Appendix A  Laser Processing Rig User Guide

A.1  Overview
This document details how to operate the laser processing rig in Lab 3, pictured in Figure A-1. It describes in a step by step manner how to setup the system, load workpieces, perform the desired laser processing step and shutdown the system. This guide is generic and therefore appropriate for all the envisioned uses of the system, i.e. ULI and other laser processing techniques. For more detail on the hardware and software which forms the rig please initially refer to Chapter 3. An accompanying slide show to this user guide and further system information which would be required for troubleshooting or adding new system functionality is held at FCAP.

Figure A-1  Image showing the main body of the ULI system. Clockwise from the bottom: laser back end, laser head and bench beamline section, raised optical bench for secondary laser sources, bank of K-cube controllers, power routing box for Aerotech components, stage drivers, Z stage and gantry beamline section, workpiece mount, X + Y stages and vacuum pump. Not shown: air filter bank, room compressed air supply point and control PC.
A.2 Setup

Start by logging into the control PC and fixing your workpiece to the mounting plate. Workpiece fixing can be achieved by temporary adhesive, such as nail polish, or by using the vacuum mounting option provided by the mounting plate, see Figure A-2. For vacuum mounting, select an appropriate number of mounting holes to unplug then position your workpiece over the unplugged mounting holes and switch on the vacuum pump. Mounting holes are plugged by M2 set screws with PTFE thread sealing tape.

![Image showing the machining end of the ULI system, i.e. inscription head, translation stages, mounting plate and vacuum pump which are all user accessible. Zoomed in top down view of mounting plate shows hole options for vacuum mounting and 10 by 10 by 2 mm fused silica sample. Red circle indicates the vacuum pump switch location.](image)

Following this, turn on all the system components that have physical switches/valves, which are: the inscription laser back end, the room compressed air supply, the K-cube controllers and the Aerotech stage drivers.

For the inscription laser back end there is a toggle power switch on the back of the rack unit to power on the system and a key switch on the front panel to put the laser in standby mode. Do not press the laser on button, laser emission will be controlled through laser driver software on the control PC. Be aware - If you accidentally push the laser on button this will begin the laser’s start up sequence and cause light to be emitted from the laser.
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head. This emission will be at the last set power, repetition rate and pulse duration which maybe unknown. For the room compressed air supply simply turn the regulator valve fully on and back off a fraction of a turn to reduce risk of the valve sticking open. The compressed air floats the X and Y machining stages and this can be tested by checking that the stages move easily by hand. For the K-cube controllers there is a toggle switch on each controller and a toggle switch on their mounting hub. Finally, for the Aerotech stage drivers there are three toggle switches on the power routing box. The on state of the equipment and location of switches is summarised in Figure A-3.

Figure A-3 Images of equipment on-states and location of switches/valves: (a) inscription laser back end; (b) room compressed air supply, use regulator valve to turn on/off supply leaving shut off valve open, when regulator is fully open should read 100 psi; (c) power routing box for Aerotech stage drivers and; (d) K-cube controllers and hub. Red arrows and circles indicate switch or valve locations.
With the equipment switched on, the next step is to establish control of the laser from the PC and select initial laser settings. In order to perform this step, start by launching the laser driver software which will open to display the main laser driver window, seen in Figure A-4, and a pop up settings window for connecting to the laser. The main laser driver window displays the current state of the laser, output power and any error messages associated with the laser. In the pop up, select communication port 4, i.e. COM4, a baud rate of 115200 and load the stored laser parameters by selecting file ‘SY-3459.ini’. Then press the connect button. Now the laser is connected initial laser settings such as repetition rate, output power and pulse duration from the synchronisation and compressor windows can be selected before turning the laser emission on. A typical selection and explanation of the options is shown in Figure A-5. Once happy with the settings press the software laser on button in the main laser driver window and wait for laser to run through its start-up sequence.

Now that the inscription laser is initialised and there is light output, computer control of the inscription power, polarisation state and beamline shutter can be attained by connecting to the K-cube controllers. To do this open the FCAP ULI software and wait for all the controllers connect. Once complete use the software to enable the motors in the rotation mounts and home the mounts, as illustrated in Figure A-6. With the mounts homed a power calibration can be performed by placing a power meter in the beamline, preferably as close to the back aperture of the final focusing objective as possible, pressing the calibrate button and following the onscreen prompts.
Figure A-4: Image of laser driver software main window. Clockwise from the top left: Selection buttons for switching between main window and other windows; error message panel; output power plot; laser state indicator panels; and laser on and interlock reset buttons.
Figure A-5 Image of the initial laser settings commonly used. Top: the compressor settings window. This will usually be set to 10120 μm which gives the minimum pulse duration for 500 kHz pulse trains entering the amplifier. As well as changing the compressor position to temporally broaden the output pulses, changing the pulse picker AOM frequency changes the amplifier dispersion and therefore requires different compressor settings for the same pulse durations. Bottom: the synchronisation settings window. In general use, only the pulse picker frequency, modulator frequency and modulator efficiency are changed. These settings determine the repetition rate for the pulse train entering the amplifier stage of the Satsuma, the repetition rate of the output beam and the output power, respectively.
A tab control allows for changing between the K-cube controller window, settings and help window, and the slope finder window used to establish the offset in the workpiece sample surface to the X-Y machining plane. Clockwise starting from the upper left in the K-cube controller window: .NET control for power waveplate; .NET control for power, options for power, polarisation and shutter position, stop button and power calibration button with indicator; .NET control for elliptical polarisation state waveplate; and the slope finder window used to establish the offset in the workpiece sample surface to the X-Y machining plane.

Figure A-6: Image of FCAP ULI control software. A tab control allows for changing between the K-cube controller window, settings and help window.
The next step is to use a low laser power to “find” the objective focus and set the position of the sample corner that serves as the origin for your inscription run to be at the objective focus. This is accomplished by first opening the Aerotech CNC operator interface, a software module in the Aerotech A3200 motion composer suite, which allows you to enable the stage motors and home the stages. With the stages homed and a knowledge of the properties of the objective being used, roughly translate the sample to ensure it is under the objective and then lower the objective so that is slightly further away from the sample than its working distance.

With the sample in its rough guess position, set a laser output power in the region of a few mW using the FCAP ULI software, making sure to stay below the modification threshold of the material. Then open Thorlabs Thorcam software to connect to the sample imaging camera. Set a long exposure time that doesn’t saturate the camera to maximise the camera sensitivity and hence minimise the chance of missing the sample surface. Open the beamline shutter and slowly bring the objective down towards the sample, watching for an image to form in the Thorcam software. When the objective focus is in the vicinity of the top sample surface, back reflections from the air-sample interface will cause a ring pattern to be imaged onto the camera. With the focus exactly at the surface this pattern will reduce to a spot, giving the Z co-ordinate of the workpiece surface. The camera image with the focus away from and at the sample surface is shown in Figure A-7.

To set the origin position for the workpiece, simply translate the sample using the CNC operator software whilst maintaining the image of the spot on the camera. At the sample edges the spot will suddenly get distorted and disappear allowing the user to identify the sample edges and subsequently the corner. In order to store this position and perform a check to test for any slope in the sample top surface, e.g. caused by polishing defects or sample mounting, run the slope finder routine in the FCAP ULI software and follow the on-screen prompts. This completes the system setup.
Figure A-7 Image of the Thorcam camera software with boxed area highlighting where the back-reflection signal occurs. Top zoomed in view shows the back-reflection signal when the objective focus is in the vicinity of the sample surface with the sample surface lower than the focus and bottom zoomed in view shows the alignment condition i.e. when the focus is exactly at the surface.

A.3 Usage

The system can now be used for machining via two routes, namely: manual control or using an Aerobasic program running in the Aerotech CNC operator environment, as can be seen in Figure A-8. Through the laser driver software, FCAP ULI software and Aerotech CNC operator interface a user can manually change all the output laser parameters, fine tune the inscription power, set arbitrary polarisation states and manually move the stages. Stage movements can be either from the GUI controls or immediate G-code command line in the CNC operator interface, also shown in Figure A-8. Whilst manual control can be useful for setting properties like initial laser parameters, it expected that machining operations will be performed using an aerobasic program. Aerobasic is a proprietary Aerotech CNC language which is based on G-code but also allows for I/O, simple logic and control flow. Aerobasic programs can be created in the motion composer IDE module of the A3200 motion controller suite or in any text editor as a .txt file which can then be compiled as aerobasic code. See Chapter 3 for examples of how to call for changes in power, polarisation and shutter state which is called from an Aerobasic program but instigated by the FCAP ULI control software.
Figure A-8 Image of the CNC operator interface. Clockwise from the top: stage status information; GUI motion and axis controls; emergency stop, error handling and further options; aerobasic program options and diagnostics; aerobasic program viewer; and command line for immediate motion commands.
A.4 Start Next Run or Shutdown

Whether seeking to start a new run or to shutdown the system, begin by ensuring all stage motion is complete, any aerobasic program running has completed or been aborted and that the laser shutter is closed. The Z stage should then be backed away to provide clearance for workpiece removal. Remove the workpiece either by turning off the vacuum pump or releasing the temporary adhesive, e.g. applying acetone if nail polish was used to fix workpiece as this will dissolve the nail polish. With the sample removed the X, Y and Z stages can be homed which resets them and clears any software home position defined by the previously run aerobasic program. Homing also has the advantage of leaving the Z stage at a consistent mid-travel position between system uses.

At this point a new sample can be mounted and following the steps in the previous two sections a new run can be performed. If the system is to be shutdown instead, proceed to disable the translation stage motors, close the CNC operator software and turn off the stage drivers. The next step is to close off the compressed air valve which allows for the X and Y stages to settle and the air filter bank to purge. After this, press the highlighted laser-on button in the laser driver software which returns the laser to its standby state. If the laser is not to be used for several days the laser back end can also be turned off but when the system is in regular use leaving the back end on reduces the settling time for stable laser output. The final step in system shutdown is to press the stop button in the FCAP ULI software which disconnects from the K-cube controllers, close the program and then to switch the K-cube controllers off.