the XYZ-750 sample chamber and the Raptor Photonics EMCCD camera contain electrical circuits operating at 12 VDC at a maximum current of 2.5 Amps. Accordingly, they pose no electric shock risk. The laser head and associated power supply, however, contain electrical circuits operating at potentially lethal voltage and current levels. Consult the manufacturer's User Manual supplied with the laser for further guidance on the safe use and routine maintenance of the laser.

3 General description

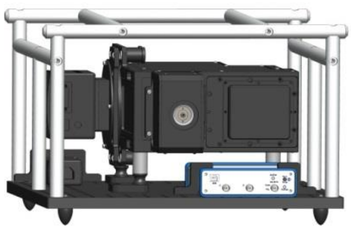
3.1 Overview

This modular LIBS system consists of the following main components:

• LIBS-6 module	Qty 2 (one configured for 1064 nm and one configured for 266 nm)
• Right-angle mirror module	Qty 2 (one configured for 1064 nm and one configured for 266 nm)
• Adaptor Platform	Qty 2 (one configured for 1064 nm and one configured for 266 nm)
• Litron Bernoulli laser (1064 & 266 nm)	Qty 1
• EMU-120/65 spectrograph with EMCCD camera	Qty 1
• Quantum Composers delay generator	Qty 1
• XYZ-750 computer-controlled sample chamber	Qty 1
• LIBSoft software	Qty 1



CAD side view of assembled LIBS system consisting laser head, Adaptor Platform, Mirror Module, LIBS-6 module and XYZ-750 sample chamber.

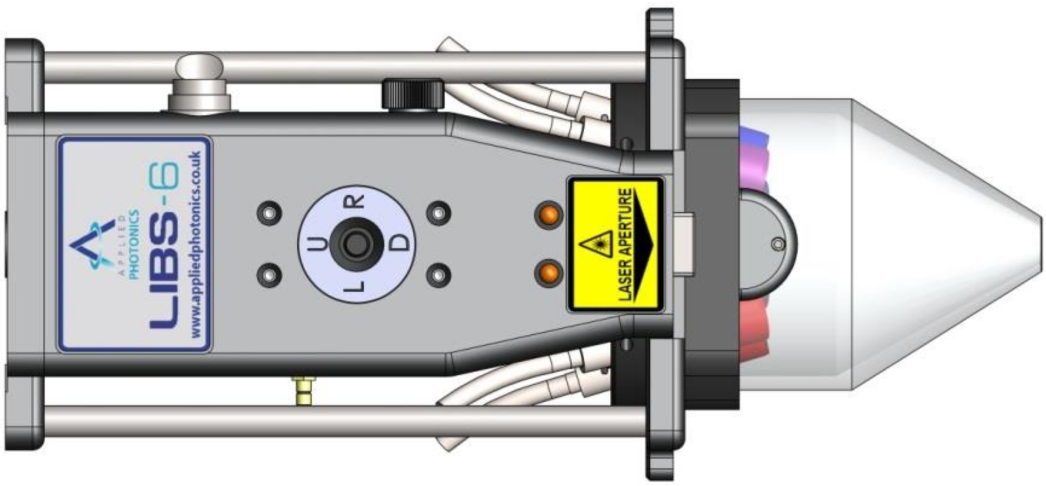


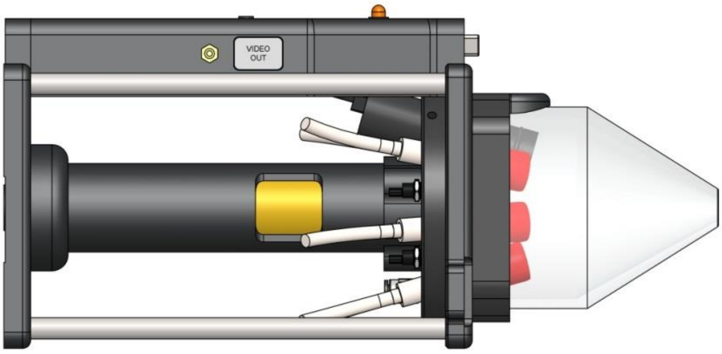
CAD view of EMU-120/65 spectrograph with attached EMCCD camera. Digital delay generator is shown attached to the baseplate.

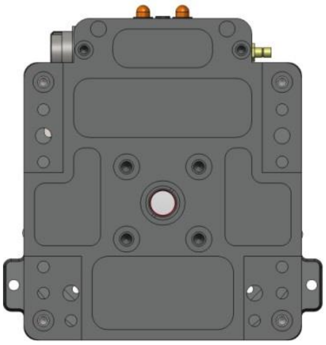
CAD view of the Litron Bernoulli laser power supply.

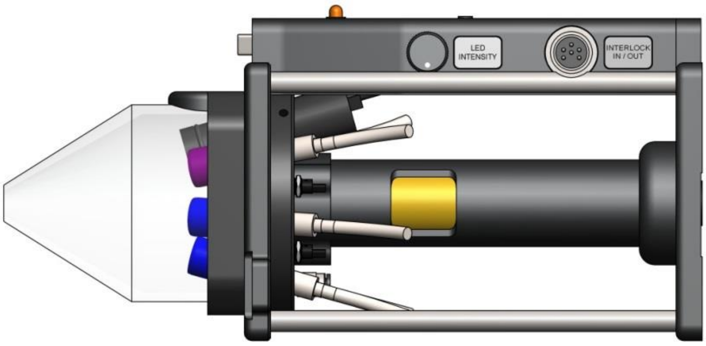
3.2 LIBS-6 modules

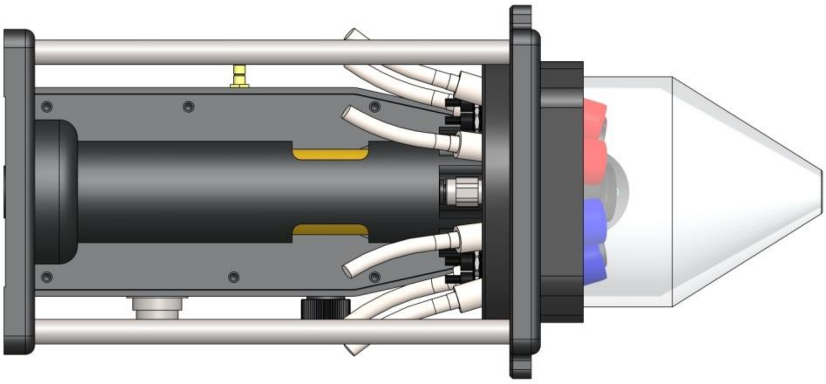
The NIM LIBS system is supplied with two LIBS-6 modules – one for 1064 nm laser configuration and one for 266 nm laser configuration. Further details on how to use these components are provided later in this User's Manual. The main components of the LIBS-6 integrated LIBS module are illustrated in the following figures.

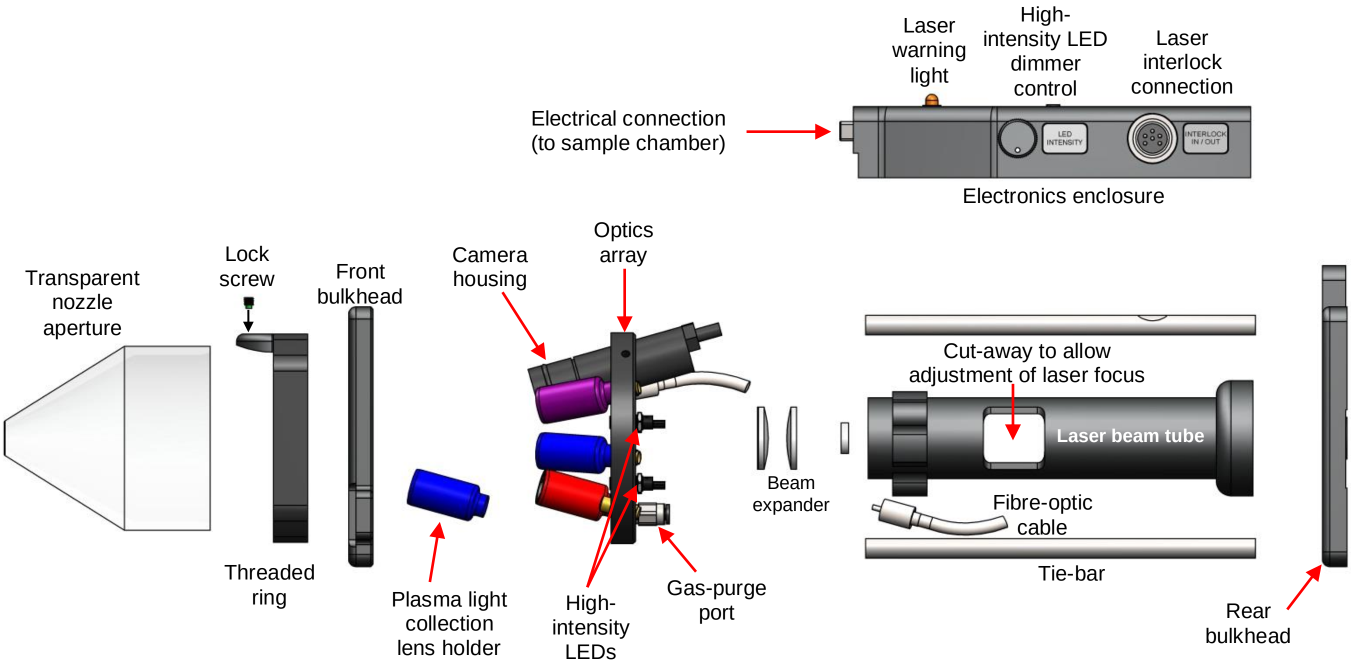


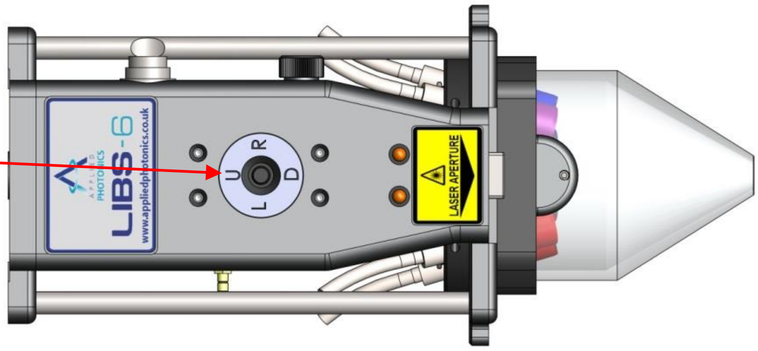

VIDEO OUT




LED INTENSITY
INTERLOCK IN / OUT




Laser warning light
High-intensity LED dimmer control
Laser interlock connection
Electrical connection (to sample chamber)
LED INTENSITY
INTERLOCK IN / OUT
Electronics enclosure
Transparent nozzle aperture
Lock screw
Front bulkhead
Camera housing
Optics array
Cut-away to allow adjustment of laser focus
Laser beam tube
Beam expander
Fibre-optic cable
Tie-bar
Threaded ring
Plasma light collection lens holder
High-intensity LEDs
Gas-purge port
Rear bulkhead

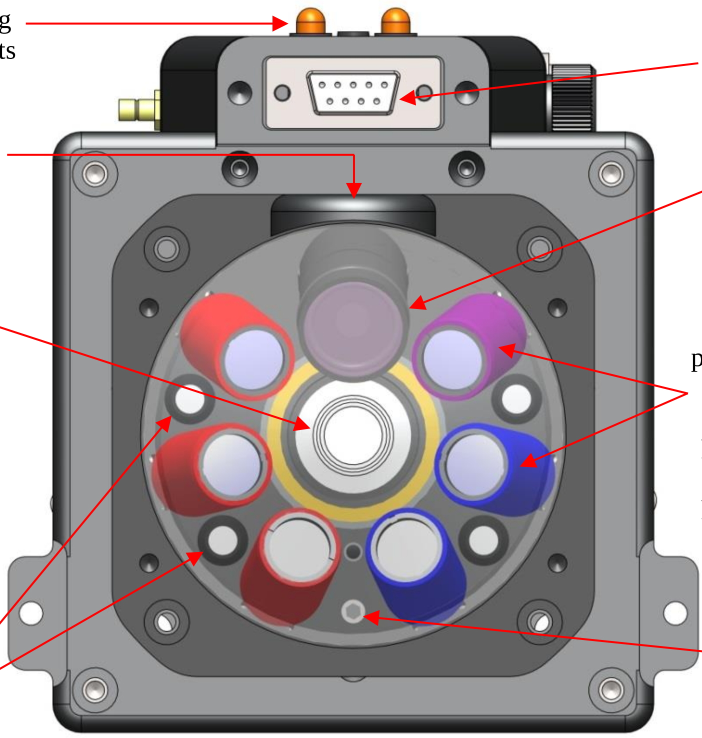


Camera specifications:

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

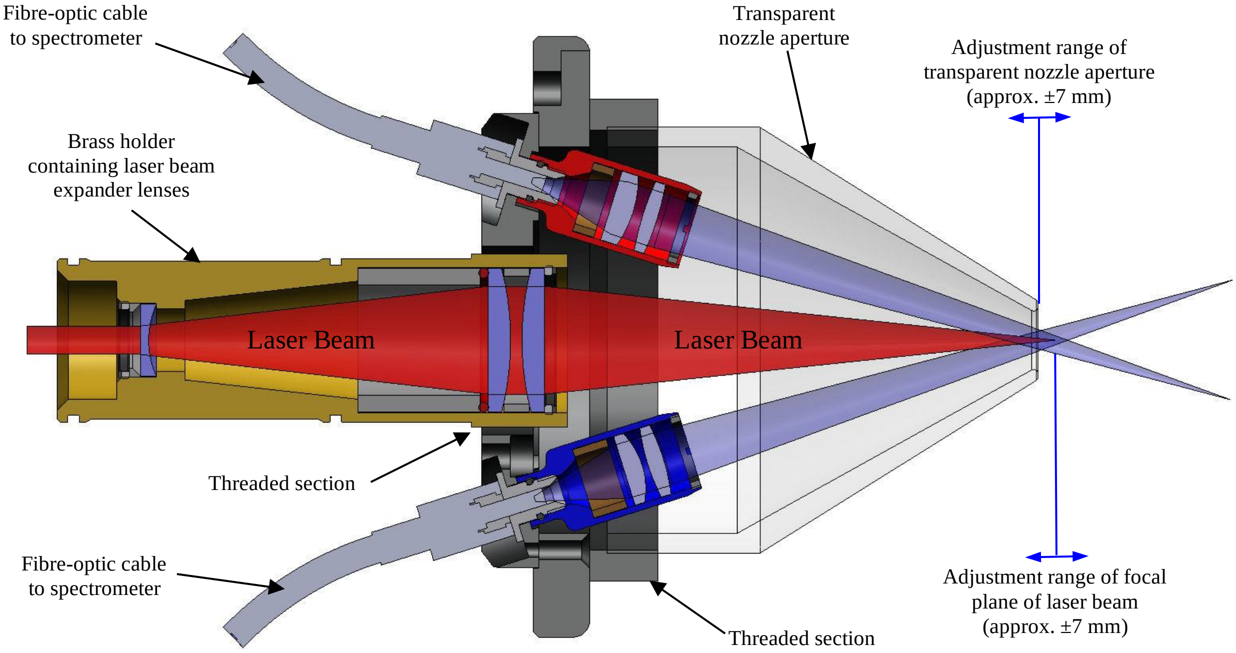
The LIBS modules have the following features:

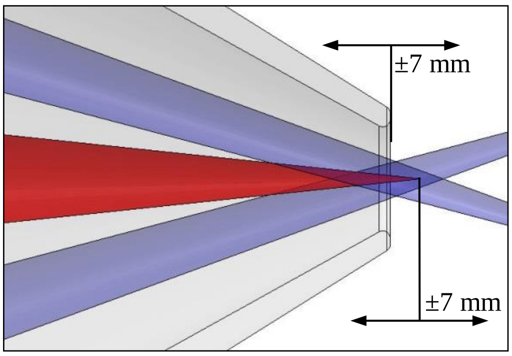
- Plasma light collection lens array (six channels) having a relatively large depth-of-field to allow efficient light collection even when the plasma position varies by approximately ±3 mm along the optic axis of laser beam.
- 3-lens laser beam expander with adjustable focus (adjustment of focal plane made by rotating the brass beam expander lens holder via the cut-way in the laser beam tube – adjustment range of approx. 14 mm).
- Adjustable nozzle aperture which provides a convenient means of setting the distance to the sample surface (adjustment range of approx. 14 mm). The nozzle aperture may be removed if this feature is not required.
- Gas-purge port (accepts 4 mm flexible nylon tube) which may be used to feed inert gas (e.g. argon, helium, nitrogen) to the sample surface. To ensure purge gas is directed to the sample, it is necessary to fit the nozzle aperture.
- Optional miniature CMOS colour video camera with array of dimmable high-brightness white LEDs for illuminating sample surface.
- Laser safety interlock with keyswitch operated override facility (via the Interlock Interface Unit).
- Compatible with the Applied Photonics Ltd (APL) range of modular sample chambers.



Front view of LIBS-6 module showing plasma light collection lens array, CMOS camera, LED lights, laser aperture and gas purge outlet

The optical configuration used in the LIBS-6 (and LIBS-8) modules 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 optical design is specific to the make and model of laser which the LIBS-6 or LIBS-8 module is to be used with – this is specified at the time of ordering of the LIBS module. For this configuration, two LIBS-6 modules are provided – one for use with a 1064 nm laser beam and the other for use with a 266 nm laser beam. These two LIBS-6 modules differ in the design of the beam expander and so it is important that the correct one is used according to the configuration (i.e. 1064 nm or 266 nm output beam) of the Bernoulli laser. The brass tubular piece which houses the beam expander lenses is threaded (1 mm pitch thread) so that rotating it causes the focal plane of the laser beam to move. The design allows for approximately ±7 mm of adjustment, as illustrated in the following diagrams. The plasma light collection optics are angled at approx. 17 degrees and are designed to collect light from the region in space defined in the following diagram. 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 mm. The nozzle aperture may be removed from the body of the LIBS-6 or LIBS-8 module by unscrewing further or by removing the threaded black acrylic piece it screws into by unscrewing the four M4 cap head screws. The main purpose of the transparent nozzle aperture is to provide a convenient means of setting the distance to the sample surface. The nozzle aperture also provides containment of the purge gas, if used, to ensure the sample surface and laser-induced plasma region are effectively purged of atmospheric air. Physical protection for the laser beam optics and plasma light collection optics (and imaging camera if fitted) is also provided by the nozzle aperture.



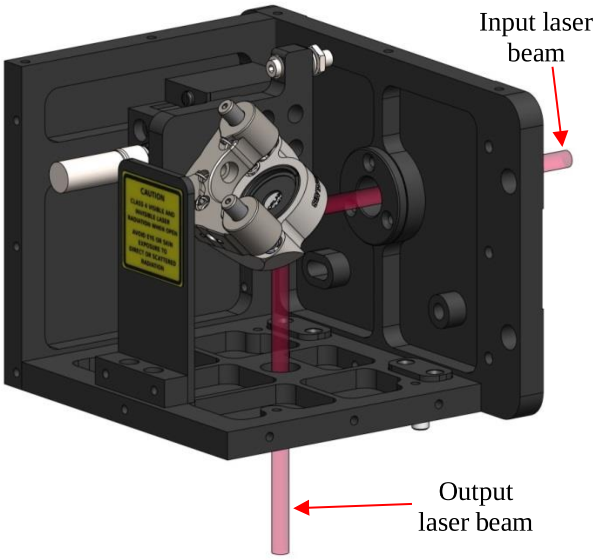


Close-up view of laser beam focus and field-of-view of plasma light collection optics

3.3 Right-angle mirror modules

This configuration is supplied with two Mirror Modules – one for 1064 nm laser configuration and one for 266 nm laser configuration. Further details on how to use these components are provided later in this User's Manual.

Mirror Module (1064 nm)

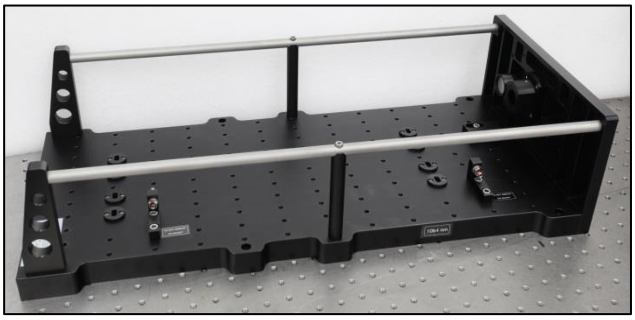


Internal view of Mirror Module showing laser beam path

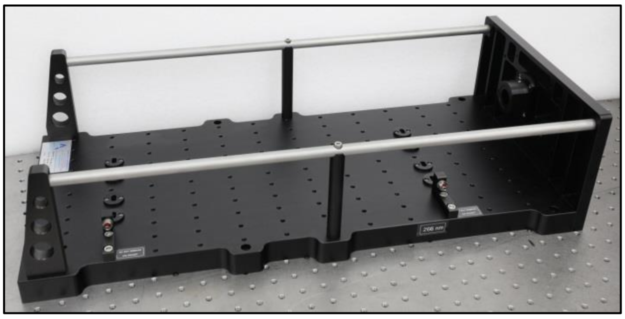
The Mirror Module provides precise alignment of the laser beam for the LIBS-6 module which is attached to the output side of the mirror module. Optical alignment is carried out at APL during final assembly of the LIBS equipment and so there should be no need for the user to adjust the internal mirror assembly. The Mirror Module, Adaptor Platform and LIBS-6 module each include dowel pin fittings so that precise optical alignment is maintained on removing and refitting these components. If you suspect that the optical alignment of the laser beam has been compromised, contact APL for advice before attempting to realign the optics.

3.4 Adaptor Platforms

Two Adaptor Platforms are included with this configuration – one for 1064 nm laser configuration and the other for 266 nm laser configuration as illustrated below.



Adaptor Platform for 1064 nm laser configuration

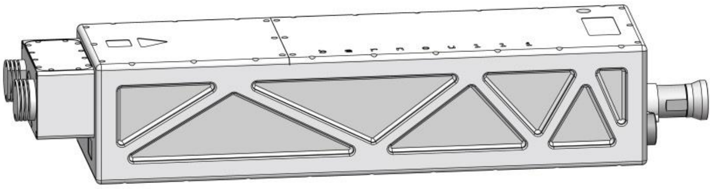


Adaptor Platform for 266 nm laser configuration

The purpose of the Adaptor Platform is to provide a rigid platform on which to attach the laser head and to provide correct positioning of the laser head so that optical alignment with the Mirror Module and the LIBS-6 module is maintained. Mechanical alignment stops are integrated with the design of the Adaptor Platform for this purpose. Further details on how to use these components are provided later in this User's Manual.

3.5 Litron Bernoulli double-pulse, dual wavelength (1064 & 266 nm) laser

The Bernoulli laser is essentially two laser heads combined into one unit. The laser may be operated in single pulse or double pulse mode. Control of the laser including choosing single pulse or double pulse output is controlled via the LIBSoft software. In double pulse mode, interpulse delay times are set within the LIBSoft software (see LIBSoft User's Manual for full details). The laser may be configured for either 1064 nm or 266 nm output – the procedure for this is explained later in this User's Manual.



Bernoulli laser head

Bernoulli laser power supply

Specifications:

- Bernoulli double pulse sealed and rugged laser system
- 200 mJ @ 1064 nm / 20 Hz
- 25 mJ @ 266 nm / 20 Hz
- Low divergence GRM resonators
- Independently triggered flashlamps and Q-switch
- Services: 90 to 240 VAC, 50/60 Hz, 1440 Watts max. (16A IEC)
- Ambient temperature: 5ºC to 35ºC

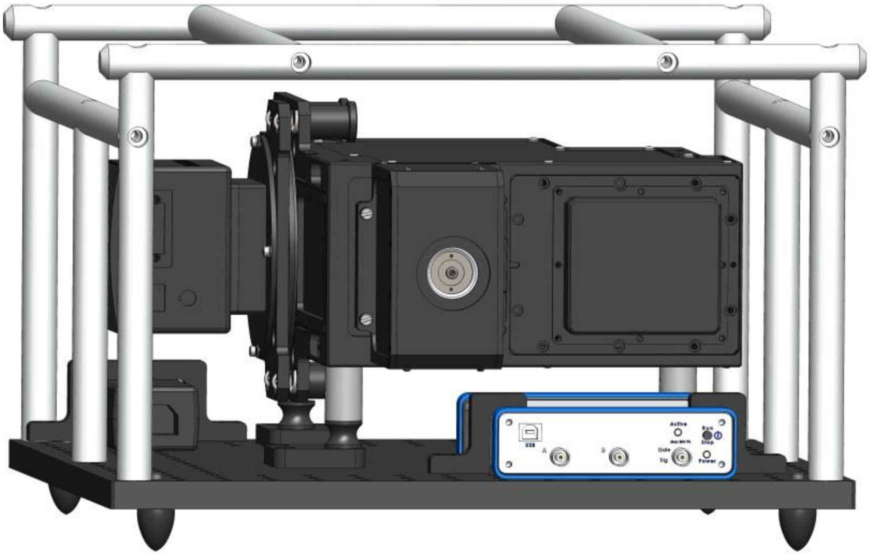
https://litron.co.uk/product-range/lasers-for-piv/bernoulli-piv/

Laser head configured for 1064 nm output beam. 1064 nm output beam exits from aperture on left. Residual 266 nm beam exits from central aperture and is dumped using a beam dump fitted to the 1064 nm Adaptor Platform.

Laser head configured for 266 nm output beam. 266 nm output beam exits from central aperture. Residual 1064 nm beam is blocked by refitting the beam dump to the left hand aperture as shown above.

3.6 EMU-120/65 echelle spectrograph with EMCCD camera

The product datasheets for the EMU-120/65 spectrograph (Catalina Scientific, AZ, USA) and the Falcon Blue EMCCD camera (Raptor Photonics, UK) are appended to this User's Manual. APL supplies the EMU spectrograph with a mounting platform equipped with vibration isolation mounts and a removable protective cage which surrounds the instrument, as illustrated below.

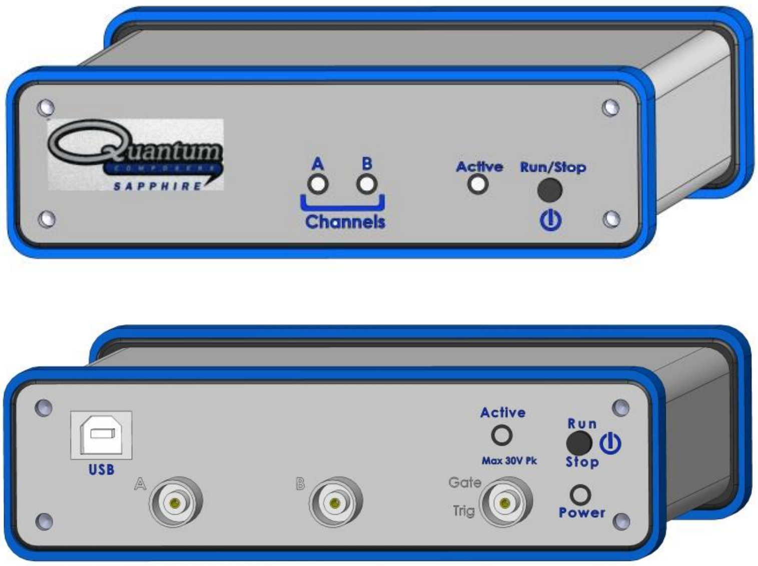


EMU-120/65 echelle spectrograph with EMCCD camera and digital delay generator

The EMU spectrograph is supplied with its own User's Manual which should be referred to when making changes to the configuration of the instrument (e.g. changing the dispersion cassette).

3.7 Quantum Composers digital delay generator

The digital delay generator takes a TTL trigger pulse from the Q-switch of the laser and provides a delayed trigger pulse to the EMCCD camera. The delay may be adjusted by the user via the LIBSoft software.



Front panel

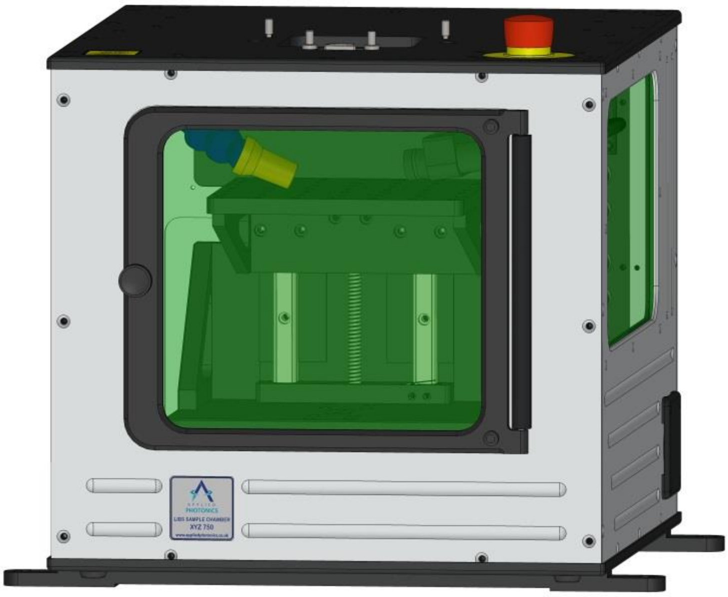
Rear panel

Model 9212+ Sapphire Pulse Generator, 2-channel digital delay generator

https://www.quantumcomposers.com/pulse-generator-sapphire-plus

3.8 XYZ-750 computer-controlled sample chamber

The XYZ-750 computer-controlled sample chamber is one of APL's range of modular sample chambers designed for use with APL's modular LIBS systems. The XYZ-750 requires LIBSoft software to operate as it has no manual control of the three stages.



XYZ-750 computer-controlled, modular sample chamber

The XYZ-750 has the following features:

- 3-axis motorised and computer-controlled translation stages each with 75 mm travel
- Precision ball-screw design which reduces rotational friction and virtually eliminates mechanical backlash
- Heavy-duty linear rail bearings (two rails per stage)
- Translation stage linear resolution of 1 µm
- Sample table breadboard with array of M6 tapped holes on 25 mm centres (5 kg load rating)
- Hinged door with magnetic catch and dual redundant electrical safety interlock
- Laser protective windows on two sides and hinged door
- Fume extraction port with internal flexible tube (external fume extraction system not included)
- Internal lighting
- External dimensions of approx. 330 x 360 x 430 mm. Weight approx. 21 kg

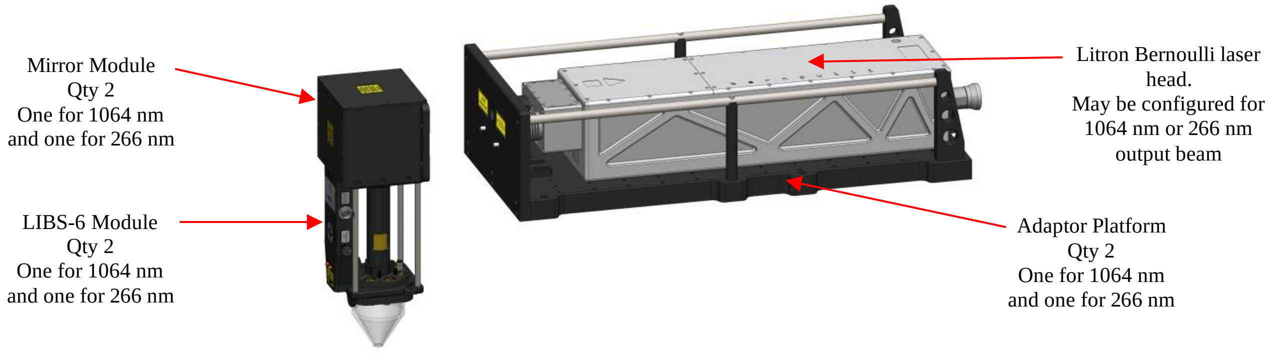
3.9 LIBSoft software

APL's LIBSoft software has been designed specifically for APL's range of modular LIBS systems. LIBSoft can control the various hardware components of the LIBS system including the laser, the spectrograph, the delay generator and the sample chamber translation stages. LIBSoft also controls data acquisition offering a number of features specifically developed for LIBS. LIBSoft has some data processing features including emission line identification and tools for constructing calibration plots for quantitative analysis. LIBSoft is continually being developed further to include more features and APL offers free software upgrades to its customers for a period of two years. A detailed User's Manual for LIBSoft is supplied with the LIBS equipment.

4 Configuring the hardware

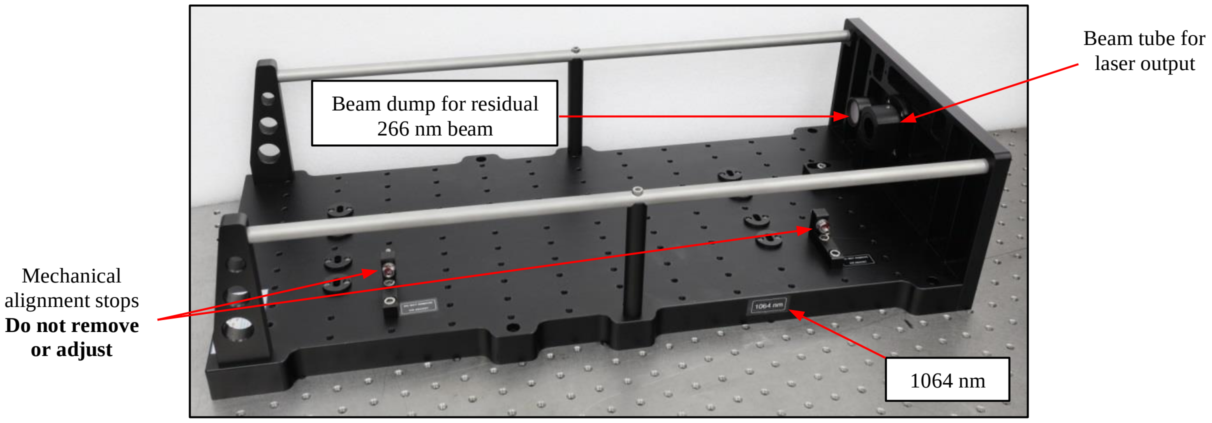
4.1 Introduction

For this particular configuration of LIBS equipment, two LIBS-6 modules are provided – one configured for a 1064 nm laser beam and another configured for a 266 nm laser beam. The LIBS-6 modules are attached to the laser head using an appropriate Adaptor Platform. For this configuration, two Adaptor Platforms are provided – one for when the laser is configured for 1064 nm and another for when the laser is configured for 266 nm. Additionally, two right-angle Mirror Modules are provided (one for 1064 nm and another for 266 nm) which fit between the LIBS-6 module and the Adaptor Platform as illustrated in the following diagram.

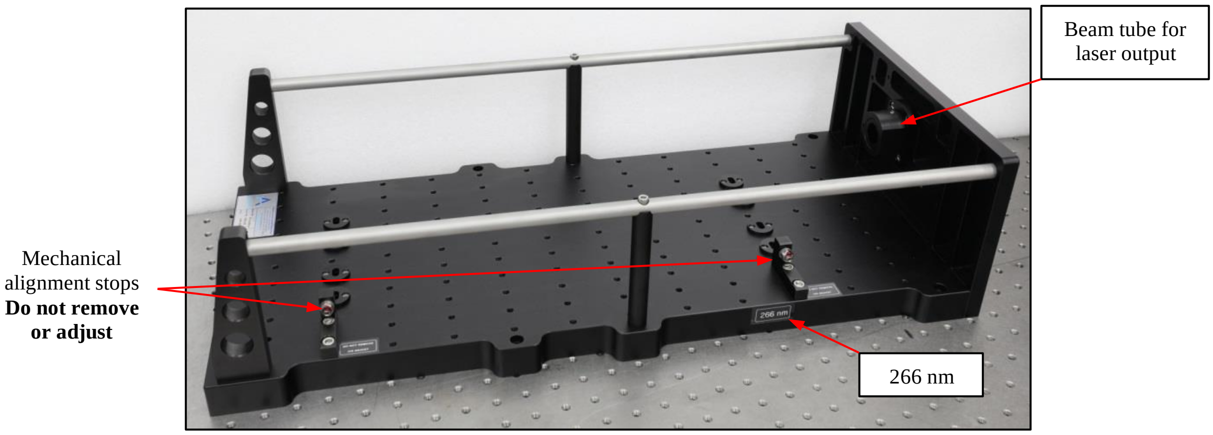


4.2 Configuring the Litron Bernoulli laser and fitting to the appropriate Adaptor Platform

The LIBS equipment may be operated with a laser beam wavelength of 1064 nm or 266 nm. The laser head needs to be configured differently for each wavelength and so two Adaptor Platforms are included – one for 1064 nm and one for 266 nm, as shown below.



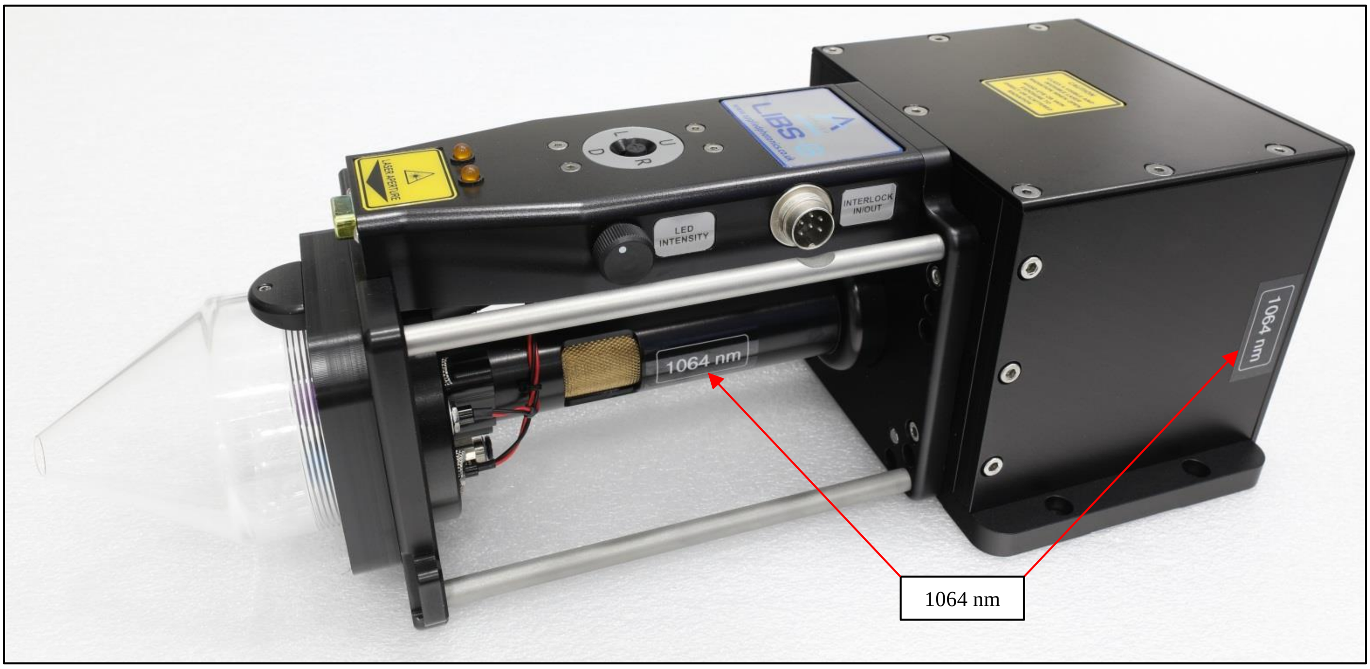
Adaptor Platform for 1064 nm configuration



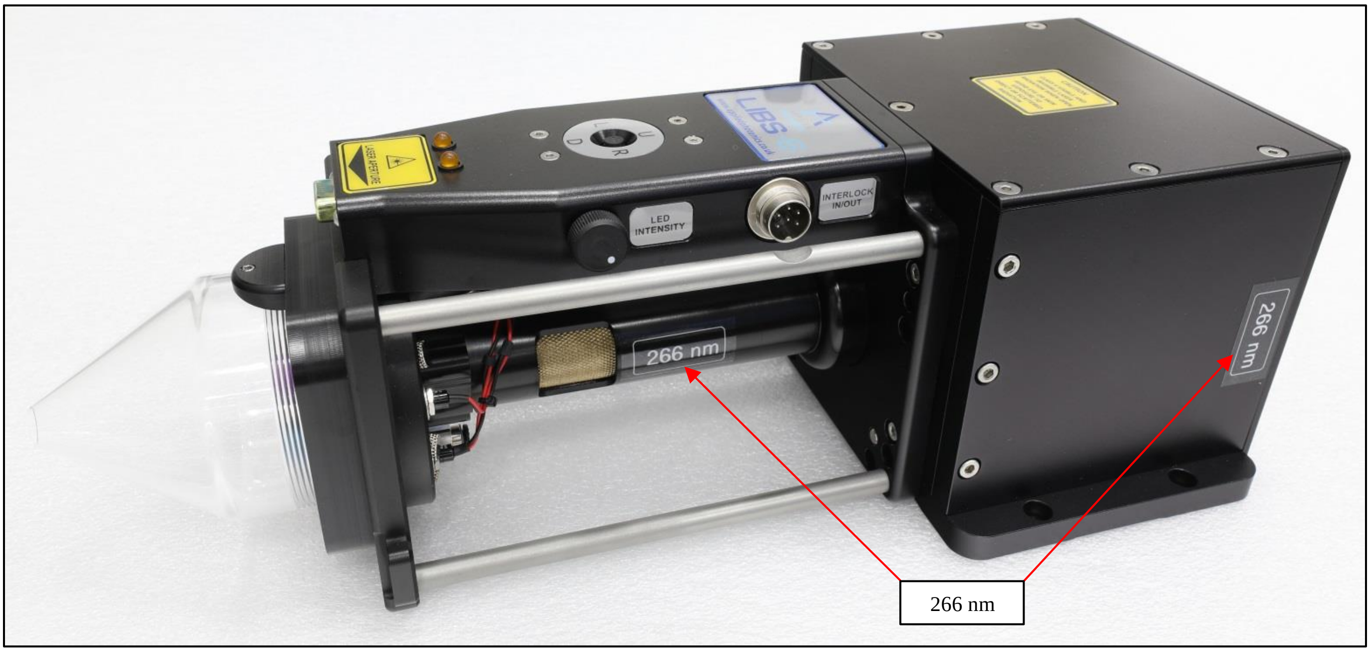
Adaptor Platform for 266 nm configuration

The LIBS-6 modules and Mirror Modules are supplied fitted together as shown below. They may be disconnected from each other but we recommend that they remain attached as two assemblies – one for 1064 nm and one for 266 nm. They are clearly labelled with the laser wavelength as shown below. It is very important that the LIBS-6 module / Mirror Module assembly is correctly chosen to suit the laser beam wavelength. Failure to do so will result in damage to the optical components and may also cause damage to the laser head.

Note: Incorrect use of these components with regard to laser beam wavelength will void the warranty.



LIBS-6 module and attached Mirror Module (1064 nm)



LIBS-6 module and attached Mirror Module (266 nm)

The following sections describe how to configure the hardware for each laser wavelength.

Operation at 1064 nm

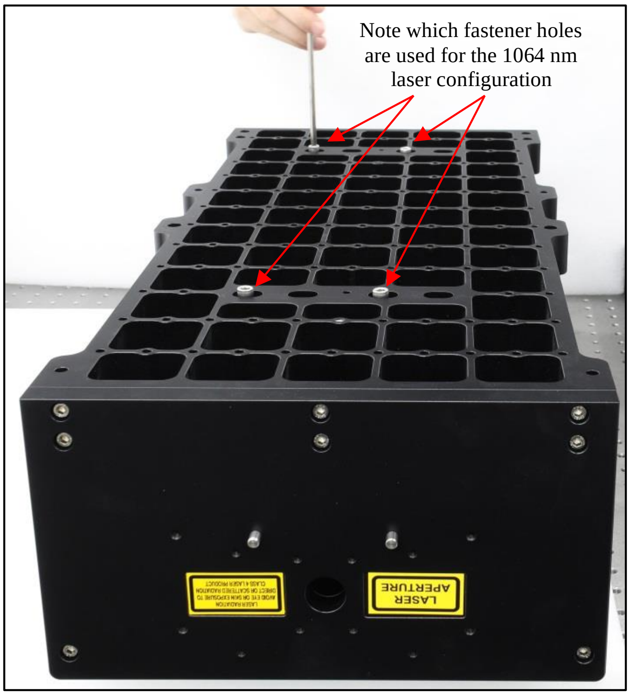
Select the Adaptor Platform, Mirror Module and LIBS-6 module which are each labelled 1064 nm. Configure the Litron Bernoulli laser for 1064 nm operation as illustrated below.

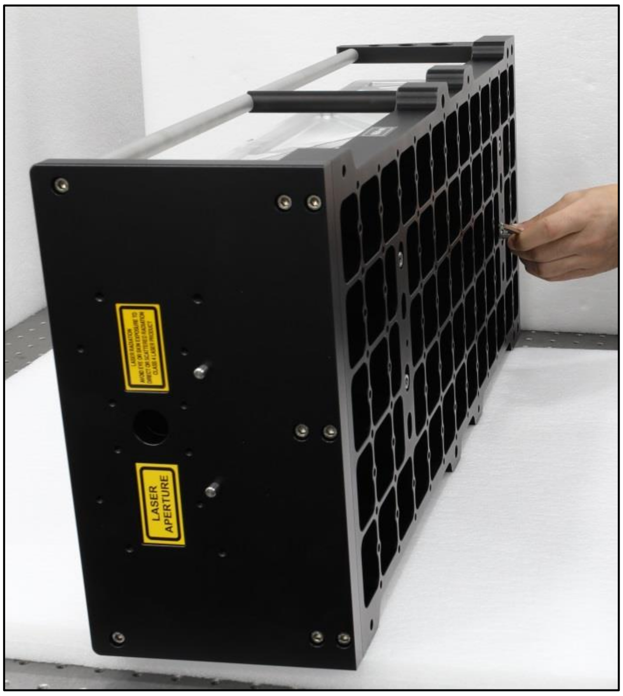
Remove the beam dump from the 1064 nm beam aperture of the laser head

Fit the laser head to the 1064 nm Adaptor Platform as shown in the following images:

Note: A video clip is available which shows how to fit the laser head to the Adaptor Platform.

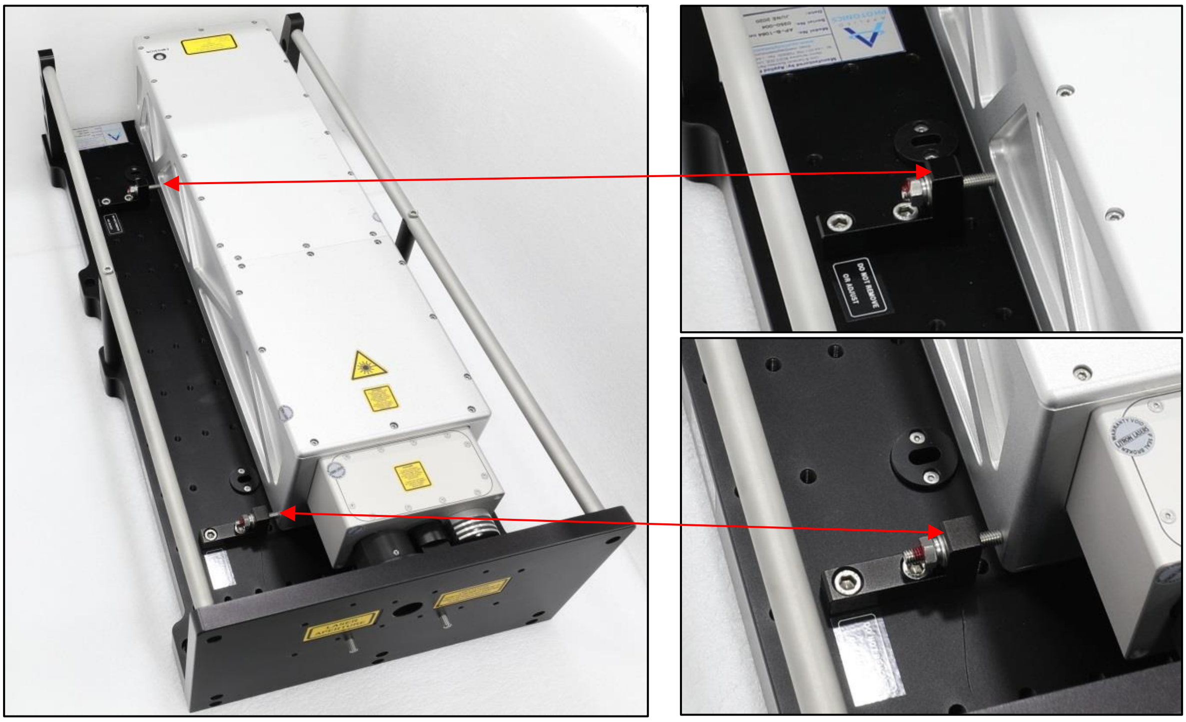
To achieve correct optical alignment, ensure the body of the laser head is in contact with the mechanical alignment stops as shown in the above image





Four M6 cap head screws are used to attach the laser head to the Adaptor Platform. It is more convenient to place the laser head upside down on some foam and then offer up the Adaptor Platform as shown above. The four M6 cap head screws should not be fully tightened at this time.

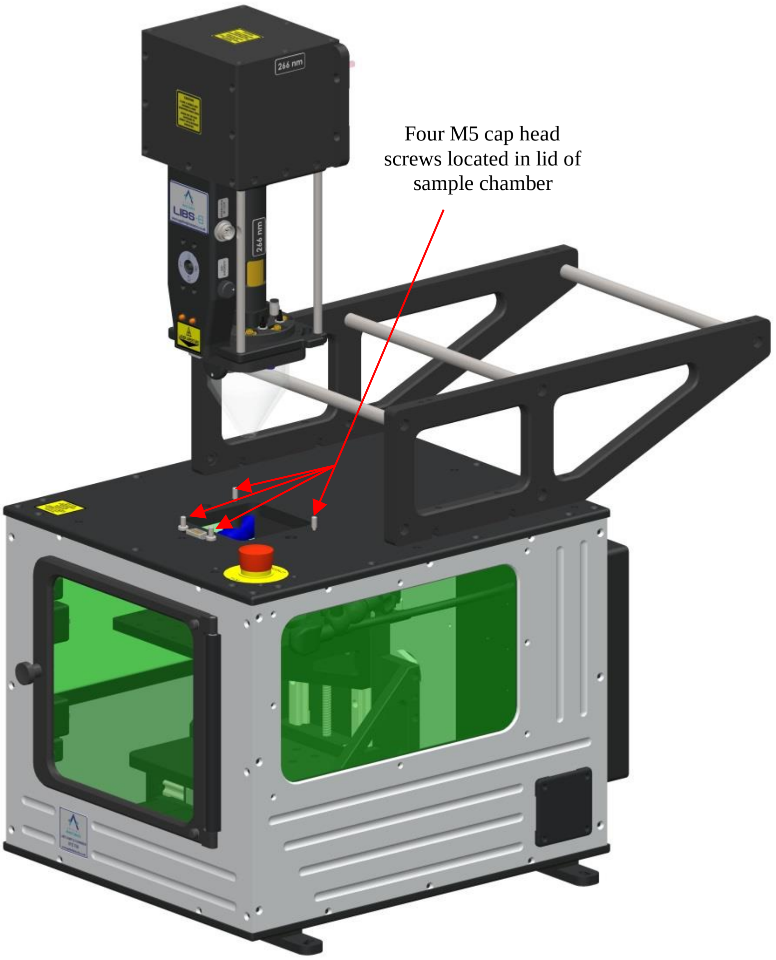
Prior to tightening the M6 screws, place the Adaptor Platform on its side as shown above so that the laser is resting on the mechanical alignment stops. This helps to ensure the laser head is correctly positioned prior to securing in place.



Close-up views of the mechanical alignment stops

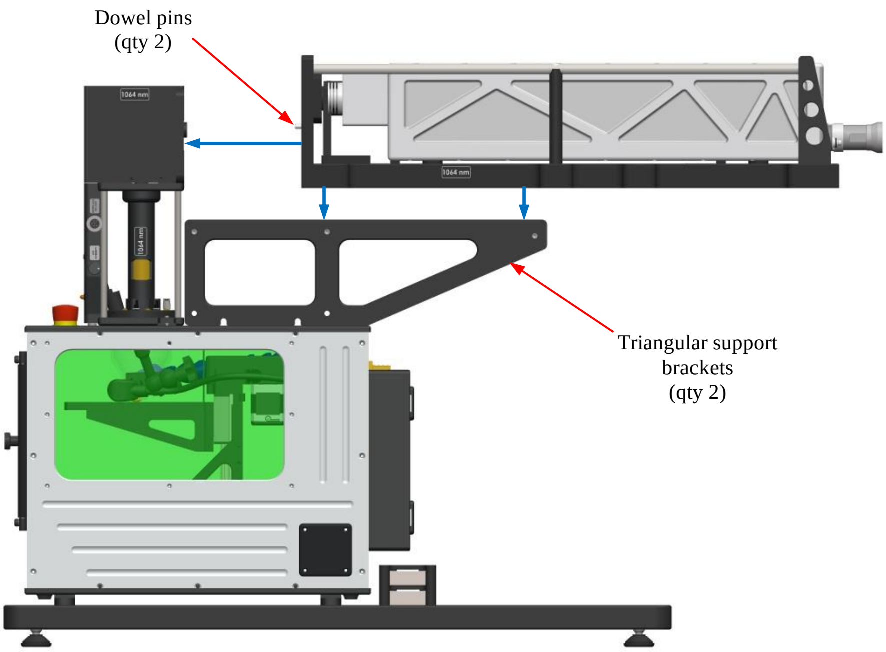
Refer to the LIBSoft software User's Manual for further information. The Quick Setup Guides appended to this User's Manual should also be referred to.

After correctly fitting the laser head to the 1064 nm Adapt Platform, fit the 1064 nm LIBS-6 module / Mirror Module to the XYZ-750 sample chamber as shown in the following images.

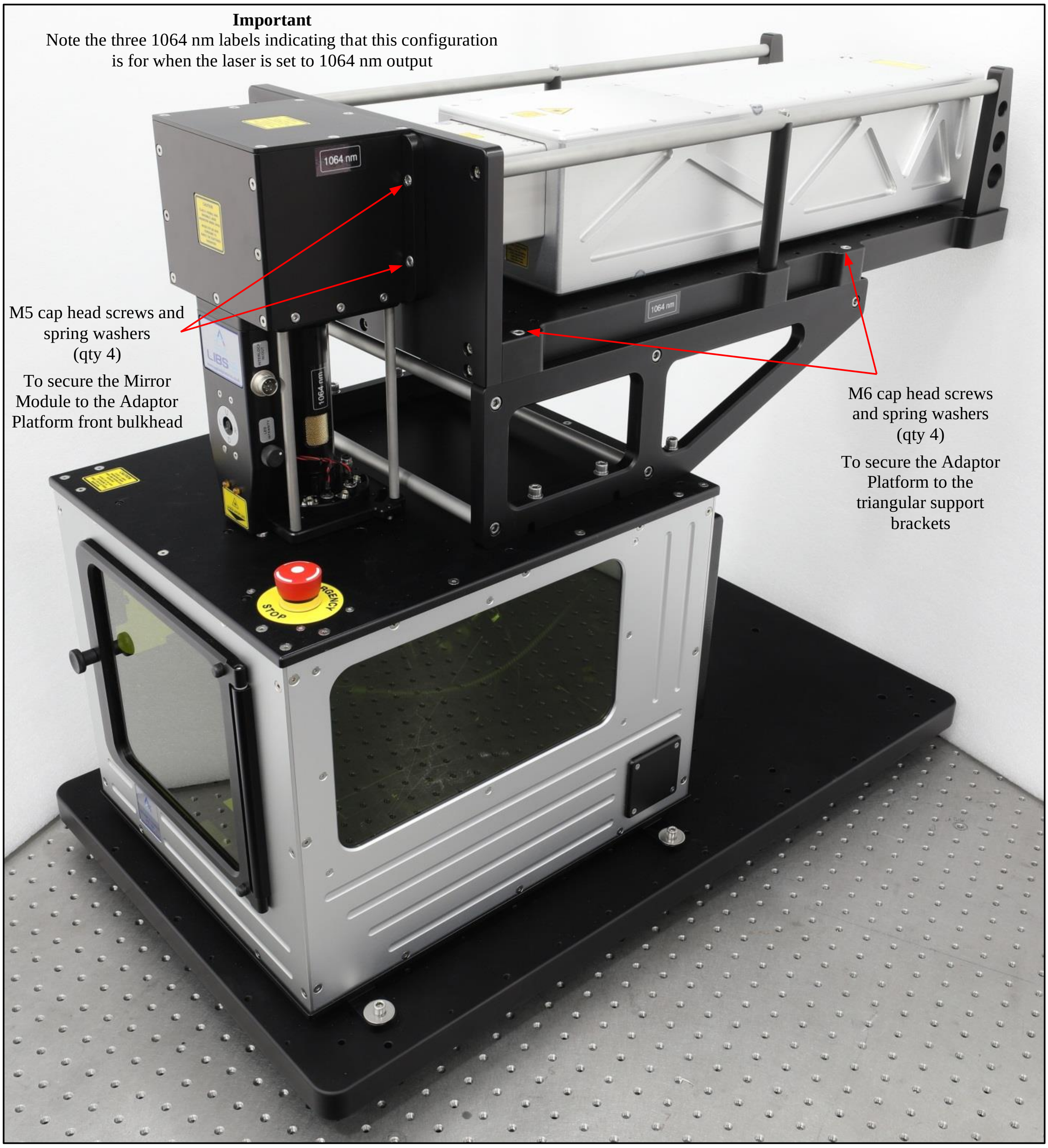


The LIBS-6 module / Mirror Module assembly should be carefully offered up to the sample chamber so that it fully fits into the top port of the sample chamber. Care should be taken not to damage the electrical connectors (9-pin D-type). The four M5 cap head screws located in the lid of the sample chamber are used to secure the LIBS-6 module to the sample chamber. They are accessed from inside the sample chamber. Do not fully tighten these screws at this time – they should be "finger tight" only.

A video clip is available which shows the above procedure.

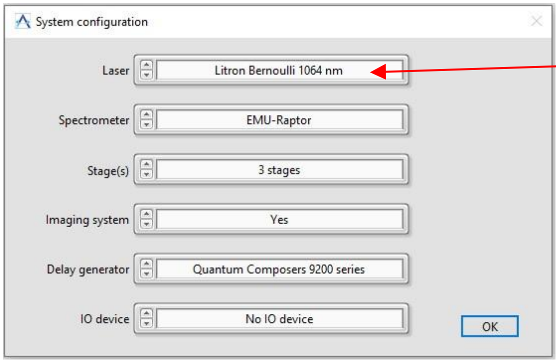


Next, take the Adaptor Platform with fitted laser head and offer up to the two support triangular brackets as shown above. **Note:** Two people will be needed to do this. Slide the Adaptor Platform along the top surfaces of the support brackets and carefully engage the two dowel pins with the holes in the Mirror Module. Then secure the Adaptor Platform to the support brackets using four M6 cap head screws and spring washers but do not fully tighten at this time. Check that the Adaptor Platform is mounted squarely with respect to the support brackets and also the Mirror Module (the rear bulkhead of the Mirror Module should be flush against the front bulkhead of the Adaptor Platform) and then secure the Mirror Module to the Adaptor Platform using four M5 cap head screws and spring washers. Tighten these screws before tightening the four M6 screws which secure the Adaptor platform to the support brackets. The four M5 cap head screws which are used to secure the LIBS-6 module to the lid of the sample chamber do not need to be tightened fully – they may remain “finger tight”. The whole assembly should now look like that shown in the following image. A video clip is available showing the above procedure.



The XYZ-750 sample chamber, LIBS-6 module, Mirror Module, Adaptor Platform and laser head assembled correctly for operation at a laser wavelength of 1064 nm.

Important: It is necessary also to select the 1064 nm laser option in LIBSoft as follows:

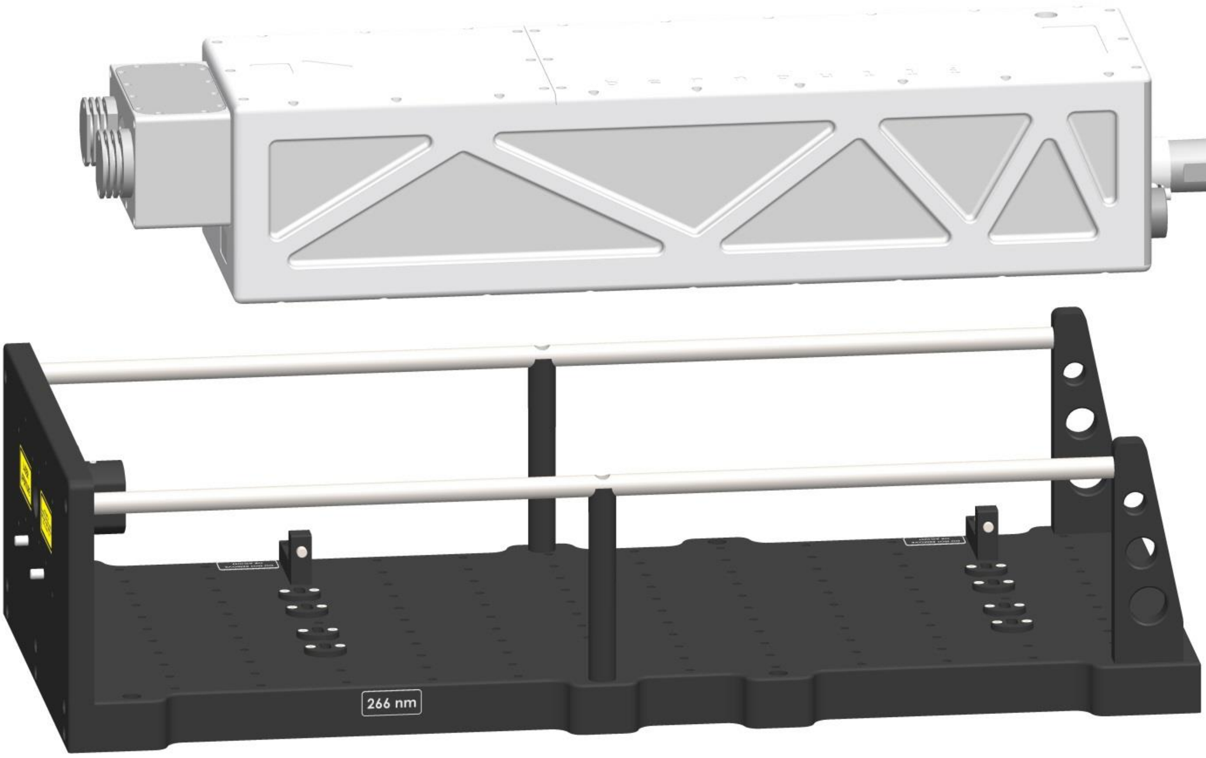


Select:
“**Litron Bernoulli 1064 nm**”

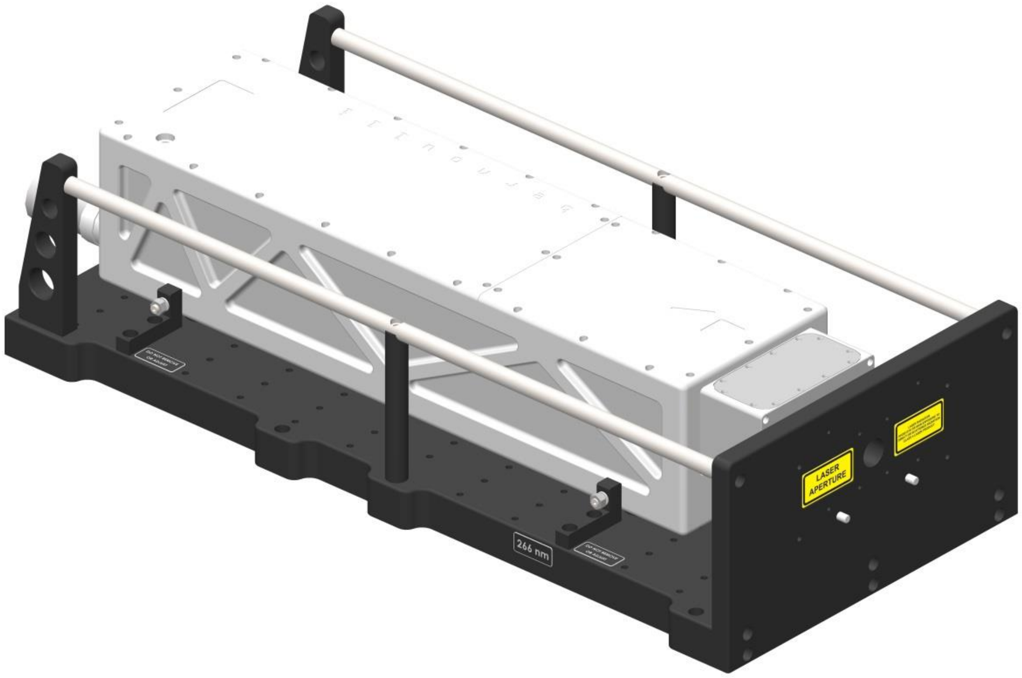
Operation at 266 nm

The procedure is very similar to that of the 1064 nm configuration. Select the Adaptor Platform, Mirror Module and LIBS-6 module which are each labelled 266 nm. Configure the Litron Bernoulli laser for 266 nm operation as illustrated below.

Fit the laser head to the 266 nm Adaptor Platform as illustrated in the following diagrams. Note that for the 266 nm configuration the laser head is mounted centrally with respect to the Adaptor Platform whereas for the 1064 nm configuration the laser head is off-set towards one side.

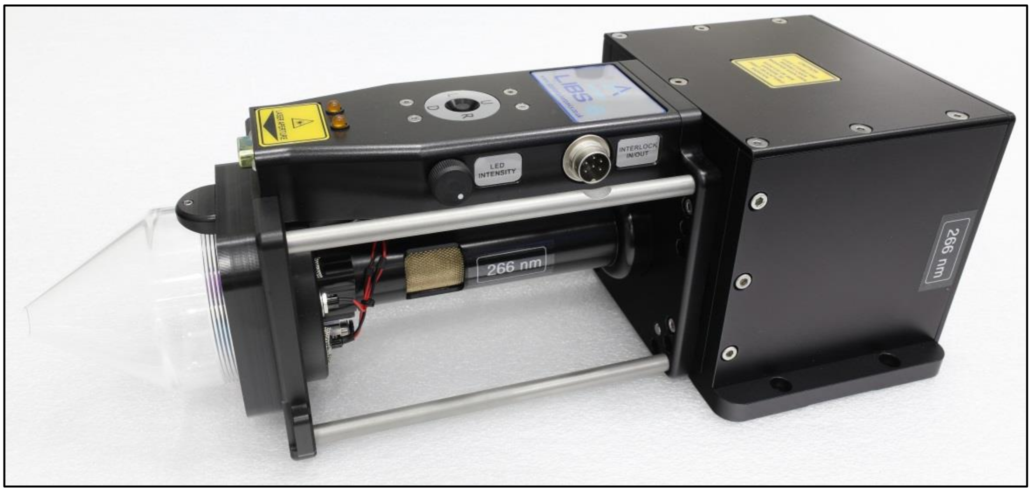


Laser head and Adaptor Platform used for 266 nm configuration



Laser head fitted to the Adaptor Platform (266 nm configuration)

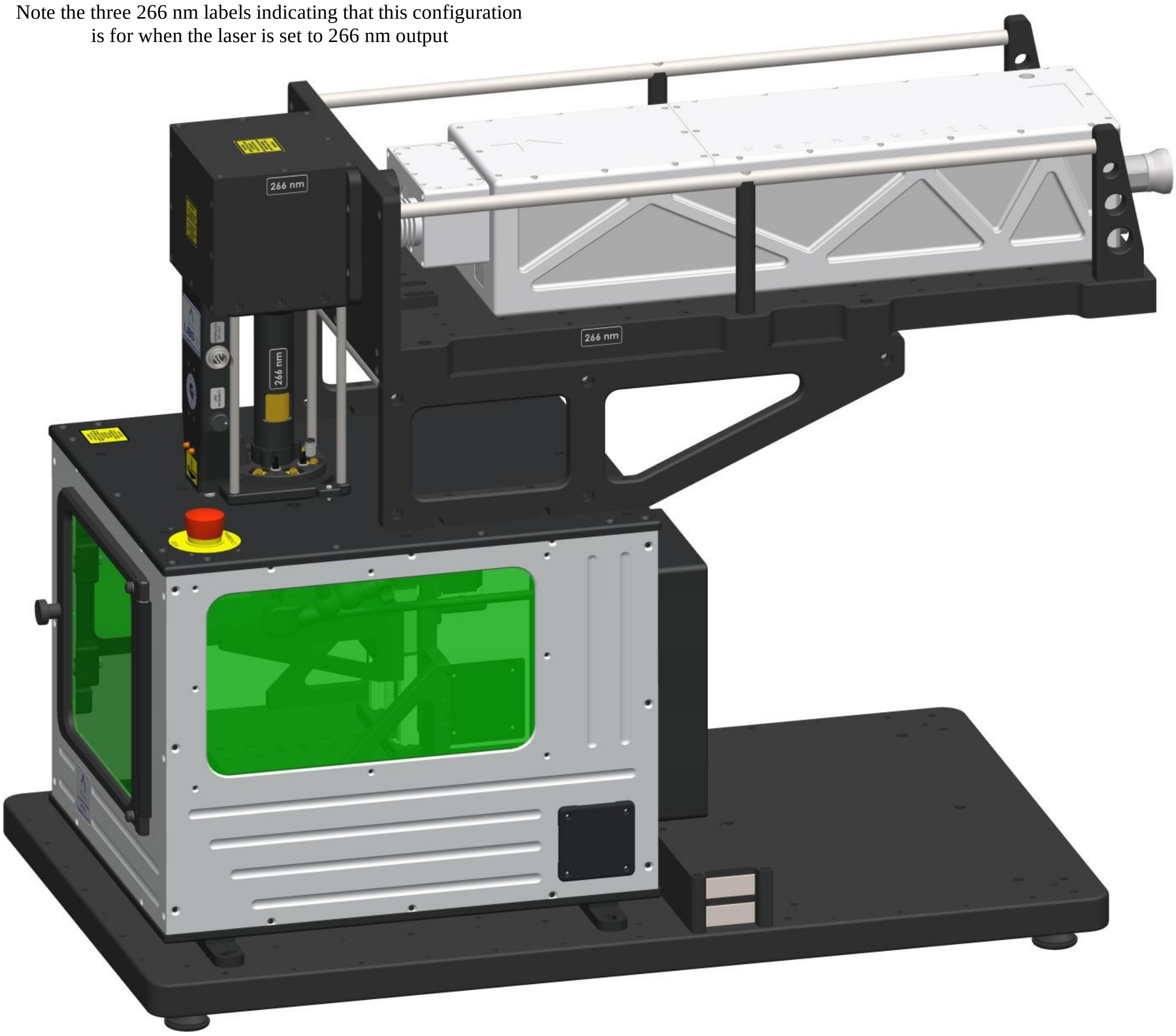
Remove the 1064 nm LIBS-6 module / Mirror Module assembly from the XYZ-750 sample chamber and replace with the 266 nm LIBS-6 module / Mirror Module assembly.



266 nm LIBS-6 module / Mirror Module assembly

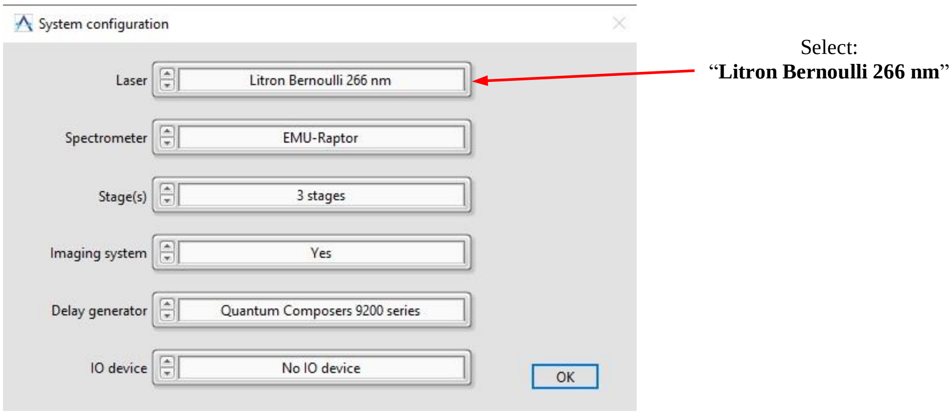
Fit the 266 nm laser head / Adaptor Platform assembly to the triangular support brackets of the XYZ-750 sample chamber in the same way as described earlier for the 1064 nm configuration. The equipment should then look like that illustrated in the following diagram.

Important
Note the three 266 nm labels indicating that this configuration is for when the laser is set to 266 nm output

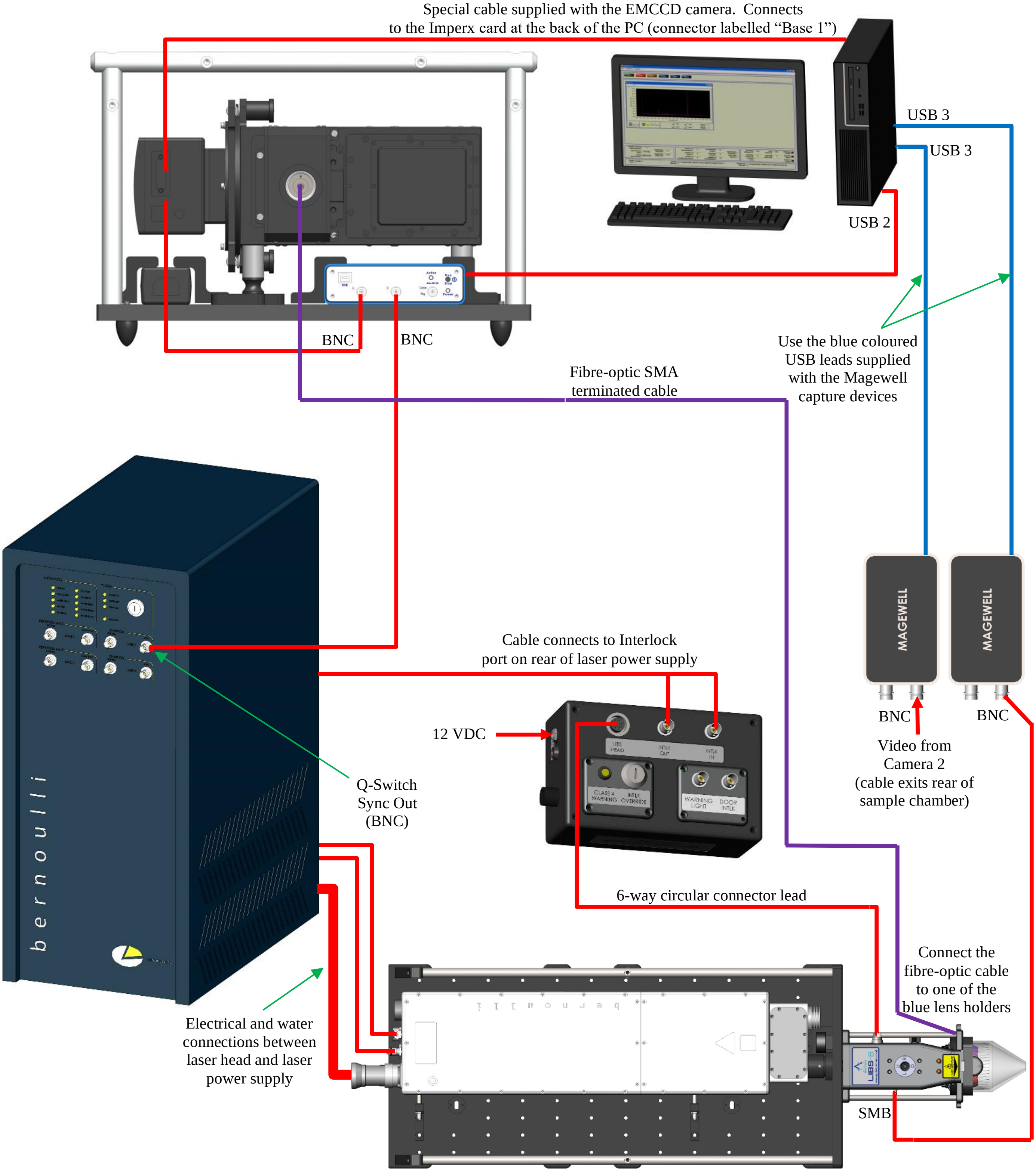


The XYZ-750 sample chamber, LIBS-6 module, Mirror Module, Adaptor Platform and laser head assembled correctly for operation at a laser wavelength of 266 nm.

Important: It is necessary also to select the 266 nm laser option in LIBSoft as follows:



4.3 Electrical and fibre-optic connections



Schematic diagram illustrating the electrical and fibre-optic connections between the various components of the LIBS system

4.4 The Interlock Interface Unit

The Interlock Interface Unit connects the interlock circuit of the LIBS-6 module and modular sample chamber with the laser power supply unit (as illustrated in the above diagram) using two special cables supplied with the LIBS equipment. The Interlock Interface Unit requires a 12 VDC supply (derived from a plug-in power supply) without which the interlock circuit will not allow the laser to become active (i.e. a “fail safe” design).

The Interlock Override feature is used to override the laser safety interlock when the LIBS-6 or LIBS-8 module is required to be used in “open beam” configuration (i.e. without a sample chamber). To override the interlock, the keyswitch should be turned “on” by turning clock-wise. The orange / yellow LED indicator to the left of the keywitch (labelled “Class 4 Warning”) will flash continuously when the 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.

Interlock Override
Class 4 warning lamp will flash when the keyswitch is activated. It is important to deactivate this feature and remove the key to allow the LIBS system to be used as a Class 1 laser product.

External warning light and door interlock connections
This feature is for optional use.
The “Door Intlk” BNC connector may be fitted to a laboratory door interlock switch if required.
If not used the “shorting link” blanking cap needs to be fitted to the “Door Intlk” BNC in order to satisfy the interlock circuit.
The “Warning Light” BNC connector provides a 12 VDC (centre +ve) output when the laser is active. This may be used to activate an external warning light or laboratory interlock system.

WARNING
When the Interlock Override keyswitch is activated, the LIBS system becomes a Class 4 Laser Product, hence appropriate safety procedures and precautions MUST be adopted when operating the LIBS system in this mode. The key should be removed when this feature is not required and held by a responsible person (e.g. your Laser Safety Officer).

The two BNC connectors on the right side of the control panel are for optional connection to a laboratory door interlock switch and/or to an external warning light. Note that the “Warning Light” BNC connector provides 12 VDC (1 Amp max., centre pin +ve) whenever the laser is active. Note also that the “Door Intlk” BNC connector needs to be electrically “shorted” before the laser can be made active – hence the use of the blanking cap when it is not connected to a laboratory door interlock switch.

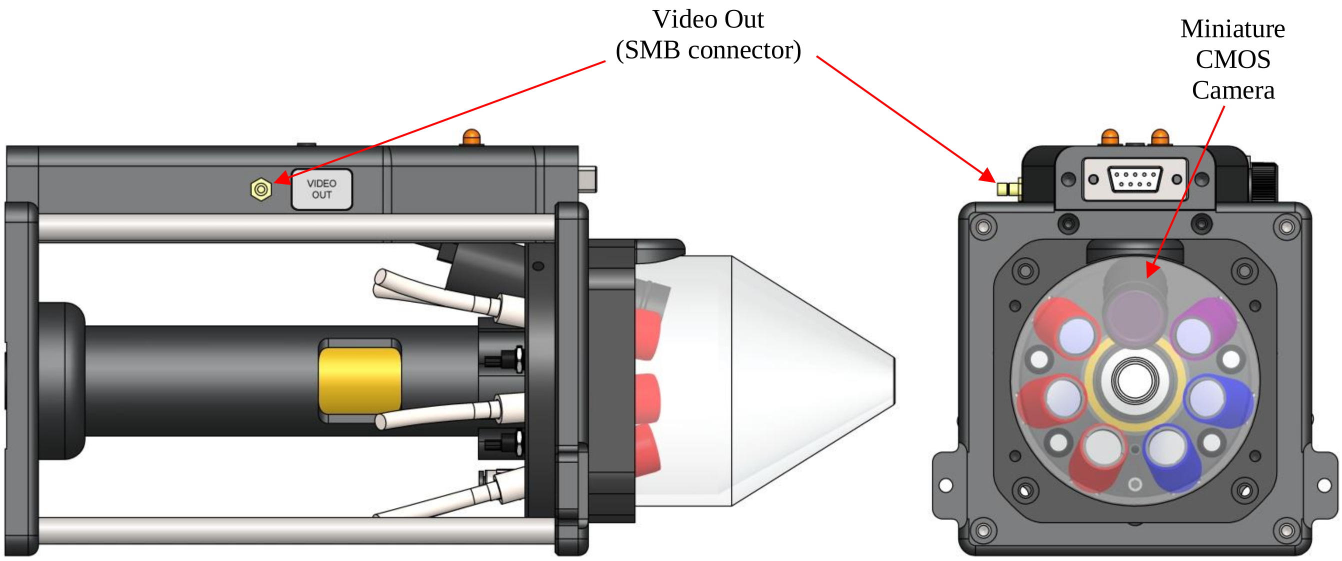
4.5 Imaging camera and associated components

This configuration of our modular LIBS instrument is equipped with two miniature CMOS cameras for viewing the sample. One is integrated with the LIBS-6 module (both the 1064 and 266 nm modules) and so views the sample from above while the other camera is fitted on an adjustable arm inside the XYZ-750 sample chamber and views the sample from the side.

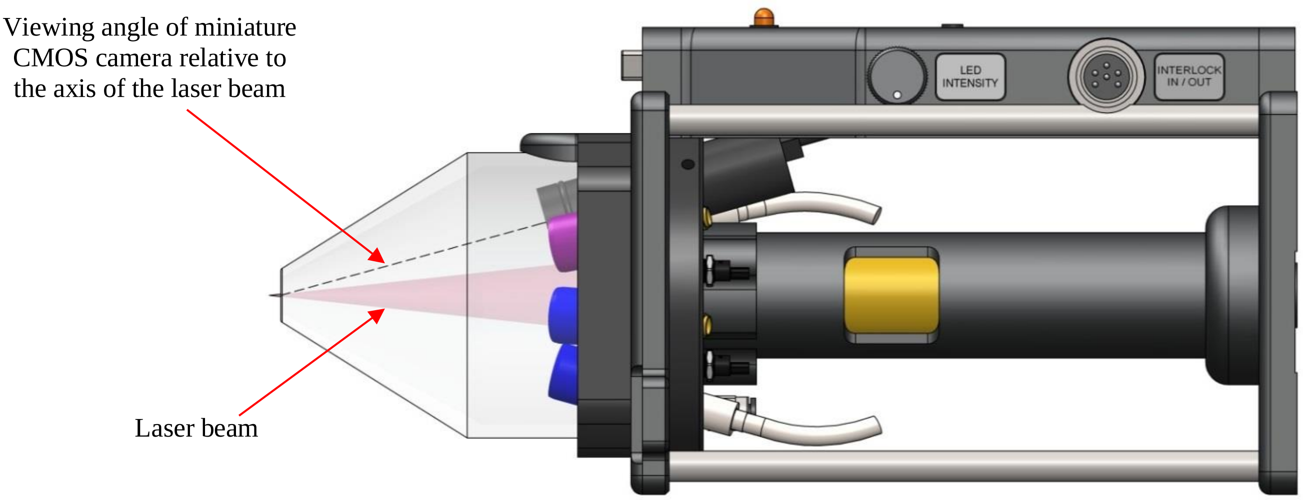
Camera specifications:

- 1/3-inch CMOS colour sensor 2.5 MP (1956 x 1266)
- Adjustable focus (approx. 20 mm to infinity – factory set during testing of LIBS system)
- Lens: f = 12 mm, f/1.8
- 12 VDC @ <1 A

Miniature CMOS camera integrated with the LIBS-6 module



CAD images of LIBS-6 module showing location of the “Video Out” SMB connector and the CMOS camera

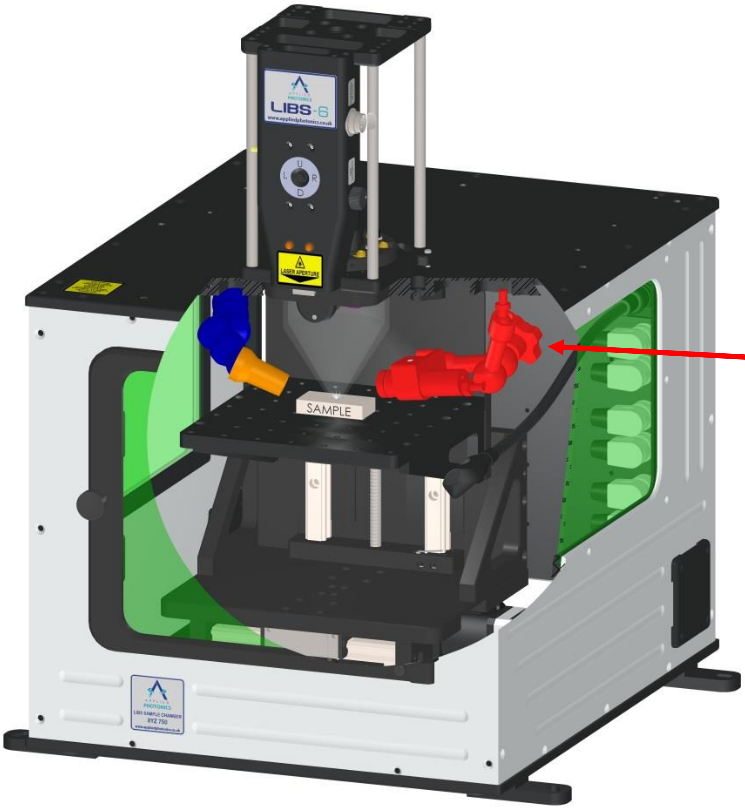


CAD image of LIBS-6 module showing viewing angle of integrated miniature CMOS camera

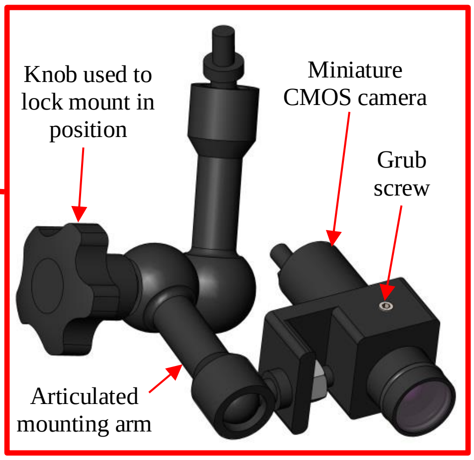
The video images are fed to the system computer via the USB frame grabber / capture device (Magewell) supplied with the imaging kit. There is one Magewell frame grabber / capture device for each camera being used. Note that these devices must be connected to USB 3 ports on the system computer using the proprietary USB cable (coloured blue) supplied with these devices.

Miniature CMOS camera integrated with the XYZ-750 sample chamber

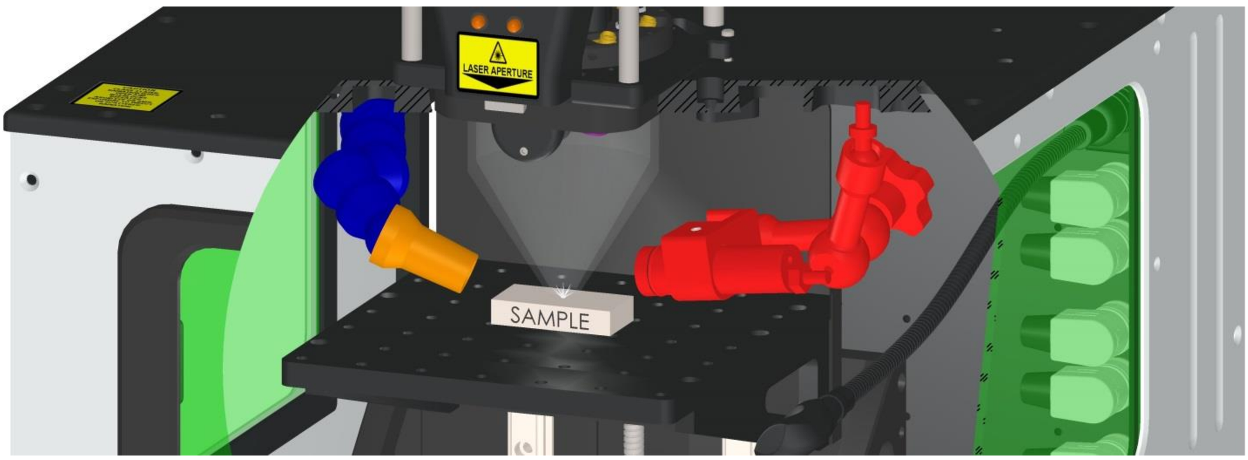
The second camera is fitted inside the sample chamber as shown in the following diagrams. This camera provides a side view of the sample in the vicinity of the laser-induced plasma. The associated cable exits the sample chamber via a cable gland located in the rear panel of the sample chamber. This camera is equipped with an articulated mounting arm which allows the camera to be positioned at the desired place and then locked in place. In the diagram below left, the camera and articulated mounting arm are highlighted in red. Note that the camera focus has been set during final testing of the LIBS equipment so it is necessary to position the camera at a distance from the object being viewed which results in a clearly focussed image. It may be necessary to adjust the position of the camera relative to the articulated arm mount by slackening the grub screw (see below) and sliding the camera towards or away from the object to help in this regard.



CAD view of XYZ-750 sample chamber showing
second camera and articulated mounting arm (highlighted in red)



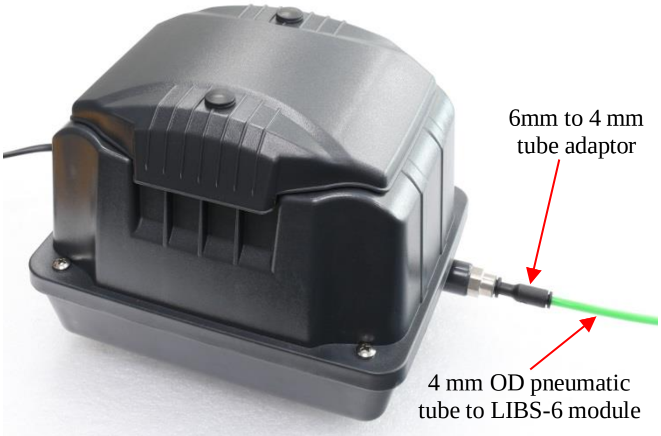
Detailed view of second camera with articulated mounting arm. The knob on the left is used to lock the knuckle joints of the articulated mounting arm when the desired position for the camera is found by manually positioning the camera. The camera may be repositioned relative to the articulated mount by slackening the grub screw which is used to secure it to the mount.



Close-up view showing camera and articulated mounting arm (highlighted in red) relative to the sample position

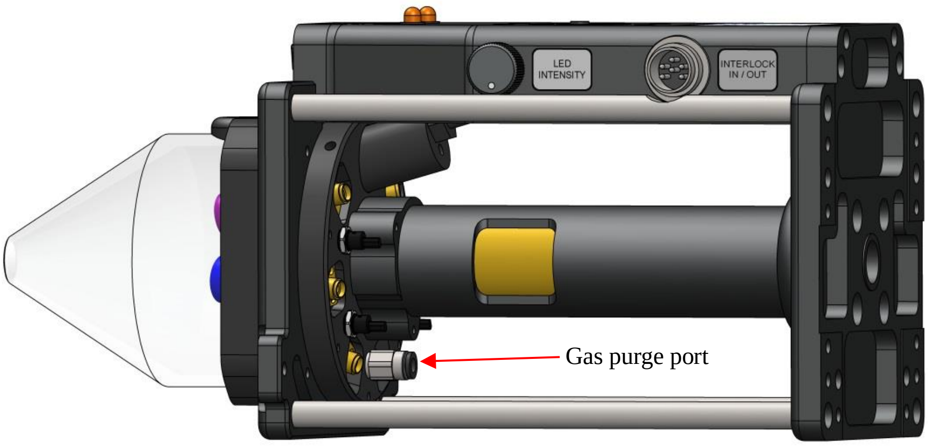
4.6 Gas purge feature and air pump

The LIBS-6 module is equipped with a gas purge feature which allows air, nitrogen or preferably argon gas to be supplied via the acrylic nozzle aperture to the area of the sample where the laser beam is directed. Argon is often used as a purge gas with LIBS since it increases significantly the intensity of the recorded spectra, especially in the UV region (see Test Report for example spectra which show this). Although it is not necessary to use gas purge when conducting LIBS analysis of a material, it is recommended that at least air is used as a purge gas so as to help to keep the optics free of ejected material from the laser plasma. In view of this, we provide with most of our bench top LIBS instruments a simple 20 litres per minute (lpm) air pump of the type used for aquariums to bubble air through the water. This is illustrated below. The pneumatic tube (coloured green) is connected to the “push fit” connector located on the optics array of the LIBS-6 module as shown below in the image on the right. This air pump may be left switched on for the entire time the LIBS equipment is in use.



230 VAC diaphragm air pump with 4 mm outside diameter (OD) pneumatic tube fitted

Image of LIBS-6 module showing pneumatic tube connected to “push fit” connector



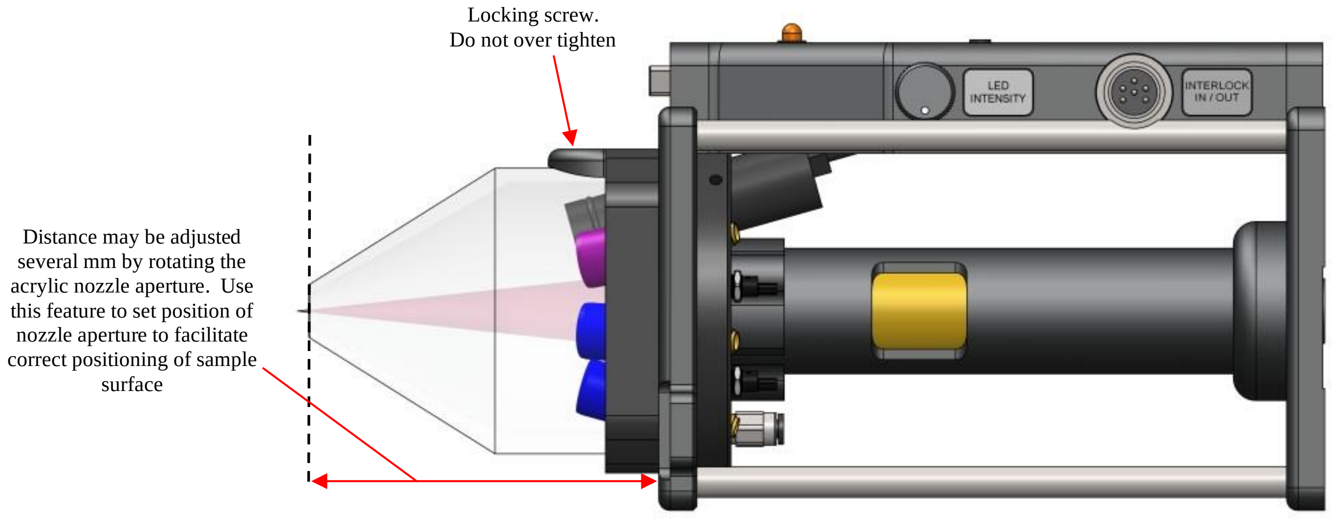
Location of the gas purge port (“push fit” connector) on the LIBS-6 module

The above air pump is not used when other gases are used, such as nitrogen or argon. When using a gas other than air, alternative means of controlling the purge gas must be used such as a suitable regulator and flow meter (not supplied with the LIBS equipment). A flow rate of typically 5 to 10 lpm is usually sufficient. The gas pressure must be limited to not more than about 5 pounds per square inch (psi), although longer lengths of pneumatic hose may require higher pressure but never more than about 10 psi.

WARNING
To avoid an explosion risk, never use flammable gases as purge gas

4.7 Setting the position of the acrylic nozzle aperture

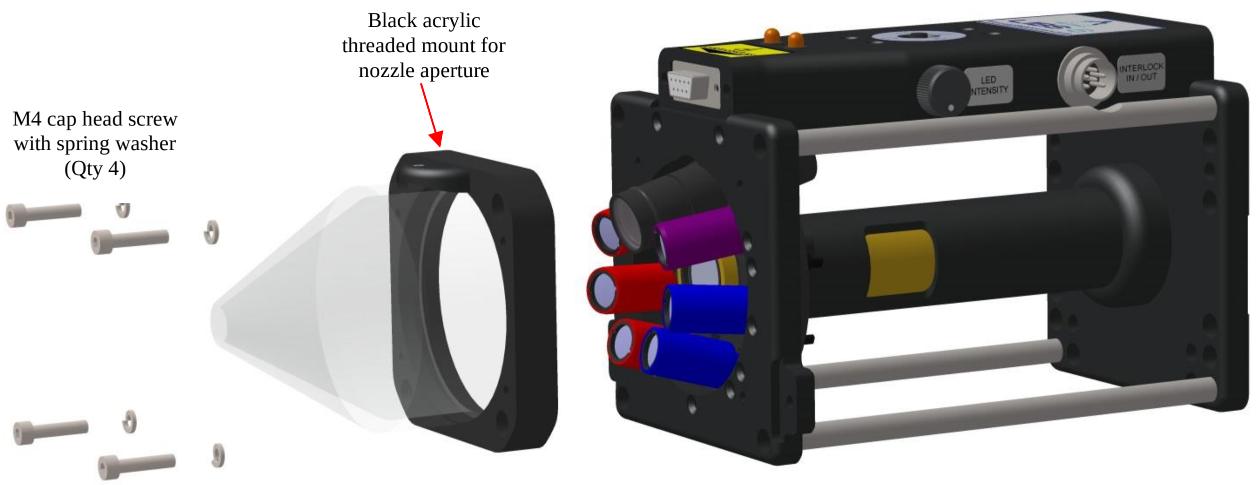
The primary purpose of the transparent acrylic nozzle aperture is to provide a convenient means of setting the sample position with respect to the laser beam focus. It also provides a means of directing the purge gas, if used, to where it is needed, i.e. the region where the laser-induced plasma is formed. The use of the acrylic aperture nozzle is optional and so it may be removed if required although an alternative method of setting the sample position will be required. The acrylic nozzle aperture is threaded so rotating it will move the position of the aperture along the axis of the laser beam. During final factory testing of the LIBS equipment, the acrylic nozzle aperture was set at a near optimum position for the solid samples used for testing the LIBS equipment (see the Test Report supplied with the equipment).



CAD diagram illustrating adjustment of the acrylic nozzle aperture

The user may choose to set the acrylic nozzle aperture such that it is several mm from the sample and then use a distance piece (e.g. a flat section of plastic of appropriate thickness) to set the correct position for the sample.

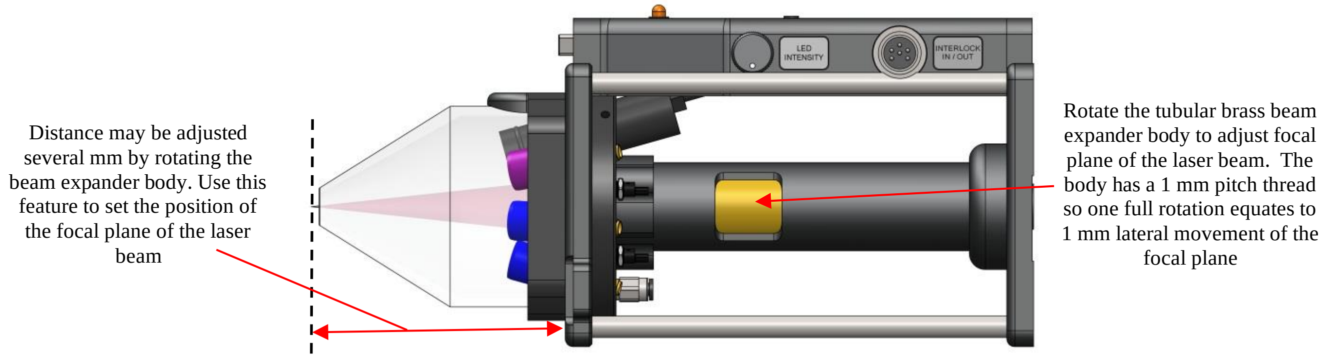
To avoid losing the position of the nozzle aperture by unscrewing it from its mount, it is recommended that the nozzle aperture complete with its mount (black acrylic threaded component) is removed from the LIBS-6 module by unscrewing the four M4 cap head screws used to secure the mount to the LIBS-6 module, as illustrated in the following diagram.



CAD diagram illustrating removal of the acrylic aperture nozzle complete with its threaded mount

4.8 Adjusting and setting the laser beam focus

The following diagram illustrates the method of adjusting the position of the focal plane of the laser beam. During factory testing, the LIBS-6 module was set such that the sample is assumed to be in contact with the acrylic nozzle aperture (or within 1 mm of contact) and the focal plane of the laser beam was set to be 2 to 3 mm beyond the plane of the nozzle aperture. This is illustrated clearly in the image below which shows a laser-induced plasma in air.



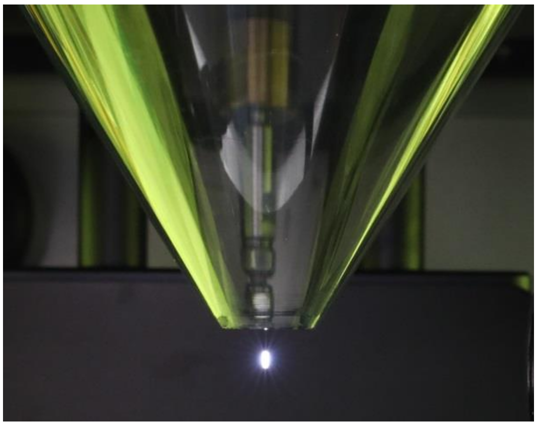
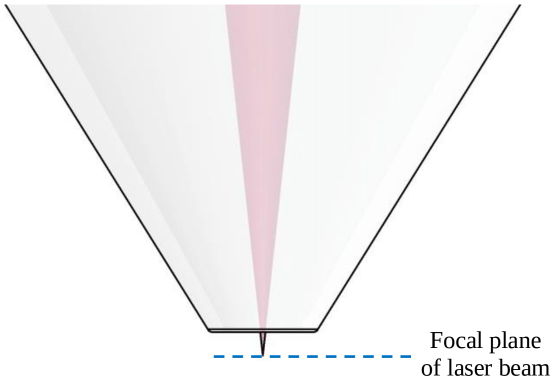
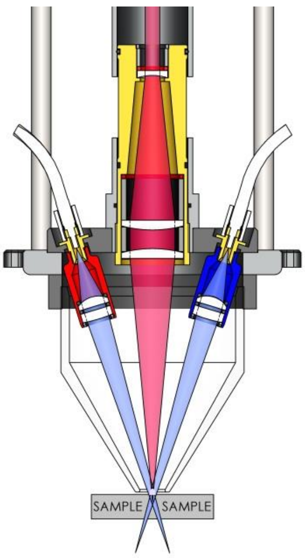


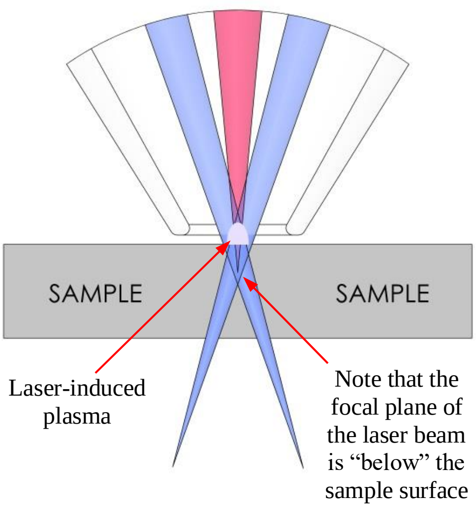
Image showing laser-induced plasma in air located a few mm below the acrylic nozzle aperture



CAD view showing position of focal plane of laser beam relative to the acrylic nozzle aperture



CAD illustration of field of view of the plasma light collection optics



Close-up view of field of view of collection optics in the vicinity of the laser-induced plasma

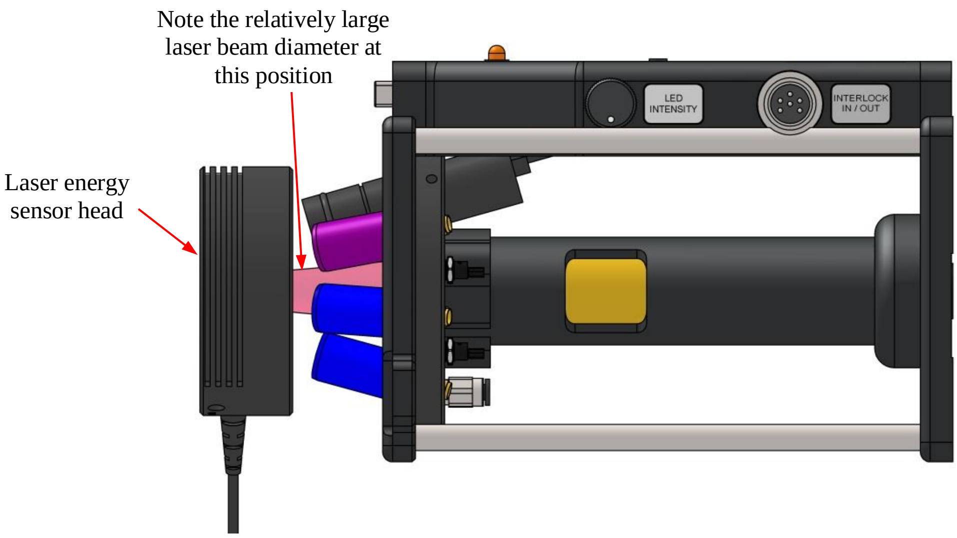
The collection optics array has a fixed field of view and so it is necessary that the laser-induced plasma is located within the convergence point of the six collection optics. This is illustrated in the diagrams on the left. Note that the focal plane of the laser beam is “below” the surface of the sample by approximately 1 to 2 mm – this is normal and what we recommend when conducting LIBS analysis of solid samples. The optimum laser focussing conditions will depend on the nature of the experiment - contact Applied Photonics Ltd for further advice.

4.9 Using an energy / power meter to measure the laser pulse energy

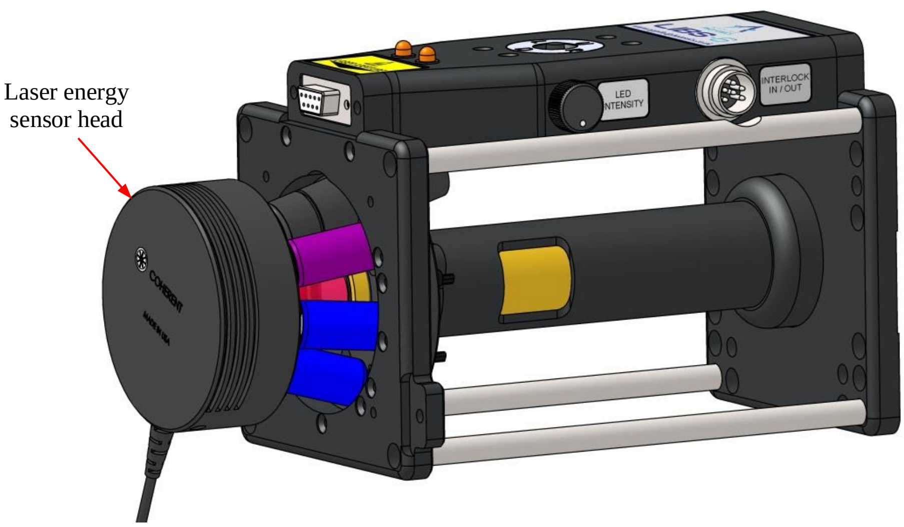
The NIM LIBS equipment is supplied with a laser pulse energy meter (Coherent LabMax). To avoid damaging the sensor head of the energy meter through exposure to excessively high laser beam power densities, it is important that the following procedure is followed.

Remove the acrylic aperture nozzle from the LIBS-6 module. To avoid losing the position of the nozzle aperture by unscrewing it from its mount, it is recommended that the nozzle aperture complete with its mount (black acrylic threaded component) is removed from the LIBS-6 module by unscrewing the four M4 cap head screws used to secure the mount to the LIBS-6 module. The sensor head of the energy meter should then be positioned centrally with respect to the laser beam axis and close the collection optics as shown in the following diagram. The laser beam diameter will be larger at this position and so the power density on the sensor head will be relatively low.

Important: Under no circumstances should the sensor head be positioned further away where the laser beam diameter is much smaller as the sensor head could be permanently damaged.



Laser energy meter sensor head correctly positioned with respect to the LIBS-6 module



Laser energy meter sensor head correctly positioned with respect to the LIBS-6 module

NEVER DO THIS!

4.10 Important note on back-reflections of laser radiation

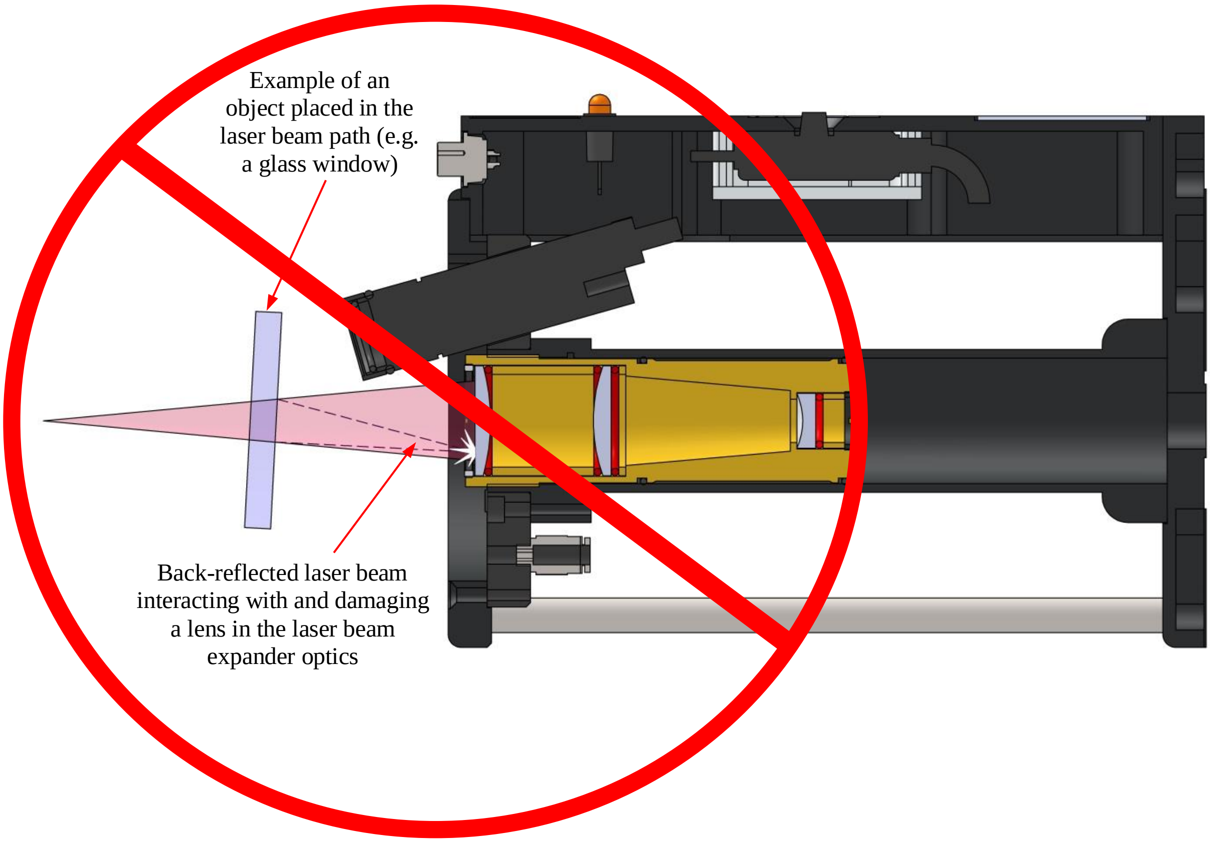
Please note that when using high-power Q-switched lasers of the type used with LIBS equipment, it is very easy to cause serious damage to the optical components of the LIBS equipment, including the laser, by inadvertently creating a situation where a significant amount of laser radiation is reflected back into the LIBS-6 module and/or laser head. Persons familiar with the use of these types of laser will appreciate that merely placing a glass window in the path of the laser beam can result in up to 4% of the laser radiation **from each optical surface** to be reflected back towards the laser source. If the laser beam is being focussed to a small spot (as in the case of a LIBS instrument), the back-reflected laser light will also be focussed to a small spot and if this happens to coincide with an optical element such as a lens, output coupler or laser rod, significant and permanent damage to that optical element can occur. Accordingly, it is very bad practice (and potentially a very expensive mistake on the part of the user) to carelessly place objects in the beam path of a Q-switched laser. Clearly with LIBS it is necessary to place an object in the laser beam path so certain precautions must be observed, as follows.

One way of considering this issue is as follows. If a laser plasma is being formed, either on the sample or object you have placed in the laser beam path or in the air / gas in front of the sample / object, then back-reflections are highly unlikely to be a problem since most of the laser energy will be absorbed by the plasma. It is when a laser plasma is not formed that you have to really worry about back-reflections. If you have placed an object in the laser beam path in such a way that a laser plasma is not formed on that object, then you should carefully consider what is happening to the laser energy which is impinging on the surface of the object since all materials will reflect at least some of the laser radiation.

Unless the user is particularly familiar with the use of Q-switched Nd:YAG lasers and is fully aware of the risks of damage to optics due to back-reflections of laser radiation, we strongly recommend that the

LIBS-6 (or LIBS-8) module is **used only with the nozzle aperture fitted**. The presence of the nozzle aperture prevents the user from placing an object too close to the laser beam expander optics in the LIBS-6 module, so that the object can only be located close to the focal plane of the laser beam, under which conditions a plasma will be formed unless the laser pulse energy is set to a very low value, or beyond the focal plane, where the laser beam will be diverging. Our advice to the user is that they should carefully consider the issue of back-reflections before placing any object in the laser beam path. Under most situations, placing an object at or beyond the focal plane of the laser beam will not result in back-reflections which are of sufficient intensity to cause damage. However, there are always scenarios where damaging back-reflections can still occur, such as placing a concave mirror in the laser beam path beyond the focal plane of the laser beam! If you have any doubts or concerns about your proposed application potentially causing damaging back-reflections, contact Applied Photonics Ltd before using your LIBS equipment. It is the responsibility of the user to minimise the risk of damage to optics caused by back-reflections of laser radiation. Please note that the manufacturer's warranty does not cover damage caused by back-reflections of laser radiation.

The following diagram illustrates back-reflected laser radiation from an object placed in the laser beam path. This object could be a piece of steel, a glass window, or virtually any type of material since most materials reflect at least some of the laser beam. The case of the glass window is a good example as some experimenters may wish to conduct LIBS analysis of a solid sample (or gas sample) inside a glass vessel or through a window of a vacuum chamber. Although most of the laser beam energy will be transmitted by the glass window, approximately 4% of the laser beam will be reflected from each surface (outer and inner) which is more than enough to cause permanent damage to an optical element on which the reflected laser beam impinges. It is possible to conduct LIBS analysis through a window but great care needs to be exercised to avoid potentially damaging back reflections. Contact Applied Photonics Ltd should you require any advice on this matter.



CAD sectional view of LIBS-6 module showing back-reflected laser beam from object placed in the beam path

5. Shut-down procedure

Step 1 Using the LIBSoft software, turn the laser flashlamps off to put the laser in an idle state.

Step 2 Shut down LIBSoft software and then switch off the laser power supply (using the keyswitch on the laser power supply) and isolate from the mains electrical supply.

Step 3 Remove the keys from the laser power supply keyswitch to prevent unauthorised activation of the laser. The keys should be help by an appointed person.

Step 4 Shut down the KestrelSpec software.

Step 5 Switch off the power supply to the EMU spectrometer by isolating the 12 Volt DC plug-in mains power adaptor used to power the EMCCD camera.

Step 6 Switch off the power supply to the XYZ-750 sample chamber by isolating the 12 Volt DC plug-in mains power adaptor.

Step 7 Disconnect purge gas supply if connected.

6. Operating the LIBS equipment in "open beam" configuration

Warning Class 4 Laser Product.
Only suitably trained and experienced persons under the supervision of a duly appointed Laser Safety Officer should operate the LIBS equipment in "open beam" configuration.

The LIBS equipment may be used without the sample chamber if required (e.g. when analysing a sample which is too large to fit inside the sample chamber). Under these conditions, the laser beam is not contained (i.e. the equipment is a Class 4 laser product) and hence additional safety precautions must be observed including the use of appropriate laser protective eyewear and operating the laser equipment in a suitable controlled environment (e.g. a laser laboratory). **Important - it is the responsibility of the user to conduct an appropriate risk assessment prior to using the LIBS modules in open-beam mode**. If the sample chamber is removed, it will be necessary to activate the Interlock Override keyswitch located on the Interlock Interface Unit (described earlier in this User's Manual). The LED warning light (labelled "Class 4 Warning") will commence flashing. Consult your Laser Safety Officer before operating the LIBS equipment in this mode. Never leave the Interlock Override key in the keyswitch – this key must be removed and held by a responsible person whenever the LIBS equipment is left unattended.

7. Maintenance and inspection

The LIBS equipment should be periodically inspected for signs of damage or wear and tear. Of particular importance are the safety features including the laser safety windows of the sample chamber and the laser safety interlock mechanisms and associated electrical circuits. It is strongly recommended that the interlock circuit is tested prior to each use of the equipment. If any damage to the laser safety windows is observed or suspected, or the sample chamber door interlock switch is not functioning correctly, the equipment should be temporarily removed from service until the fault is rectified. For maintaining and inspecting the laser, the documentation supplied with the laser should be consulted. If in any doubt, contact the manufacturer, Applied Photonics Ltd (www.appliedphotonics.co.uk), for further advice on maintenance and inspection of their LIBS products.

8. Shipping and storage

The LIBS equipment 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 equipment should be packed in such a way as to prevent damage from shock or vibration and protected from ingress of dust. For shipping or storage of the laser, refer to the laser manufacturer's instructions for the correct procedure.

Important:
When there is a need to ship the LIBS equipment, it must be carefully packed in the original packaging in order to minimise the risk of damage during transit. Failure to do this will automatically void the warranty.

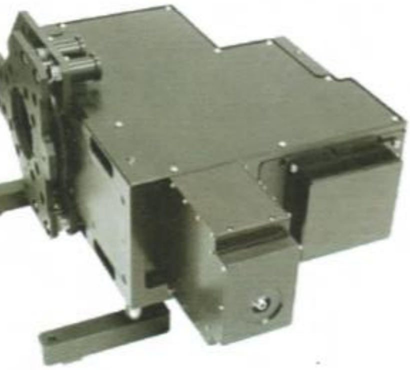
Note: Permanent damage to the laser can occur if it is subjected to temperatures of below 4 Celsius while it contains coolant water. The coolant water MUST be completely drained from the laser head and the power supply if there is any possibility of the laser being subjected to temperatures below 4 Celsius (e.g. during shipping). Refer to the instructions provided by the manufacturer of the laser.

Appendix A1

Datasheets for EMU-120/65 echelle spectrograph and Falcon Blue EMCCD camera

kestrel™ spectroscopy systems

Catalina Scientific



The portability, resolving power, throughput (étendue), low stray light, and broad wavelength coverage of the EMU-120/65 makes the instrument ideal for LIBS (laser-induced breakdown spectroscopy), Raman, absorption, OES/AES, photoluminescence and other spectroscopy applications.

The EMU-120/65 is suitable for isotopic analysis and other applications requiring a high resolution spectrograph. The maximum resolving power (λ / FWHM) across the spectrum can exceed 60,000 with the IX grating cassettes.

The resolving power, wavelength coverage and throughput of the EMU instruments are critical for combined LIBS/Raman data acquisition. The F/4 120mm collimating mirror combined with the F/2.2 65mm camera focusing optics will reduce the slit image size by 0.54x. The slit demagnification allows the use of larger slits for improved throughput. The throughput of the EMU-120/65 can be 10x to 20x higher than other broadband echelle instruments, which are typically ~F/10.

The EMU-120/65 is designed to take advantage of the characteristics of EMCCD cameras. These cameras have higher quantum efficiency, resolution, and frame rate than ICCD cameras. EMCCDs are more compact and less expensive than ICCDs. EMCCD cameras cannot be easily damaged by overexposure to light, unlike ICCDs.

The low stray light, along with software-controlled stray light removal algorithms, make this spectrograph a very powerful instrument for absorption spectroscopy.

The EMU-120/65 is designed, manufactured and marketed by Catalina Scientific Instruments, LLC, and it is protected under US Patents 7,936,454 and 7,936,455.

EMU-120/65 UV/VIS/NIR

High Resolution High Throughput Very Low Stray Light Echelle Spectrograph

- EMU is the **E**chelle **M**ultiplex **U**nit
- High étendue (numerical aperture x slit area) allows for high throughput.
- Covers the entire wavelength range of the detector (190nm - 1100nm) and acquires completely linearized spectra in units of wavelength or Raman shift.
- Can be used with a variety of CCD, EMCCD, ICCD and CMOS cameras.
- A variety of user interchangeable grating cassettes, aperture stops, and entrance slits to optimize applications.
- Highest resolving power up to 60,000 with the IX series grating cassettes.
- Proprietary stray light and order cross-talk correction algorithms provide the highest quality spectra.

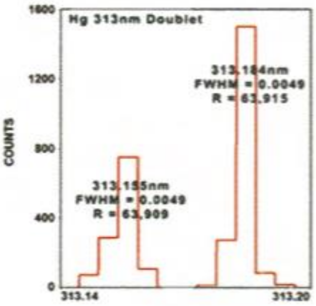
Interchangeable Grating Cassettes

HT Series:	up to R = 9,500
HR Series:	up to R = 12,000
UV Series:	up to R = 30,000
IS Series:	up to R = 40,000
IX Series:	up to R = 60,000

The grating cassettes for the EMU-120/65 are user interchangeable. The above values for R (λ / FWHM) are based upon 8x8µ pixel size and 10-14µ wide entrance slit.

Resolving Power

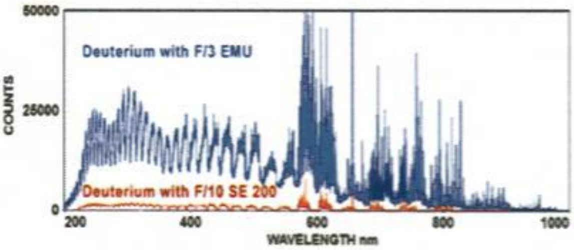
The EMU-120/65 optical design can yield ***single pixel*** resolving power with high throughput.



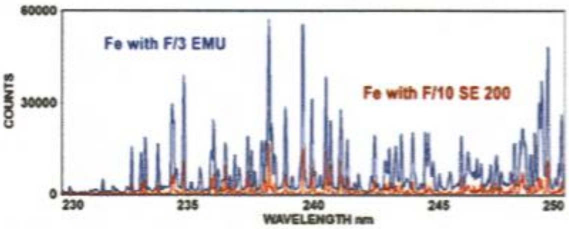
The Hg 313.155nm and 313.184nm doublet is clearly resolved using the IX series cassette. Each peak is one CCD pixel wide (8 microns) using an entrance slit 10 microns wide. Each peak has 0.0049nm FWHM resolution, for a resolving power of about 63,900. The IX cassettes have the highest resolving power.

Throughput/Etendue Comparisons

The deuterium/tungsten spectra below compare the throughput of an EMU (blue) with an SE 200 (red) echelle spectrograph. The EMU is configured with F/3 camera focusing optics and the SE 200 is F/10. Both systems had the same grating, same camera and same sized slit.

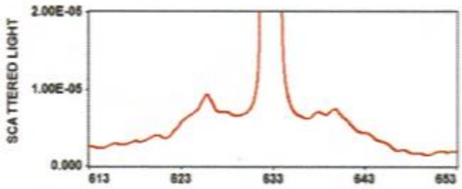


The iron LIBS spectra below compare the throughput of the EMU and EMCCD system (blue) with an SE 200 and ICCD system (red). Both echelle spectrographs used similar sized slits and exposures, and both used 10 laser shots.



Stray and Scattered Light

The overexposed HeNe laser line below shows the small angle scattering caused mostly by the grating. Scattered light is measured as a fraction of the HeNe peak intensity, and it drops below the CCD dynamic range limit at a fraction of a nm from the peak. The EMU-120/65 is designed to minimize stray light beyond the region affected by the scattering.



KestrelSpec™ Software

Industry-standard KestrelSpec™ software controls the EMU-120/65 system, with complete real-time camera control and spectra acquisition. Our unique "3-point calibration" to calibrate the EMU spectrograph is performed quickly and easily with high accuracy. Spectral diffraction orders are automatically linked, linearized and plotted as the data is acquired in either nm or cm^{-1} units. Image and spectral data can be easily exported in various formats. An Element Identification tool with a user-editable reference library can identify the elements in atomic emission spectra. A Windows DLL (dynamic link library) is available for control of the EMU spectrograph by third party developers' applications.

EMU-120/65 Specifications

- At the collimator: maximum F/4 input optics
- At the detector: max. F/2.2 camera focusing optics
- Focal Length (collimator): 120mm
- Focal Length (camera focusing optics): 65mm
- Magnification: ~ 0.54x
- Wavelength Coverage: 190nm - 1100nm
- Scattered Light: 2.0E-05 at 1nm from the HeNe 633nm peak with an HR2 cassette
- Stray Light: ~2.0E-06
- Unit Volume: 7575 cm^3 (462 cubic inches)
  Fits into a 390 x 255 x 170 mm box (15.5 x 10.0 x 6.5 inches) excluding camera, adapters and base
- Weight: 7 kg (15 lb) without camera, base, adapters
- Fiber Optic Input: SMA connector
- Entrance Slits: user interchangeable in varied sizes 8 to 128μ wide, 12 to 128μ tall
- Aperture Stops: user interchangeable in varied sizes 12 to 30mm in diameter
- Grating Cassettes: user-interchangeable gratings with blaze angles from 32° to 76°

Computer System Requirements

- Windows™ 7/8/10 (32-bit or 64-bit)
- Appropriate driver to interface with the detector

For more information please contact:

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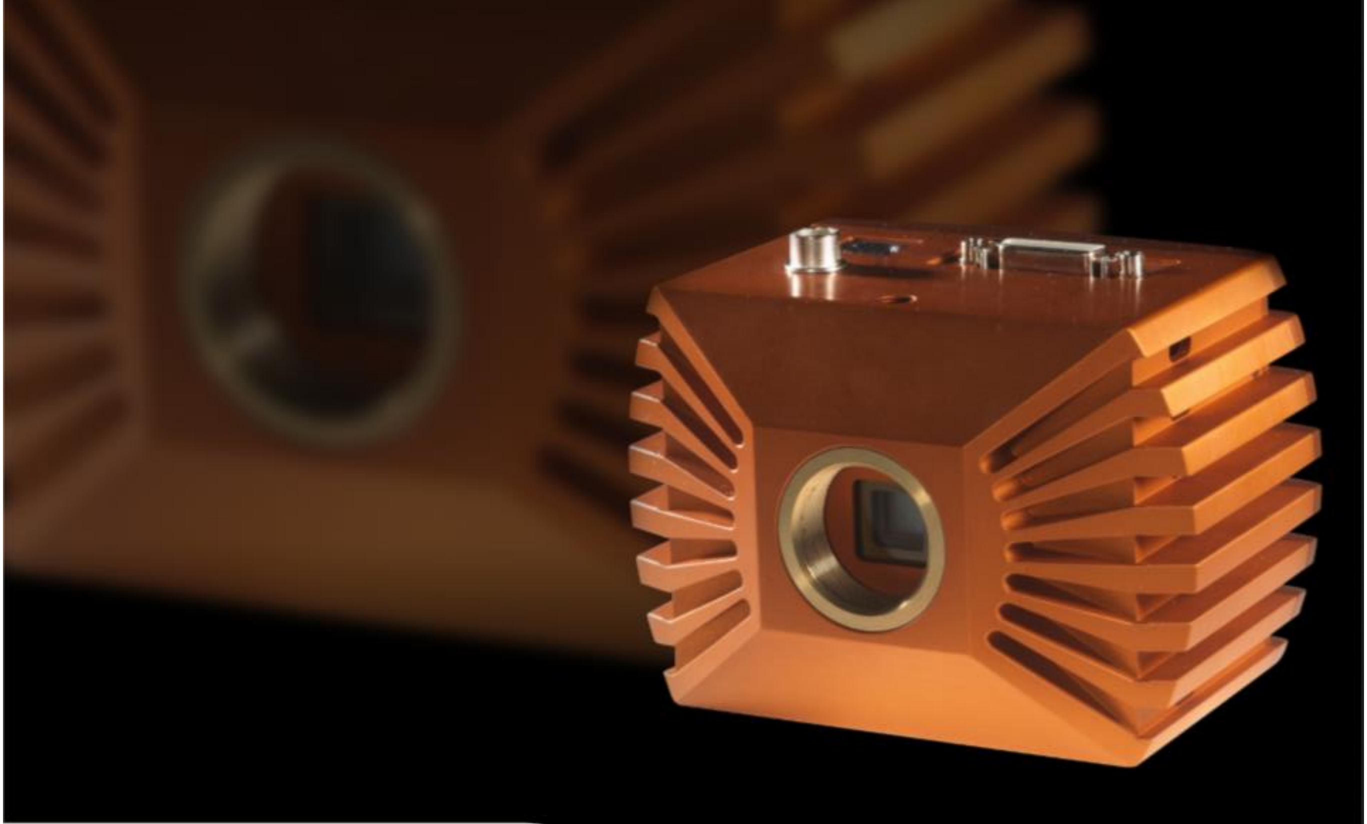
2555 North Coyote Drive, Suite 113
Tucson, Arizona 85745 USA

Tel: 520 571 8000
Web: www.catalinasci.com
Email: info@catalinasci.com

Falcon BLUE EMCCD

Digital Monochrome Scientific Frame Transfer EMCCD



Key Features and Benefits

Ultra low noise readout for improved image quality!

- **1004 x 1002 EMCCD sensor.**
  Enables optimum image resolution in low light imaging applications
- **B/W EMCCD technology.**
  Enables high sensitivity imaging with up to 1000x on-chip gain
- **UV Transmission with a Fused Silica window.**
  Offering transmission down to 180nm
- **16 bit CameraLink output.**
  Provides wide dynamic range
- **65% QE from Virtual Phase sensor.**
  Optimum Photon collection
- **Frame Transfer.**
  No mechanical shutter required, vibration-less CCD readout

Resolution Readout	1004 x 1002
Read Out Noise	<1e Noise
Digital Output Format	30Hz
CameraLink	16 bit

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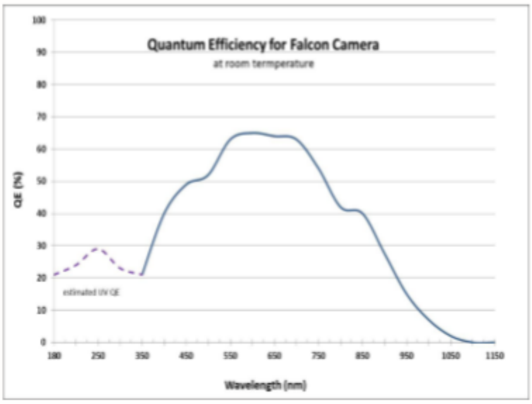
Specification for Falcon BLUE EM285 CL

Sensor	Texas Instruments TC285SPD
Sensor Type	2/3" Frame Transfer Impactron
Active Pixel	1004 x 1002
Pixel Size	8μm x 8μm
Active Area	8mm x 8mm
Full Well Capacity	30,000 electrons
Shift Register Well Depth	80,000 electrons
Non Linearity	< 1%
Readout noise	< 1 electrons with EM gain ON
	< 27 electrons with EM gain OFF
Dynamic Range	89 dB
Frame Rate	30Hz
Dark Current	< 1e / pix / sec
Digital Output Format	16 bit CameraLink (base configuration)
Peak Quantum Efficiency	65% @ 530nm, 24% @ 200nm
Spectral response	180 - 1100nm
Cooling	-20°C with ambient air @ +20°C
Binning	1x1, 2x2, 3x3, 4x4, 5x5
Antiblooming protection	Yes
Lens Mount	C mount
Synchronisation	Trigger IN and OUT - TTL compatible
Power Supply	12V DC ±10%
Total power consumption	< 15W
Operating case temperature[1]	-20°C to +55°C
Storage Temperature	-30°C to +85°C
Dimensions	109mm x 76mm x 76mm
Weight (no lens)	< 650g

Quantum Efficiency



Sample Applications

- Adaptive Optics and Astronomy
- Bio & Chemi-luminescence
- Calcium signaling
- Fluorescence imaging / spectroscopy
- Flow cytometry
- FRET / FRAP / TIRF
- Genome sequencing
- High content screening
- High resolution fluorescence imaging
- Hyperspectral imaging
- LIBS
- Live Cell Imaging
- Single molecule detection
- Solar Cell Inspection
- X-ray tomography

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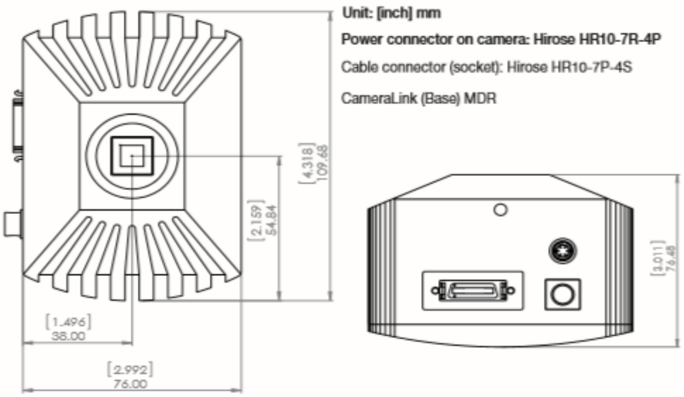
Note 1: Extended operating temperature range on request.

Dimensions



Ordering Information

Camera

Falcon BLUE EM285 digital B/W camera	FA285B-CL
Falcon BLUE Power Supply Cable	RPL-HR4-K
Optional Accessories	
EPIX(R) base CL card	RPL-EPIX-EB1
EPIX(R) base Notebook CL card	RPL-EPIX-ECB1-34
EPIX(R) XCAP STD software	RPL-XCAP-STD
CameraLink Cable, 2m[2]	RPL-CL-CBL-2M
Optical Visible lenses[3]	RPL-xx-xxxx

Note 2: Longer CL cable available up to 25M
Note 3: Please consult us to check our range of lenses

Equipment may require UK Government authorisation for export purpose

Document #: FA285B-CL 0114R1

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