Standard Operation Procedure for Femtosecond Laser Irradiation Experiments Using Astrella Regenerative Amplifier.

Version 1.3/March 16, 2023

Hazards Present: Class IV visible and invisible laser radiation capable of severe physical injury and starting a fire.

Hazard Mitigation:

- Administrative Controls: Approved laser safety classes by UCSB ES&H, training by OCF personnel.
- Physical Controls: Inflammable beam blocks, shields, and enclosures.
- PPE Required: Laser safety glasses/goggles with OD>4 at the laser wavelength (800 nm, LPA Alex or similar), fire retardant lab coats.

Equipment required:

- High power thermal powermeter (P_{max}> 10W)
- NIR viewer scope
- Neutral density filter set

Start-up sequence:

1. Turn on the Polyscience chiller, Verdi G and Vitara power supplies.
2. Turn on SDG Elite and Revolution controllers. The former can be silenced by pressing reset button.
3. Turn on the laptop computer on top of the Astrella laser box. Start Vitara and Revolution control programs if they have not started automatically.
4. In the Vitara software, press “Remote” button and then “Diode on” button. Turn the key on the Verdi G controller. After short time, the power reading on the controller LCD display should be close to the set point in the software (~4.7 W). If this does not happen, verify that (a) SDG Elite and Revolution are energized (Red “Fault” LED will be on in this case on the Verdi G power supply box), (b) The safety key is in “on” position, (c) “Remote” button is pressed in the Vitara software.
5. Open water bypass valves per addendum at the end of this document.
6. Open cooling water valves on the wall slowly, starting with the return valve. **Verify that the water pressure is greater than 17-20 psi. There is no built-in protection in the chiller against running without external water supply.** A “hot oil smell” is usually an indication of the chiller overheating. Water pressure oscillations and “hydraulic hammer” effect may occur shortly after opening external water supply valves. It is normal and pressure oscillations should cease shortly.
7. “Rastering” button should be illuminated in the Vitara software and in 0-15 minutes, “Lasing”, “Modelocking”, and “Power Track” indicators should turn green, and the power reading in the

software should be >500 mW. If the laser fails to start in approximately 15 minutes and time-out error is thrown, OCF staff must be contacted.

8. Once the Vitara is up and running, clear SDG Elite error by pressing “Reset” button. Verify that Delay 1 on the SDG box is off, and Delay 2 and Delay 3 are on.
9. At this point, one can wait until the coolant temperature in the chiller reaches the setpoint, 20C. Though not mandatory, this reduces the laser warm up time significantly.
10. Turn the safety key on the Revolution power supply to “On” position. Verify that the Q-switch mode is set to “External” in the Revolution software (“Evolution settings” option needs to be enabled to see the Q-switch mode selector.). Ignore the warning message about the danger of this mode. Press and hold the green “On” button in the Revolution software until the alarm sounds. Wait until the current setpoint is reached and the internal power meter reads normal power values. If possible, verify that internal power meter reading is consistent with the current setpoint (>30 W).

The startup procedures from this point onward are related to simplified startup for fs irradiation experiments. For the detailed startup and tune-up procedure please refer to the specific SOP document.

11. Verify the laser repetition rate and adjust, if necessary.

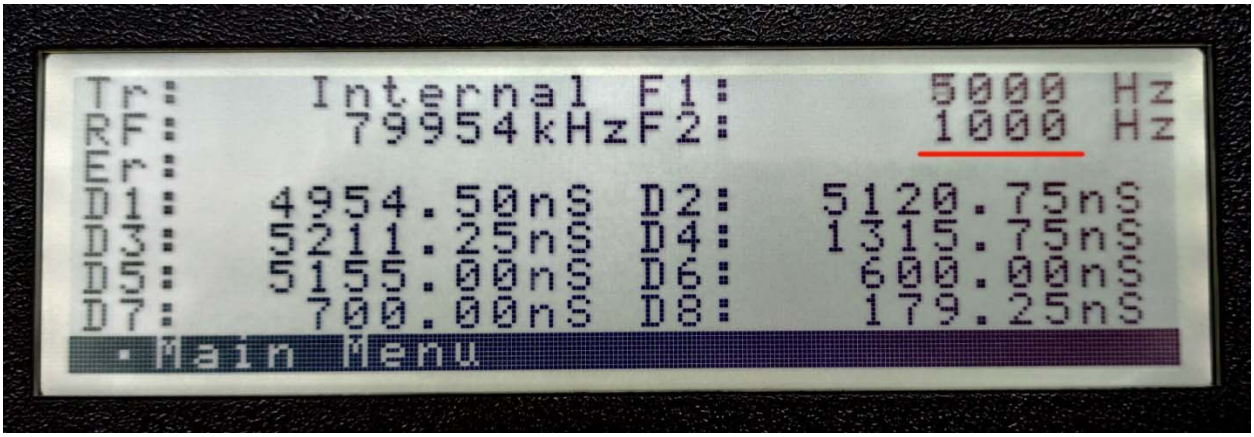

Figure 1. The laser repetition rate setting.

1 kHz repetition rate is commonly used for laser irradiation experiments with direct 800 nm output of the Astrella laser. Using higher repletion rates, especially maximum 5 kHz setting, is dangerous and may lead to a personal injury or fire. Please consult the OCF staff, if you want to use laser repetition rates higher than 1 kHz. It is recommended to change the laser repetition rate by recalling predefined timing presets:

Optimized timing presets are usually saved by the OCF staff in numbered memory slots of the SDG Elite controller. The slot number n, corresponds to the repetition rate of 5000/n Hz. Thus, the slot 1

contains timings for 5 kHz operation and the memory slot 5 contains settings for 1 kHz mode. To change the repetition rate using saved presets:

a. Verify that the laser output is disabled (Delay 1 is inactive) and blocked by a metal beam block.
b. From the timings screen of SDG controller, enter the main menu by pressing “Menu Select” button, and navigate to “Recall/Save Setup” using “Menu Up” and “Menu Down” buttons. Press “Menu Select” to enter the submenu. To return to the upper level of the menu use “Menu Exit” button (Figure 2(A) and Figure 2(B)).
c. In the “Preset save/recall” menu use “Menu Up” and “Menu Down” buttons to select “Recall” item. Us the knob to select the desired slot number (5 for 1 kHz operation and 1 for 5 kHz operation. Figure 2(C).). Then use “Menu Select” button to recall timings. Press “Menu Exit” button several times to reach the main screen (Figure 2(A)). **Warning:** ***Before recalling the timings, please verify that “Recall” is selected. If “Save” option was selected, one can overwrite the saved timing. No warning is given and OCF staff needs to be notified to restore the timings.***

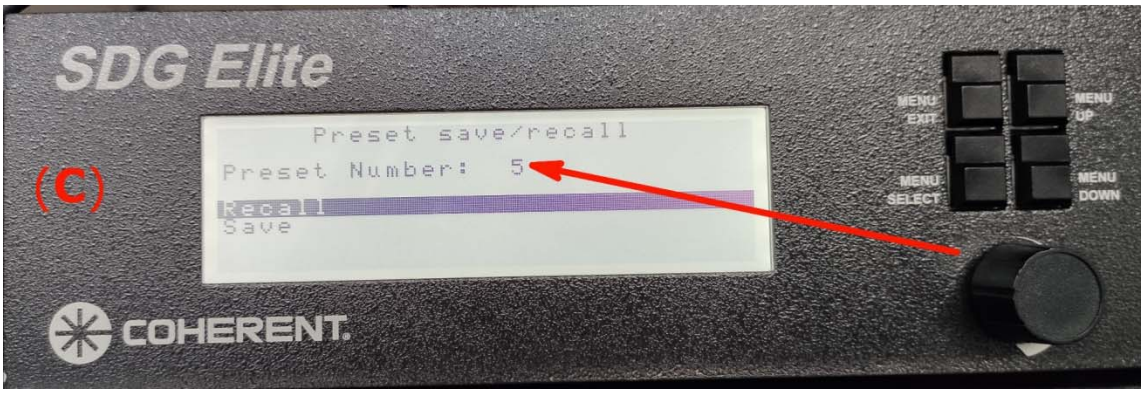

Figure 2.

<u>Warning:</u> After timings recall, Delay 1 may activate and high power laser beam may emerge from the laser. Always block the Astrella output with a black metal beam block. If Delay 1 is activated upon timings recall, disable it manually.

d. Verify that the laser repetition rate is set correctly (Figure 1).

12. Verify that the correct optics configuration is set up on the bench and all necessary safety controls and measures are in place:
    a. For irradiation experiments, the beam tube between the Astrella laser and TOPAS OPA must be removed and diverter mirror must be raised. A beam block is required in front of the sample.

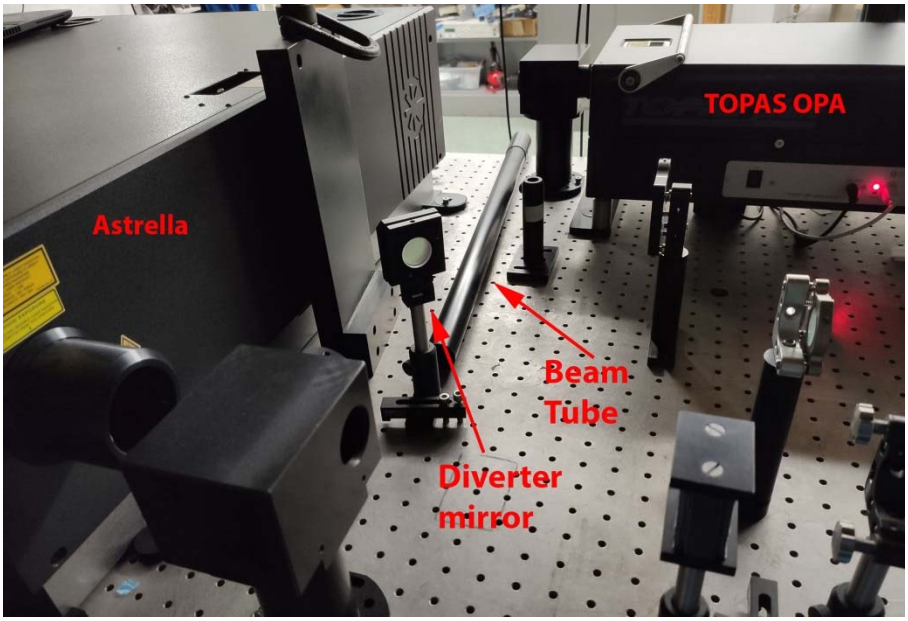

Figure 3. Folding diverter mirror and OPA beam tube set up for irradiation experiments.

13. While wearing 800 nm blocking laser safety eyewear (LPA Alex, or any other with OD>4 at 800 nm) enable Delay 1. Remove beam block at the laser output (but keep the one on the sample

side in place!). Using NIR viewer scope, verify that the laser beam is hitting the beam block next to the sample. If the beam is not visible on the beam block, verify that the Revolution laser is up and running and Delays 1 and 2 are activated on the SDG Elite controller. **If the equipment is up and running normally and the beam is not visible through the NIR viewer or misaligned on the beam block, deactivate Delay 1 on the SDG Elite controller and contact OCF staff, unless you have been trained and cleared for such situation by the lab manager.**

14. Remove the beam block and verify that the laser beam hits the target mark on the optical table. If there is a significant beam displacement on the target or the bean appears clipping, replace the beam block, disable Delay 1, and contact OCF staff for assistance.
15. Place the thermal powermeter sensor head at the sample position. Without attenuation, the power should be >800 mW. It is recommended that at this time, the laser if left to warm up for about 45-60 minutes (make sure that the beam is blocked during the warmup period). The power may increase significantly after the warm up period. **If at any time, the power at the sample position exceeds 1 W, replace the beam block, disable Delay 1, and verify the laser repetition rate.**
16. After warm-up, verify the full output power value, and calibrate ND filters, if needed. Remember to block the laser beam when changing ND filters.

Shutdown sequence:

1. Block the laser output with an appropriate beam block. Disable “Delay 1” output on SDG Elite control unit.
2. Turn off Revolution laser by pressing red “Off” button in the control software. Exit Revolution software.
3. Turn off Verdi G by pressing “Diode On” button in the Vitara control software. Exit Vitara software.
4. Silence SDG Elite alarm, turn safety keys to “Off” position on Verdi G and Revolution power supplies. Turn off Revolution power supply and SDG Elite control box. Turn off the oscilloscope.
5. Turn off Polyscience chiller, Vitara and Verdi G power supplies.
6. Close cooling water bypass valves.
7. Turn off laptop computer and close external water supply valves starting with the “Supply” valve.

General operation and maintenance notes:

1. Under no circumstances Delay 2 should be disabled on the SDG controller unless instructed by the OCF staff.

Addendums

A. Use of the cooling water bypass.

Elevated cooling water pressure in the water chiller supply line causes “hydraulic hammer” effect which can damage the plumbing. To avoid it, one needs to use the water bypass loop installed above the water chiller.

1. Open return valve 1 completely (See Figure A1).
2. *Slowly open* supply valve 2 until the pressure in the supply line drops to ~20 psi (Figure A2). Valve 2 should not be fully open at this point (See Figure A1).
3. Bypass closing procedure: Close valve 2, then close valve 1.

Figure A1. Bypass valves in open positions.

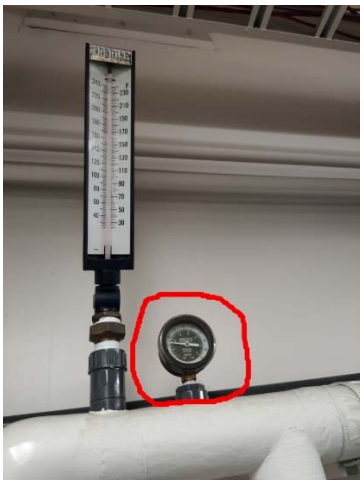

Figure A2. Supply pressure gauge.