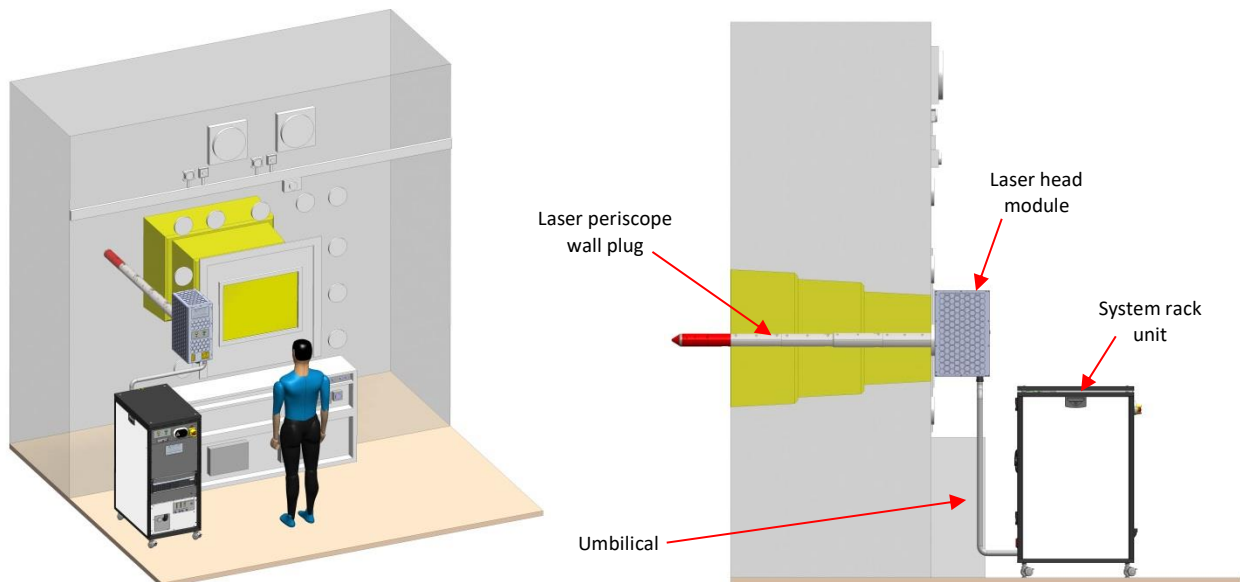


## **Laser-Induced Breakdown Spectroscopy (LIBS) instruments installed at Cave 6, B13 Windscale Laboratories, Sellafield, UK**

### **Introduction**

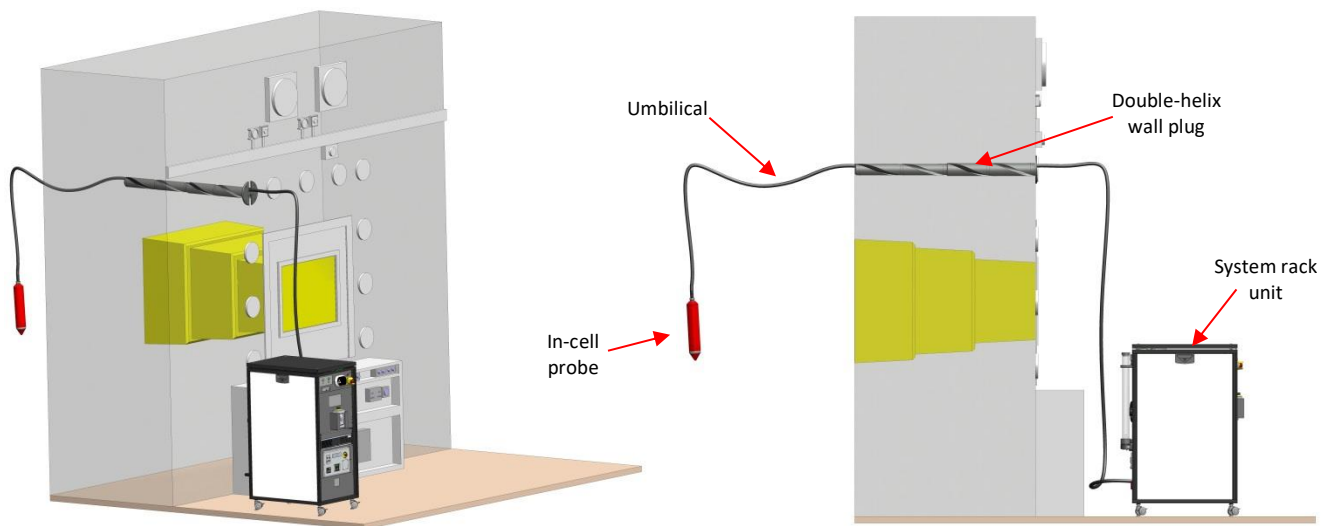
The Cave 6 LIBS systems are based on a technique known as Laser Induced Breakdown Spectroscopy (LIBS) and are used to perform elemental analysis of various solid materials and surface residues, both radioactive and inactive, at NNL's Windscale Laboratory at the Sellafield site. The LIBS systems are able to perform in-situ elemental characterisation of these materials by directing a pulsed laser beam onto them.

In the Wall Plug Periscope LIBS System the laser head is located outside the hot cell and the laser beam is delivered to the sample through a specially-designed wall plug fitted to an existing wall plug port in the hot cell shield wall. This system is illustrated in the following CAD schematic diagram.



**CAD illustration of Wall Plug Periscope LIBS System**

In the In-Cell LIBS Probe System the laser head is integrated into a probe located inside the hot cell and is used to deliver the laser beam directly to the sample. The probe is connected to the system rack unit located outside the cell via an umbilical which passes through a standard double-helix wall plug. This system is illustrated in the following CAD schematic diagram.



**CAD illustration of In-Cell LIBS Probe System**

## Overview of system hardware

### Wall Plug Periscope LIBS System

The Wall Plug Periscope LIBS system comprises four main components:

- The laser periscope wall plug which is installed in an existing port in the shield wall adjacent to a shield window, as illustrated in the preceding CAD images.
- The laser launch module containing the laser head and associated optical system which is fitted to the laser periscope wall plug on the cold side of the hot cell.
- The LIBS system rack unit which contains the laser power supply, high-resolution EMU optical spectrograph, system computer, safety interlock interface unit, and peripheral devices. The wheeled rack unit is located within a few metres of the laser periscope wall plug on the cold side of the hot cell.
- The laser protective windows fitted to the shield windows of the Cave 6 hot cell.

The laser periscope wall plug contains the optical components required to transmit the pulsed laser beam into the hot cell and to focus the laser beam on the material being analysed. It also contains the optical components required to collect the plasma light from the laser-induced plasma and transmit this light to the optical spectrograph located in the system rack unit. The cold side of the laser periscope wall plug has a removable enclosure (the laser launch module) which houses the laser head and associated optical components required to direct the laser beam into the periscope wall plug.

The Wall Plug Periscope LIBS System utilises a pulsed high-power laser (Q-switched Nd:YAG, 1064 nm, 10 Hz, up to 300 mJ pulse energy), and two visible (red, 635 nm, Class 1) low-power targeting lasers. The pulsed high-power laser utilises a closed-loop water cooling circuit to remove heat generated by the flashlamp in the laser head. A water-to-air heat exchanger is integrated with the laser power supply. Maximum electrical power to the laser is approx. 1 kW (100 – 240 VAC, single phase, 50 Hz)

The system rack unit contains the laser power supply, the system computer, a high-resolution EMU optical spectrograph used to analyse the collected plasma light, the safety interlock interface unit and peripheral devices. The rack unit is connected to the laser launch module of the wall plug via two short lengths (less than 3 metres) of flexible umbilical.

## In-Cell LIBS Probe System

The In-Cell LIBS Probe System comprises four main components:

- The in-cell probe which contains the laser head and associated optical system.
- The umbilical which connects the in-cell probe to the LIBS system rack unit and passes through the hot-cell wall via a standard double-helix wall plug.
- The LIBS system rack unit which contains the laser power supply, high-resolution EMU optical spectrograph, system computer, safety interlock interface unit, and peripheral devices. The wheeled rack unit is located within a few metres of the wall plug through which the umbilical passes, on the cold side of the hot cell.
- The laser protective windows fitted to the shield windows of the hot cell.

The in-cell probe contains the optical components required to focus the pulsed laser beam onto the material being analysed. It also contains the optical components required to collect the plasma light from the laser-induced plasma and transmit this light to the optical spectrograph located in the system rack unit.

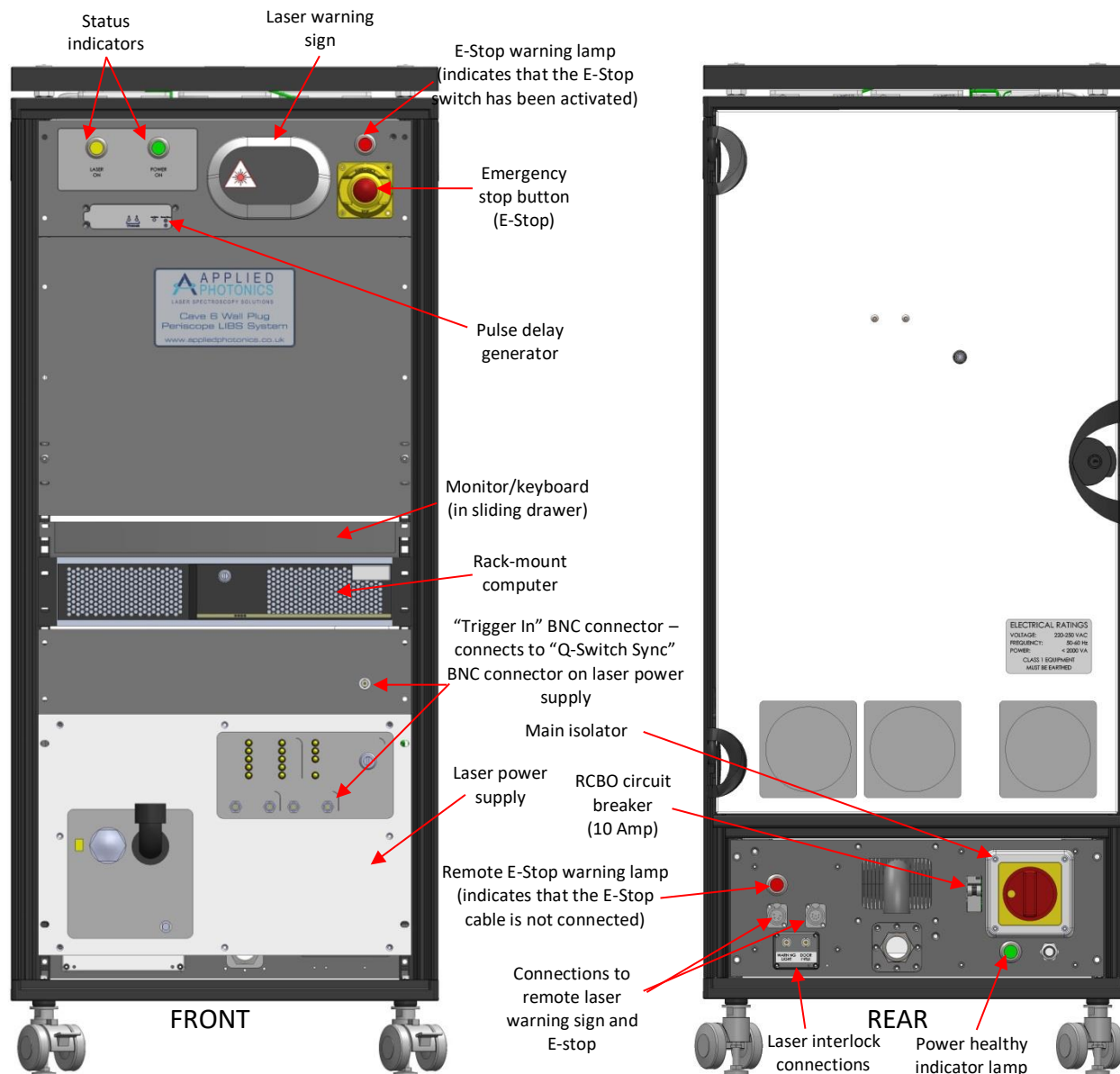
The In-Cell LIBS Probe System utilises a pulsed high-power laser (Q-switched Nd:YAG, 1064 nm, 8 Hz max., up to 200 mJ pulse energy), and two visible (red, 635 nm, Class 1) low-power targeting lasers. The pulsed laser utilises a closed-loop water cooling circuit to remove heat generated by the flashlamp in the laser head. A water-to-air heat exchanger is integrated with the laser power supply. Maximum electrical power to the laser is approx. 1 kW (100 – 240 VAC, single phase, 50 Hz)

The system rack unit contains the laser power supply, the system computer, a high resolution EMU optical spectrograph used to analyse the collected plasma light, the safety interlock interface unit and peripheral devices. The rack unit is connected to the in-cell probe via 10 metres of flexible umbilical. The umbilical contains electrical and water cooling connections to the laser head and optical fibres for the transmission of plasma light from the sample to the high-resolution optical spectrograph.

## Operation

### Wall Plug Periscope LIBS System hardware activation

The Wall Plug Periscope LIBS System is controlled from the system rack unit the main components of which are highlighted in the illustration below.



**CAD illustration of the Wall Plug Periscope LIBS System rack unit**

In addition, there is a remote laser warning sign and a remote E-Stop switch (see illustration below) which are both connected to the rear of the system rack via ~ 6 metre lengths of cable.



**CAD illustration of the remote laser warning sign and remote E-Stop switch**

To activate the system hardware, the following steps should be followed:

- Check that the laser safety windows are fitted correctly to the hot cell shield wall windows.
- Check that all connections are made correctly including those between the system rack unit and the laser head enclosure and the remote E-Stop switch (this must be connected to the rack unit in order to satisfy the interlock circuit).
- The remote laser warning sign may be connected to the rack unit if required.
- Open the drawer to access the computer monitor and keyboard.
- Check that the RCBO circuit breaker (located to the left of the main isolator switch) is set to the ON position.
- Apply mains power (230 VAC, 50 Hz) to the system rack unit via the supplied lead located on the rear panel of the rack unit and switch the main isolator to the ON position.
- Activate the key-switch on the front of the laser power supply and check that both the remote E-Stop switch and the E-Stop switch on the top right front of the system rack unit are deactivated (i.e. the buttons have been released by rotating  $\frac{1}{4}$  of a turn).
- All the components in the rack will be powered automatically with the exception of the pulse delay generator and the computer should automatically boot up into Windows.
- Once the computer has booted Windows, power the pulse delay generator by pressing the *Run/Stop* button on its front panel.
- The status of the various indicators on the system will be as follows:
  - The green *Power On* status indicators on the front of the system rack unit and the laser head module will be illuminated
  - Both laser warning signs will display “**NO HAZARD – LASER OFF**”
  - The red indicator lamps next to E-Stop switch on the top right front of the rack unit and the remote E-Stop switch will not be illuminated (these are illuminated only when these E-Stop switches have been activated).
- Test the operation of each of the E-Stop switched in turn – when activated the red indicator lamp next to the E-Stop switch will be illuminated and a warning buzzer will sound until the E-Stop is reset (by rotating the button by  $\frac{1}{4}$  of a turn).
- Test the fail-safe connection of the remote E-Stop switch - when the cable is disconnected from the lower rear panel of the rack unit the red indicator lamp next to the cable socket will be illuminated and the warning buzzer will sound until the remote E-Stop cable is reconnected.

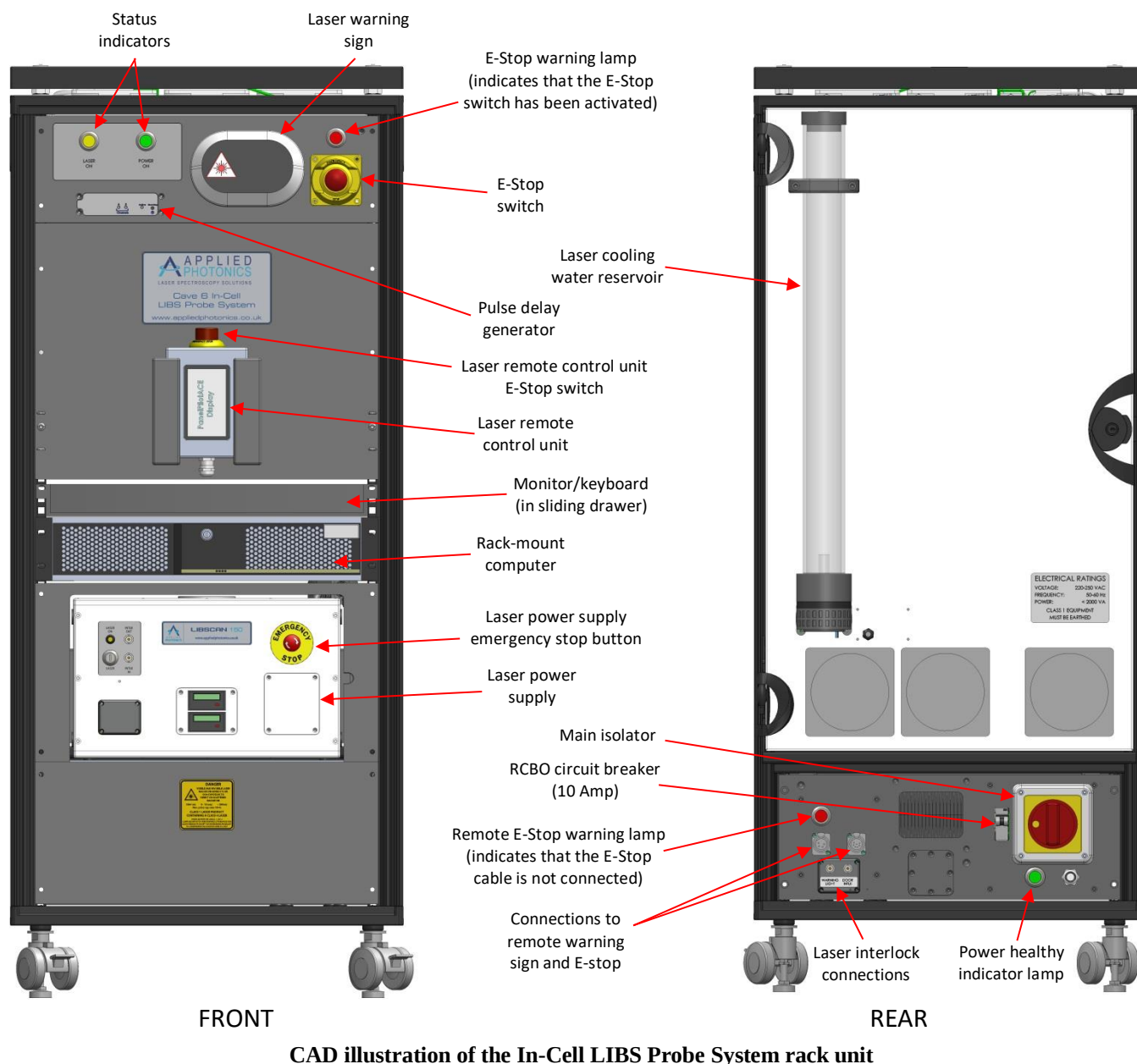
The Wall Plug Periscope LIBS System is now ready for use. The system software will control the operation of the LIBS system as explained earlier. Note that activation of any of the E-Stop switches will disable the high-power laser and leave the equipment in a laser safe state. The status of the laser beam will be indicated by the illuminated laser warning sign on the front of the rack unit, and the remote laser warning sign if connected. When the high-power laser is armed the laser warning sign(s) will display “**DANGER – LASER ON**”.

### In-Cell LIBS Probe System hardware activation

The In-Cell LIBS Probe System is controlled from the system rack unit the main components of which are highlighted in the illustration below. The laser power supply used for this system is similar in design to that used in the Wall Plug Periscope LIBS System but has a different method of operation and there is an additional laser remote control unit mounted on the front of the system rack unit and the laser cooling water

reservoir is mounted externally on the rear of the rack unit. There are also two additional E-Stop switches: one on the front of the laser power supply and one on the laser remote control unit.

It is necessary to use the laser remote control unit to initialise and arm the high-power laser such that it is ready to be controlled by the system software. Details of how this is done are provided below. It is also possible to fire the laser directly using this control unit however this is unnecessary in normal operation and therefore it should be left in the holder on the front of the system rack unit once the laser has been armed for use.



To activate the system hardware, the following steps should be followed:

- Check that the laser safety windows are fitted correctly to the hot cell shield wall windows.
- Check that all connections are made correctly including those between the system rack unit and the laser head enclosure and the remote E-Stop switch (this must be connected to the rack unit in order to satisfy the interlock circuit).
- The remote laser warning sign may be connected to the rack unit if required.
- Open the drawer to access the computer monitor and keyboard.

- Check that the RCBO circuit breaker (located to the left of the main isolator switch) is set to the ON position.
- Apply mains power (230 VAC, 50 Hz) to the system rack unit via the supplied lead located on the rear panel of the rack unit and switch the main isolator to the ON position.
- All the components in the rack will be powered automatically with the exception of the pulse delay generator and the computer should automatically boot up into Windows.
- Once the computer has booted Windows, power the pulse delay generator by pressing the *Run/Stop* button on its front panel.
- The status of the various indicators on the system will be as follows:
  - The green *Power on* status indicator on the front of the system rack unit will be illuminated
  - Both laser warning signs will display “**NO HAZARD – LASER OFF**”
  - The red indicator lamps next to E-Stop switch on the top right front of the rack unit and the remote E-Stop switch will not be illuminated (these are illuminated only when these E-Stop switches have been activated).
- The laser remote control unit will display the **Laser status** as off (grey) and **Interlock status** as activated (red warning triangle) as key switch has not been activated (see Figure 6 below).

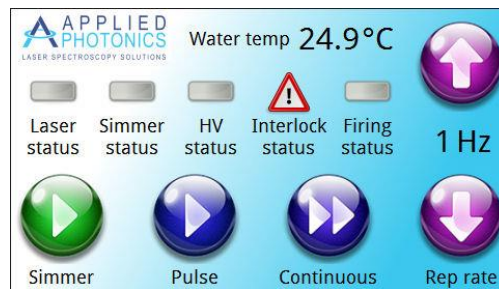


Figure 6: Laser remote control unit screen on system power-up

- Test in turn the operation of the remote E-Stop switch and the E-Stop switch on the top right front of the rack. When either E-Stop switch is activated the red indicator lamp next to it will be illuminated and a warning buzzer will sound until the E-Stop switch is reset.
- Test the operation of the E-Stop switch on the laser power supply and the one on the laser remote control unit. When either emergency stop is activated the laser remote control unit displays **Interlock status** activated (i.e. warning triangle symbol as shown in Figure 6 above) and a warning buzzer will sound until the emergency stop is reset. Note that there is no red indicator lamp with either of these two E-Stop switches.

**NB** If either of the laser power supply E-Stop switches is activated, it is necessary to reset the E-Stop switch AND reactivate the key switch on the laser power supply (i.e. turn the keyswitch off then back on again) to reset the interlock such that the laser can be operated.

- Test the fail-safe connection of the remote E-Stop switch - when the cable is disconnected from the lower rear panel of the rack unit the red indicator lamp next to the cable socket will be illuminated and the warning buzzer will sound until the remote E-Stop cable is reconnected.
- Ensure that all E-Stop switches are deactivated.
- Activate the key-switch on the front of the laser power supply. The amber **Laser On** LED on the laser power supply will be illuminated, the **Laser status** on the laser remote control unit indicates that the laser is now on (laser radiation warning symbol) and the **Interlock status** that the interlocks are satisfied (green) as shown in the illustration below. Both laser warning signs will display “**DANGER – LASER ON**”.



**Laser remote control unit screen when key-switch activated**

- Press the green **Simmer** button on the laser remote control unit. The laser remote control unit indicates that the simmer is on (**Simmer status** icon green) and that the capacitor charging power supply is enabled (**HV status** icon green) as shown in the illustration below.



**Laser remote control unit screen when simmer activated**

- Return the laser remote control unit to its holder on the front of the rack unit.

The In-Cell LIBS Probe System is now ready for use. The system software will control the operation of the LIBS system as explained earlier. Note that activation of any of the E-Stop switches will disable the high-power laser and leave the equipment in a laser safe state. The status of the high-power laser will be indicated by the illuminated laser warning signs. Note that when the laser power supply keyswitch is turned on, the laser warning signs will display “**DANGER – LASER ON**” even if the laser has not been armed using the remote control unit.

**End of Document**