

Standard Operating Procedures for the High Watt Laser

Section 1: Overview:

This Standard Operating Procedure (SOP) dictates the requirements for an authorized user of the High Watt lasers in room 123 Laser Research Laboratory and describes the normal operation of the lasers and hazards that may be encountered during normal operation. The SOP provides techniques to minimize hazards and instructions on how to respond to emergency situations. The High Watt is a Class IV KrF excimer laser that can produce a 20 nanosecond 800 mJ/pulse at a wavelength of 248 nm and a repetition rate of 1–50 Hz during normal operation. The emerging beam divergence is 1 mrad, and the beam diameter is 1 mm. Safety glasses marked with the appropriate wavelength and optical density (OD) are provided and must be worn during normal laser operation. The High Watt laser is used in atomic and molecular spectroscopy.

Section 2: Risk Assessment:

Laser Hazards

Severe damage to skin and eye tissue can occur from direct exposure to any Class IV laser; specular or diffuse reflections can cause eye damage. The High Watt laser produces (invisible) ultraviolet light that is harmful to the skin.

Electrical Hazards

Electrical shock or electrocution could result from contact with the high voltage (HV) power supply used to excite the gas mixture. Also, large currents are used in the heaters of the vacuum chambers adjacent to the laser.

Chemical Hazards

The gas mixture used as the lasing medium contains fluorine, krypton, and neon. Fluorine is a toxic gas, and a lethal dose can be received if proper safety procedures are not followed.

Pressure Hazards

The lasing gas mixture and He purge gas are in compressed form and represent possible explosion hazards if proper safety procedures are not followed. Also, the lasing cavity is kept at a nominal pressure of 3600 mbar, which is significantly above atmospheric pressure.

Section 3: Hazard Controls

Lasers

- Access to the laser facility is controlled; only authorized users have key access.
- Lasers shall be operated only by authorized personnel.
- A warning sign outside the door to the lab shall be lit whenever the laser system is operating.
- The shield curtain should be fully closed when the laser is running to separate the laser and non-

laser areas.

- During operation of the laser system, unauthorized personnel shall be allowed entry to the laser area (inside the curtain) only under the supervision of an authorized user.
- Protection from high voltages produced in the laser power supply is provided by the grounded metal enclosure of the power supply. The outer casing of the laser is also interlocked, and the laser will not energize the cavity if a panel is taken off of the outer housing. The metal casing shall not be opened until the high-voltage capacitors are completely discharged and the main cable has been disconnected.
- The 10 mW HeNe laser shall be used for assisting with beam alignments of the High Watt laser. Be aware that although this is a Class II device, you may not safely stare into the beam and should treat this device with the same care and respect as you would the High Watt laser.
- Laser glasses for protection against 248 nm must be available and are located near the entrance of the laser area in room 123 Laser Research Laboratory. Laser glasses must always be worn when the laser is firing, whether or not the shutter is open.
- Specular and diffuse reflections shall be controlled using apertures, beam housings and enclosures, and various optical components. The housings covering the beam path at various points (exiting the laser, entering the chambers, or going through optics) must be in place during normal operation. Access ports for making adjustments are to be used only when using the HeNe laser for alignment or when the laser shutter is closed.
- To locate an invisible beam, thermal-sensitive paper may be used. Use only by securing it in place over an optic, then closing all access ports and making sure all enclosures are secure before opening the shutter and activating the laser.
- Laser alignment must be performed only by following the steps outlined in the alignment supplement, and energy measurements must be performed directly in front of the focusing lenses with the beam enclosures in place.
- If the beam path must be changed significantly (i.e., not in the normal course of adjusting the mirrors) by relocating mirrors or other optics, all users of the laser must be notified of the change.
- The same precautions that are taken in safe operation of the laser and optics must also be followed when changing vacuum chamber optics and adjusting the focusing lenses to line up incident onto the chamber targets with a specific spot size.
- Any stray or unused beams are terminated by using beam stops or dumps.
- The beam is enclosed as much as practical; the shutter is closed as much as practical during coarse adjustments; optics/optical mounts are secured to the table as much as practical; beam stops are secured to the table or optics mounts.

Electrical

The High Watt laser uses high voltage to excite the lasing gas mixture, so all maintenance to the internal components of the High Watt laser may be performed only by authorized repair technicians,

and there must be more than one authorized user present for any maintenance operation that requires access to the internal components of the laser.

Chemical

- Corrosive and toxic gases are used as the lasing medium of the High Watt laser. Even in small concentrations, fluorine gas can be hazardous. In addition, ozone and nitrogenous gases may be created by high-power UV pulses. Ensure that the room ventilation is working properly before operating the laser.
- The smell of fluorine (a sharp, pungent odor) indicates that the laser cavity or Swagelok tubing is leaking, provided the exhaust is within normal parameters. If fluorine is detected, the gas cylinder could be leaking.
- Nitrile gloves shall be used when changing optics or using polishing powder on the laser windows. Be aware that some of the laser windows are coated on one side. Wear nitrile gloves when changing the halogen filter.
- A new fill may be performed only by authorized users or qualified laser repair technicians.

Pressure

- All large compressed gas cylinders shall be securely fastened to the wall with Unistrut and chains or similarly approved assemblies. Small cylinders used for experiments shall also be securely fastened.
- Do not adjust the laser cavity windows unless following the guidelines laid out in the alignment supplement. The laser cavity can be alternately pressurized or under vacuum and thus represents both an explosion and an implosion hazard.
- The use of compressed gases shall be performed only through a regulator.
- The laser cavity pressure shall not exceed 4000 mbar, and lasing will not be efficient under 3100 mbar.

Section 4: Normal Operation

Laser Startup

- Remove all jewelry from fingers and arms (e.g., rings, watch, bracelet). If wearing a necklace, either remove it or ensure that it is secured between your shirt and body.
- Wear appropriate clothing to protect hands and arms from excessive laser radiation.
- Remove all unnecessary equipment, tools, and combustible materials from near the beam path to minimize the possibility of stray reflections and non-beam accidents.
- Ensure that all personnel inside the Nominal Hazard Zone are wearing appropriate laser safety glasses.
 - Verify that the wavelength is suitable for the laser in use.

- Verify that the optical density (OD), as indicated by inscriptions on the lenses or frame of the glasses, is adequate.
- Ensure that the glasses are in good condition (i.e., no deep scratches or cracks in lenses, good frame integrity).
- Check for exposed wiring or electrical components. Be aware that high voltage capacitors have electrical potential long after they have been de-energized and unplugged.
- Do not open the laser cover except under instructions from a knowledgeable person. Besides exposing high voltage electrical sources, removing the cover may expose users to secondary wavelengths that may be invisible and that fall outside the protection range of the selected eyewear.
- Avoid having eyes (including when wearing safety eyewear) in the same optical plane as the beam. Generally, personnel should remain standing while the laser is in operation. If personnel must be seated, provide tall stools that will keep the eyes above the plane of the optical table.
- Assure that the chiller is turned on and cooling water is flowing to the laser.
- Verify that the High Watt laser back panel indicates the laser is on.
- Confirm that the beam path is set up by using the HeNe alignment laser so that a focused spot will land onto the exposed target in the chamber.
- Confirm that the HeNe alignment laser is out of beam path.
- Confirm that all beam enclosures are in place before the High Watt laser shutter is opened.
- **Warn all personnel near the NHZ by saying “Firing” before starting to 1) fire the laser or 2) open the laser shutter.**
- If necessary, use an energy meter to check the laser energy.
- Close the laser shutter and take the energy meter out of the beam path.
- Record the laser status in the laser logbook. When ready to begin the run, open the shutter and ensure that all safety enclosures, beam stops, and shields are in place.
- During the run, ensure that the laser beam is striking the target by indirectly noting the plasma glow of the plume. **Do not stare directly at where the focused spot hits the target.**
- Record any anomalous behavior in the laser logbook, and alert other users.
- If there are warnings from the laser computer application, refer to the laser manual for troubleshooting.

Laser shutdown

- When the run is finished, close the laser shutter and stop the laser computer from triggering.
- After the last user of the day, disconnect the power from the laser.
- Record pertinent details for the laser usage in the log book.

- Allow the chiller to run for at least a few minutes following laser usage. Before leaving the lab, turn off the chiller.
- Ensure that the beam enclosures are left in place. This ensures that the laser will be ready to go in a short time period for the next user and protects the next laser user and other personnel in the area from potential stray beam reflections.
- Place dust covers over optics as necessary.

Alignments

Beam alignment requires work with an open beam and involves directing the beam toward a series of reflective or partially reflective surfaces, such as mirrors or lenses, so that it follows a predetermined path. Laser alignments may be internal or external.

Internal alignments take place within the laser cavity or head and often place the work at increased risk of electrical accidents as well as primary beam exposure and ancillary wavelength exposure. The need for internal alignments usually arises because of problems associated with beam mode or power.

External alignments are those that occur from the laser's end window to a terminal target. A number of optical components (optics) arrayed in more or less complex configurations may be between these two locations. The need for external alignments occurs because of reconfiguration of the optical setup or replacement of components either within the laser head or in the open beam path.

Perform alignments with a colleague. Review alignment operating procedures with your colleague and communicate at all times. Identify equipment and materials necessary such as safety eyewear, tools, power meter/detector, and beam stops prior to performing alignment.

View beams indirectly. Use thermal paper to view the excimer laser beam and paper business cards to view the HeNe laser alignment beam.

- **Internal Alignment** (with laser windows cleaning/replacement)
 - Place dielectric pieces (with holes through the middle) on the front and back in front of the windows.
 - Position the HeNe laser on a stand and direct it at the hole in the front piece. Adjust the tilt to get the laser beam through both holes at once to make the beam parallel. Do not look at the beam directly; use a business card to view the spot.
 - Adjust the back laser mirror to position the reflection in the center of the front piece. Then remove the dielectric pieces.
- **External Alignment**
 - Using thermal paper, look at the excimer laser spot at the front shutter. A uniform plateau-like laser spot is ideal. Adjust the front window to produce a uniform rectangular shape.
 - Check that the beam is centered on the first aperture.
 - Tape thermal paper to the aperture, and trigger the laser to create a spot.

- Use the HeNe laser and direct it to the center of the spot created by the excimer pulse. Remove the paper.
- Repeat this process until the laser spot is roughly in the center of the excimer laser spot at all points of interest throughout the optics setup.
- Open up the sample deposition chamber. Check the spot at the deposition target. Adjust the spot position on the target with the last mirror. Adjust the aperture to produce a small circular spot.
- Save the thermal paper of the final spot at the target for comparison with previous and future alignments.
- Normal laser hazard controls shall be restored when the alignment is completed. This includes replacing all enclosures, covers, beam blocks/barriers and checking affected interlocks for proper operation.

Maintenance procedures

Maintenance not described in this procedure shall be performed only by a qualified technician, normally a factory representative. Any deviations from this protocol shall be approved in writing by the PI.

For optics cleaning or replacing the halogen filter, please consult the laser manual.

Section 5: Emergency Response

In the event of a laser accident, do the following *immediately*:

- Ensure that the High Watt laser shutter is CLOSED and that the laser is not pulsing or that it is in an otherwise safe condition.
- Provide for the safety of personnel (first aid, evacuation) as needed.
- If a laser eye injury is suspected, have the injured person keep his/her head upright and motionless to reduce bleeding in the eye. A physician should evaluate laser eye injuries as soon as possible.
- Obtain medical assistance for anyone who may be injured.

Dial 911 from any university or personal telephone for an ambulance (urgent medical care) or the fire department.

- If there is a fire, leave the area, pull the fire alarm, and call 911. Do not fight the fire unless it is very small and you have been trained in fire-fighting techniques.

After normal working hours, contact the U of I Police Department (non-emergency: 217-333-1216; emergency: 911 from campus phone), which can contact the above using their emergency call list.

- Inform the PI, the group safety officer, and the building manager as soon as possible. If there is an injury, the PI needs to submit a report of injury to Risk Management.
- Inform DRS at 217-333-2755 as soon as possible.

Section 6: User Training and Authorization

The High Watt laser may be operated only by authorized personnel who are fully cognizant of all safety issues involved in operation of such a device. These personnel are to ensure that the laser is operated in accordance with the instructions in this document. To become an authorized user, one must:

- Complete the DRS online training;
- Read and fully understand this SOP;
- Receive training on the High Watt laser by the primary user;
- Receive and document annual laser safety training;
- Sign the authorized user sheet to affirm that the above steps have been completed.

No unauthorized personnel may enter the laser area during laser operation unless accompanied by an authorized user. All visitors should be briefed on proper safety protocol and should wear appropriate laser safety goggles located near the entrance.