

## **Standard Operating Procedures for**

### **Room 013/015**

#### **Laser Controlled Area**

Version 3 (September 23, 2014, Jacob Hoffman)

#### **Introduction**

This Laser Controlled Area (LCA) comprises rooms 013/015, which house three lasers: A pulsed Spectra-Physics Quanta-Ray Nd:YAG Pro 230 laser (a Class IV laser that can produce output at 1064, 532, 355, and 266 nm), a pulsed nanosecond nitrogen laser (Class IIIb, output at 337 nm), and a pulsed nanosecond excimer laser (Class IV laser, output at 308 nm). The diagram of the room and the LCA is given in Appendix A. The LCA area is separated from data collection area and can be accessed through interlocked doors.

The LCA area consists of two laser flash photolysis set-ups. The first set up makes use of Nd:YAG laser as the excitation source. The second set up makes use of Nitrogen/Excimer lasers. In the Nd:YAG area, there are currently two optical tables (see diagram of LCA in Appendix A). One optical bench contains the excitation and detection optics, along with the monochromator and photodetectors. Contiguous to this bench another optical table contains the operational Spectra-Physics laser. The remainder of the data acquisition system (computer, scope, etc.) is outside the LCA in the operator's area. Since described benches are contiguous with each other, there are no open laser beams between the optical tables when the standard flash photolysis experiments are being run.

The N<sub>2</sub>/ Excimer set up consists of three optical tables. One optical bench contains the sample excitation and detection optics, along with the monochromator and photodetectors. The two lasers are on placed separately on two tables. Since the space between the laser tables and detection table allow easy passage, there are open laser

beams between the laser tables and the detection/sample table. The rest of the data acquisition system (computer, scope, etc.) is just outside the LCA in the operator's area.

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### **Authorized Users**

Authorized users need to have taken the Laser Safety Class provided by UND Risk Management. In addition, they must be trained on the laser-operating procedures for the specific laser they intend to use by the LCA Supervisor before they use the laser. Finally they must read and sign this SOP in the authorized users section located in Appendix B.

### **Scientific Collaborators & Spectators**

A *Scientific Collaborator* is a visitor who handles some other parts (non-laser) of the experiment. This person is allowed to enter the LCA when the lasers are powered up, but not when they are lasing (see Warning Light Codes below). Proper goggles must be worn once the lasers are powered up. See the Eyewear Section below for a description of the proper goggles to wear for each laser.

A *Spectator* is a visitor who is not involved in the experiment. This person should not enter the LCA when the lasers are powered up, and, in particular, they should not enter the LCA when the laser beams are exposed. They should be confined to the operator's area outside the LCA. They can be shown the optical equipment inside the LCA only under conditions when there is no power at all to any of the lasers.

### **Normal Laser Operation**

Startup/Shutdown procedures for all the lasers are located in Appendices E (for the Nd:YAG laser) and F (for the Excimer/Nitrogen lasers). Additionally these procedures are also posted on site in the operator's area.

**(Nd:YAG):** The Spectra-Physics Quanta-Ray laser is triggered by the data acquisition system in the operator's area. The laser beams are aligned to irradiate the width of the slit on the sample cell (see diagram in Appendix C) at the center of the optical bench that contains the optical detection system. This consists of the pulsed xenon arc lamp, the cell, the monochromator, and the associated optical components (mainly lenses). The usual alignments of the laser beams are also indicated in Appendix C only for the standard flash photolysis.

The YAG laser is from Spectra-Physics, Quanta-Ray Pro 230. In our installation, this laser is only operated at 10 Hz. The laser's pulse width is approximately 12 ns (full width at half height). Operating at 10 Hz, the rated energy per pulse of the laser is 1250 mJ/pulse at 1064 nm, 650 mJ/pulse at 532 nm, 375 mJ/pulse at 355 nm, and 130 mJ/pulse at 266 nm. When the laser is in operation, these four beams are simultaneously available at the four ports of the laser's wavelength selection box (see Appendix C). Inside this box there are also beam dumps for the 1064 and 532 nm beams. These dumps stop 90% of the laser power so the working power for these beams is closer to 125 mJ/pulse (for 1064 nm) and 65 mJ/Pulse (for 532 nm). These four exit ports are normally closed by removable beam stops. The fraction of the laser's energy going into each beam is determined by the adjustments of the nonlinear optical crystals and the polarization rings. See the laser's operating manual for these power adjustments or check with the LCA supervisor.

The cross-section of the laser beams is circular ( $\approx 1$  cm diameter) with a Gaussian distribution of energy. There is very little divergence of the beams from the laser's output ports to the cell. The laser beam is usually aligned so that its cross-sectional area is between 0.25 and 0.5 cm<sup>2</sup> at the cell. The Laser Vision glasses with solid side panels are the best goggles that we currently have in stock for this laser. They are still marginally adequate for the 1064 nm beam, so the beam stop for this wavelength should always be in place if at all possible.

The beam should normally be attenuated with the variable attenuator. The attenuator is situated in the laser's beam just after the directional prism (see Appendix C). The prism, itself, is located immediately outside of the laser's wavelength selection box. The position of the prism is adjustable on an optical rail running perpendicular to the laser's four output beams. In addition, the laser beam is usually not focussed down to the 0.25 to 0.5 cm<sup>2</sup> slot in the cell holder. Leaving the beam somewhat unfocussed is another way effectively to attenuate the beam for excitation purposes.

The Laser Vision glasses with solid side panels are adequate for this laser. However, **extra caution should be used behind the dielectric mirrors because laser power can be transmitted through these mirrors**; dielectric mirrors can operate as beam splitters depending on the angle of incidence of the laser beam. Exposed skin should be kept out of the beam of this YAG laser. This is a Class IV laser. It is mandatory to wear a lab coat and gloves to keep potential skin exposure to a minimum, especially when performing the daily alignment procedures, in particular for operations involving making micro-adjustments that usually require placing the operator's fingers close to the laser beam.

**(Nitrogen / Excimer Lasers):** The nitrogen laser and the excimer laser are not to be operated simultaneously. These lasers provide different excitation wavelengths for sample excitation. These two lasers are externally triggered by the data acquisition system in the operator's area. Although they are set to operate at either at 1 or 10 Hz, it is recommended that the nitrogen laser is only be operated at 1 Hz. Both are aligned to come close to focus on the sample cell at the center of the optical bench that contains the optical detection system, consisting of the pulsed xenon arc lamp, the cell, the monochromator, and the associated optical components (mainly lenses). The usual alignments of the laser beams are indicated in Appendix D.

The nitrogen laser is from Laser Photonics PRA/Model UV-24. The output wavelength is 337.1 nm, pulsed at either 1 or 10 Hz although now it is recommended to

operate only at 1 Hz. The pulse is approximately 8 ns (full width at half height). The current energy is between 4 and 6 mJ/pulse. There is considerable divergence of the beam, and its total beam length between the laser and the cell is minimized given the physical constraints inside the LCA. The cross-section of the beam is rectangular, and it is usually focused so that its cross-sectional area is between 0.25 and 0.5 cm<sup>2</sup> at the cell. The dark amber goggles with OD 14 between 200 and 400 nm are more than adequate for this laser. This is a Class IIIb laser.

The other laser in the LCA is a Lambda Physik COMPex 102 excimer laser. It is conditioned at the factory such that it is supposed to be only used with “chlorine” mixtures. For our Lab that means that it will only be operated as a XeCl laser with an output at 308 nm and pulse width around 20 ns. This laser is also operated at either 1 or 10 Hz by the computer-controlled equipment in the operator’s area. The pulse energy can be around 200 mJ when the power supply is at 20 kV. The beam is also rectangular with the long dimension being horizontal. The divergence is not large. The beam is usually attenuated with pyrex neutral density filters. In addition the beam is usually not focused down to the 0.25 to 0.5 cm<sup>2</sup> slot in the cell holder. Leaving the beam somewhat unfocused is another way effectively to attenuate the beam for excitation purposes. It is particularly **important that the black laser shielding is in place behind the cell for safety**. The dark amber goggles with OD 14 between 200 and 400 nm are sufficient for this laser. However, **extra caution should be used behind the dielectric mirrors because laser power can be transmitted through these mirrors**; dielectric mirrors can operate as beam splitters depending on the angle of incidence of the laser beam. Exposed skin should be kept out of the beam of this laser, and because of this a lab coat and goggles should be worn during operation. This excimer laser is a Class IV laser.

## **Eyewear Section**

Calculations for the required ODs can be found in appendix G, but the minimal OD for max laser powers are shown in figure 1 (with the available laser goggle ODs)

- (1) The dark amber glasses with separate amber side shields have an OD of 14 between 200-400 nm and are adequate for the excimer and more than adequate for the nitrogen laser. With respect to the YAG-laser applications, these goggles also have OD 7 in the 532 nm range, but only OD 4 in the 1064 nm range. They should not be used for aligning operations with the YAG because of this. They can be used with the Nd:YAG when exciting at 266, or 355.
- (2) The Laser Vision glasses with solid side panels are the ideal glasses when aligning the YAG. They are rated at OD 6+ at 1060 – 1064 nm and OD 7+ between 190 – 532 nm. Extra care should be used with 1064 nm when pre-attenuator as the goggles offer minimal protection at the max power.
- (3) The light amber goggles have OD 5+ and are not suitable for use when aligning any of the lasers associated with this LCA. They provide safety for non-alignment operations inside the LCA.
- (4) Use special safety glasses when replacing the Xenon arc lamp units inside the Lamp Housings.

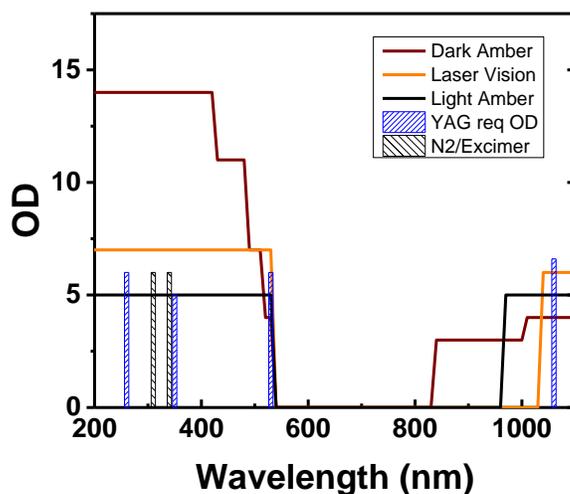


Figure 1: OD of available goggles and required OD for each laser

### Alignment Hazard Control

All three lasers are factory aligned within the laser cavity and should not require internal adjustments. During the daily laser alignment, Scientific Collaborators and Spectators should never be in the LCA. Only approved users are allowed to be present in the LCA. If the user-of-the-day requires assistance with the alignment, an approved user or the LCA Supervisor should be called. Often a second person is recommended for safety considerations, such as when it is necessary to open shutters some distance from where a detailed adjustment is being made by the user-of-the-day.

**Daily alignment of the Nd:YAG laser:** The large black, wavelength selection box (Appendix C) has also been pre-aligned by Professor Fessenden, and the optics inside of this box should not be changed. Only the nonlinear crystals and polarization rings should be changed in order to maximize the energy output at the desired wavelength. These controls are accessible through the sliding door on the side of the wavelength selection box and through the hinged door on the front of the laser's case.

The options available for excitation of the cell on the detection table are quite limited, mainly to right-angle (to the detection beam from the Xenon lamp) excitation or some angle between 90 and approximately 150 degrees. However, the laser beam is

confined to run along an optical rail that is parallel to the detection beam of the Xenon lamp (see Appendix C). The alignment of the laser beam along this parallel optical rail is the most critical from a safety point of view. The wavelength is selected by removing the appropriate beam stop (Appendix C). Then it is necessary to move the prism along the optical rail, and the prism has to be placed so that the laser enters and exits the attenuator (Appendix C). Great care should be taken at this point since the beam is not attenuated. It is advisable to get assistance on the first few times this procedure is performed. At a minimum, adjustments of the dielectric mirror (Appendix C) and the lens just before the cell must be checked daily by the user-of-the-day.

Extra precautions should be taken because of the high intensity, low divergence of the YAG beams. In particular, **the attenuator should be used during the alignment procedure. In addition, for the 532 nm and 1064 nm alignments, the low intensity, long pulse mode should be used.** After the alignment procedures, the normal pulse length can be chosen, and the power needed for the experiment can be set with the variable attenuator before the experiment starts. In addition the power of the laser beam chosen can be optimized with the nonlinear crystals and the polarization rings. The **warning that dielectric mirrors can transmit as well as reflect the beam** is critically important with this powerful laser.

With the above settings the rest of the adjustment can be begun. Except for the 1064 nm beam, the laser beams are safely monitored using the luminescence visible when the 355 and 266 nm laser beams are absorbed by a paper business card. The 532 nm light is easy to see reflected from the business cards. **Warning: proper laser goggles must be worn during this operation** (check the Eyewear Section). **Additionally, a lab coat and gloves must be worn to reduce the chances of skin exposure to pulses of laser light** during the alignment operations. This is particularly true for operations that require placing the operator's hands near the laser beams when making micro-adjustments with the dielectric mirror and the prism.

**To align the Nd:YAG laser in the daily routine:**

- (a) Before putting the laser into the operate mode (Q-switch on or long-pulse on), position the prism (Appendix C) along the short optical rail before the attenuator so that it is roughly in position to intercept the chosen beam.
- (b) Remove the beam stop in front of the chosen wavelength port of the black wavelength selection box. Make sure that the other three beam stops for the other three laser wavelengths remain in place.
- (c) Activate the Q-switch of the laser, choosing the long pulse mode if 532 nm or 1064 nm is to be used.
- (d) Using the micro-adjustment screws on the prism holder, direct the laser spot onto the input window of the attenuator box.
- (e) With appropriate further adjustments of the position of the prism (using the micro-adjustments and translations along the optical bench) make sure the laser beam is exiting the attenuator box.
- (f) Use a business card as a monitor and check that the laser is coming straight down the laser's optical rail and can pass unhindered through the hole in the laser's shutter. If the laser optics are already in place for the desired geometry, it may be simply a matter to check only whether the laser cross-section is hitting the proper spot on the cell. If the spot is way off the target or if the geometry has to be changed, then the following procedure is recommended.
- (g) With the laser beam blocked, make sure that the dielectric mirror before the cell is in the desired position on the laser's optical rail. In addition, turn the dielectric mirror to roughly the proper angle with respect to the optical rail so that the beam will strike the cell.
- (h) With the laser beam still blocked, remove the laser's lens just before the cell. For most operations this lens will NOT be needed to focus the laser beam further.

- (i) Unblock the laser beam, and make sure the laser beam is hitting the center of the dielectric mirror.
- (j) With the micro-adjustments on the mirror, adjust the laser beam so that it is centered to hit the slot in the sample cell. **Warning: when using the adjustments on dielectric mirrors, remember that this type of mirror can transmit laser beams to the extent that the incident angle deviates from 45 degrees.**
- (k) If a tight focus of the beam is not required, the alignment is complete. If a tight focus of the laser beam is required, then follow with parts (l) and (m).
- (l) With the beam again blocked, place the lens between the cell and dielectric mirror into its approximate place.
- (m) If a tight focus of the laser beam is required, then unblock the laser beam and adjust the position of the lens making the final adjustments so that it strikes the desired spot on the cell. The laser beam should be passing nearly through the center of the lens otherwise “dog-legs” develop in the alignment. In this case, the laser beam will probably not be irradiating the desired volume of the cell. In a normal alignment, the laser beam hits the cell so that the Xenon lamp’s beam is totally covered over its pathlength through the sample, meaning that the long dimension of the rectangular cross-section is 0.5 to 1.0 cm for the normal cells.

**Daily alignment of the Nitrogen laser.** The options available for excitation of the cell on the detection table are quite limited, mainly to right-angle (to the detection beam from the Xenon lamp) excitation or some angle between 90 and approximately 150 degrees. However, the laser beam, just before the final mirror that is closest to the cell, is confined to run along an optical rail that is parallel to the detection beam of the Xenon lamp (see Appendixes D). The alignment of the laser beam along this parallel optical rail is normally handled by the Laser Supervisor, and nothing is required by the user.

Adjustments of the final mirror and the lens just before the cell must be checked daily by the user-of-the-day.

This adjustment should be done by monitoring the beam with the luminescence visible when the laser is absorbed by a paper business card. **Warning: proper laser goggles must be worn during this operation** (check the Eyewear Section). If there is any doubt where the beam is going, it should be checked first whether it is indeed along the optical rail, parallel to the Xenon lamp's beam. If the laser beam is to be tightly focussed for some operation, it is recommended that the alignment should be done with neutral density filters in the laser beam, preferably somewhere on the laser's optical rail, but between the laser and the last mirror before the cell.

**To align Nitrogen laser in the daily routine,**

First use the business card as a monitor and check that the laser is coming straight down the laser's optical rail and can pass unhindered through the hole in the laser's shutter. If the laser optics are already in place for the desired geometry, it may be simply a matter to check only whether the laser cross-section is hitting the proper spot on the cell. If the spot is way off the target or if the geometry has to be changed, then the following procedure is recommended.

- (a) With the laser beam blocked, make sure that the final mirror before the cell is in the desired position on the laser's optical rail. In addition, turn the mirror to roughly the proper angle with respect to the optical rail so that the beam will strike the cell.
- (b) With the laser beam still blocked, remove the final lens before the cell.
- (c) Unblock the laser beam, and make sure the laser beam is hitting the center of the mirror.
- (d) With the micro-adjustments on the mirror, adjust the laser beam so that it is centered to hit the cell. This beam cross-section will probably be too wide, but remember that the final lens has not yet been replaced. **Warning: when using the adjustments on dielectric mirrors, remember that this type of mirror can transmit laser beams to the extent that the incident angle deviates from 45 degrees.**

- (e) With the beam again blocked, place the lens between the cell and final mirror into its approximate place.
- (f) Unblock the laser beam and adjust the position of the lens, making the final adjustments so that it strikes the desired spot on the cell. The laser beam should be passing nearly through the center of the lens otherwise “dog-legs” develop in the alignment. In this case, the laser beam will probably not be irradiating the desired volume of the cell. In a normal alignment, the laser beam hits the cell so that the Xenon lamp’s beam is totally covered over its path length through the sample, meaning that the long dimension of the rectangular cross-section is 0.5 to 1.0 cm for the normal cells.

**Daily alignment of the Excimer laser.** The same procedures should be followed for the daily alignment of the excimer laser. This laser beam comes along the same optical rail as does the nitrogen laser beam, but in the opposite direction (see Appendix D), at least for right-angle excitation. For “front-face” excitation, accommodations for running the beam in the other direction may have to be made. This has yet to be worked out for the new laser installation. Before attempting “front-face” excitation with the excimer laser, the user should check with the LCA supervisor.

Although the general daily alignment procedure is the same for the excimer laser as it is for the nitrogen laser, extra precautions should be taken. In particular, **neutral density filters should be used during the alignment procedure.** If maximum power is needed for the experiment, then these neutral density filters can be removed before the experiment starts. The **warning that dielectric mirrors can transmit as well as reflect the beam** is critically important with this powerful beam.

### **Laser Hazard Control**

**Borders of the LCA.** The LCA is enclosed on all sides by permanent walls. There are three entrances to the LCA from the operator controlled area. Two sliding doors and a double door separate the LCA allow access from the operator’s area. One of the

sliding doors is located near the Nitrogen/Excimer system while the other is located near the Nd:YAG system. Both of these sliding doors are connected to external shutters that are designed such that if any sliding door is open on lasing will occur in the LCA. **The double door is not connected to an external shutter and should be opened in case of emergency to evacuate the room.** There is an additional door to room 009 (another LCA) in the back corner of the LCA that should remain closed during the laser operation and can serve as an emergency exit.

**Warning Light System.** There is a Green-Yellow-Red light stack located on the wall immediately outside the LCA. This is intended to make potential users and visitors aware of the current system status.

(1) Green means no power to the laser, but it provides a sign to personnel that the warning light system is functioning. When the Green lights are on, it is safe for anyone to enter the LCA without laser goggles. Note that because the green light is turned on most of the time, its bulb often burns out. If one notices that all three lights (Green-Yellow-Red) in the light stack are turned off, they should immediately contact the LCA supervisor, Prashant Kamat.

(2) Yellow means there is power going to the laser, but the external laser shutter is blocking laser exposure to the LCA. On Yellow, the proper laser goggles must be worn (see Eyewear Section). Only the user-of-the-day and their Scientific Collaborators can enter the LCA when the Yellow light is ON. Spectators are not permitted in the LCA when Yellow is ON.

(3) Red means there is lasing action and the external laser shutter is open. Only the users-of-the-day and other authorized users should be inside the LCA under these conditions, and then only for the purpose of aligning the laser optics. Scientific Collaborators and Spectators are not allowed inside the LCA when the Red light is ON. If help is needed to align the lasers, then other approved users should be called.

**Other Warning Signs.** There is a laser-danger warning sign under the current on the all doors into the LCA

**Normal Operation.** When data is being collected, both sliding doors into the LCA should be closed and the user, collaborators, and spectators should not be inside of the LCA. The computer which controls data collection is in the operator's area outside the LCA (Appendix A). Once the laser and the system optics have been properly aligned, experimental parameters are to be set, the data is collected and analyzed by the computer controls located outside of the LCA.

**Control of Additional LCA Hazards.** All three lasers have high voltage circuitry that is contained in the laser cabinet. These cabinets cannot be accessed except by defeating the interlock systems that prevent charging when the cover is open. All three lasers use xenon lamps where the xenon is inside a high-pressure quartz tube. When hot this tube can easily break and then explode. **The operator should use safety glasses and protection on the hands and arms when changing the xenon tubes.** The tube is normally inside a metal lamp housing, but this has to be opened when the lamp needs to be changed. The quartz should not be touched directly when a new lamp is being installed to keep skin oils off the quartz tube. If the quartz envelope is touched, it should be wiped clean with alcohol. The lamp housing should not be opened when the quartz is hot.

**Warning: the tube can still explode when cold if stress is put on the tube structure.**

The xenon lamp also has a high voltage power supply. Care should be taken when working around the high-tension cables leading from the power supplies to the lamp housing.

When operating in the LCA it is required to wear the correct laser goggles, gloves, and a lab coat. Additionally, wearing watches and jewelry in the LCA is prohibited due to the reflective nature of these items.

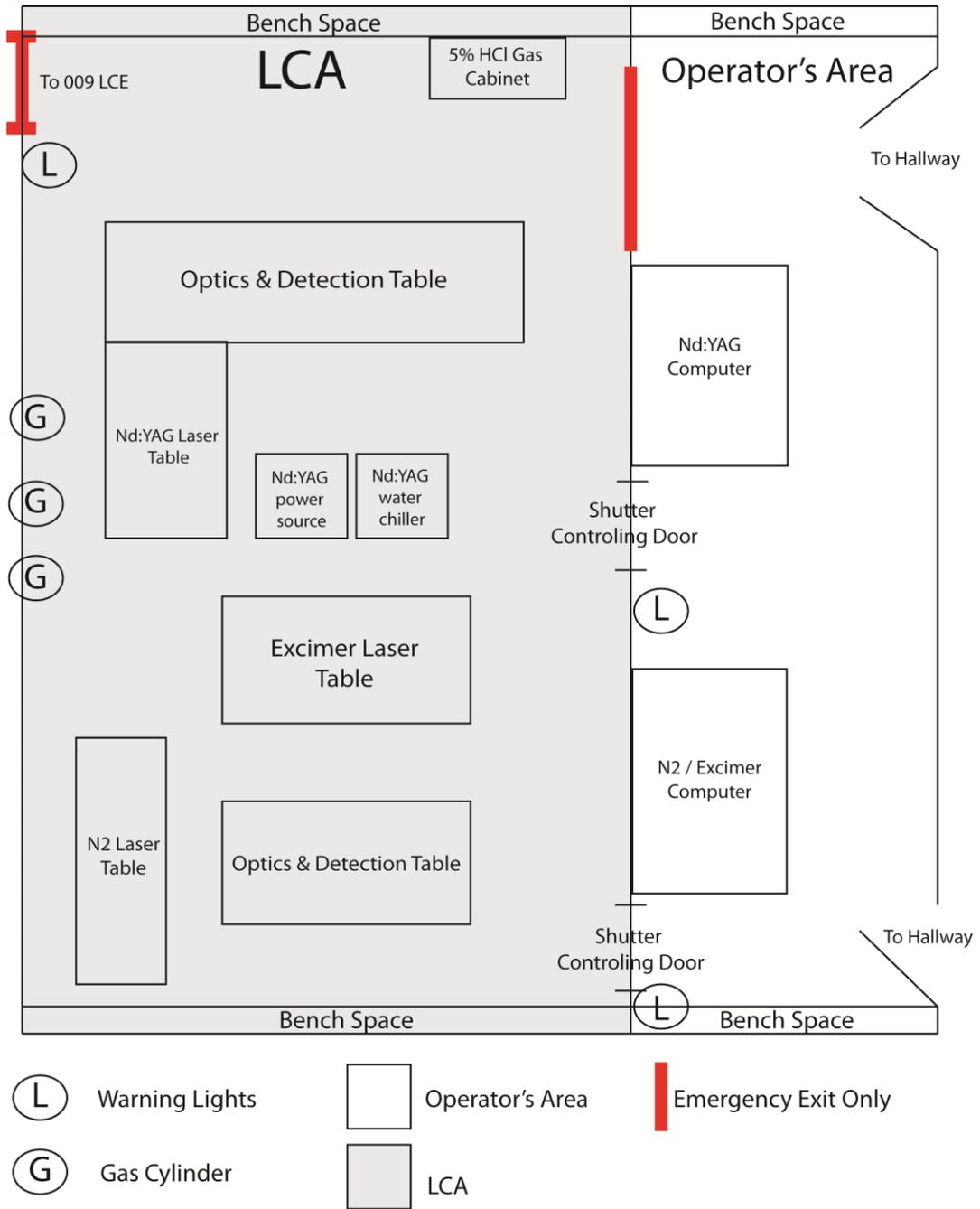
**Hazards specific to the Nitrogen/Excimer Lasers.** The Lambda Physik COMPex 102 Excimer Laser uses compressed gases He, Ne, Xe, and 5% HCl. These

gases are under pressure and containers must be strapped into onto solid supports and the proper gas regulators must be in place. The HCl tank has to have a special regulator, and its gas cylinder is placed inside a specially vented cabinet inside the LCA (see Appendix A). The cavity of this laser is vented to the outside.

**Associated Chemical Hazard Control.** The only dangerous chemical specifically associated with the LCA is the XeCl mixture used in the Excimer laser. Gas leaks associated with this laser would be a serious threat to one's health. To minimize this hazard, a vented cabinet for the 5% HCl gas cylinder and the connection of the laser cavity to the outside ventilation system are employed. The Excimer also has an electronic-processor-controlled filling procedure that minimizes the chance of releasing excess HCl. The primary danger of low levels of HCl released in the air is to the mucous membranes.

**Control of Emergencies & Abnormal Situations.** (a) If HCl is released to a major extent, the users should protect their noses and eyes and shut off the source of the leak if possible. Otherwise, evacuate the room and possibly the building if conditions warrant. (b) In the case of electrical shock from high voltage, the voltage should be turned off if possible without danger to the non-injured users, and 911 should be called. (c) Cuts from exploding Xenon tubes from the Xenon lamp should be treated as other emergency cuts. (d) Exposures to laser beams should also be treated as other medical emergencies and reported to the management team.

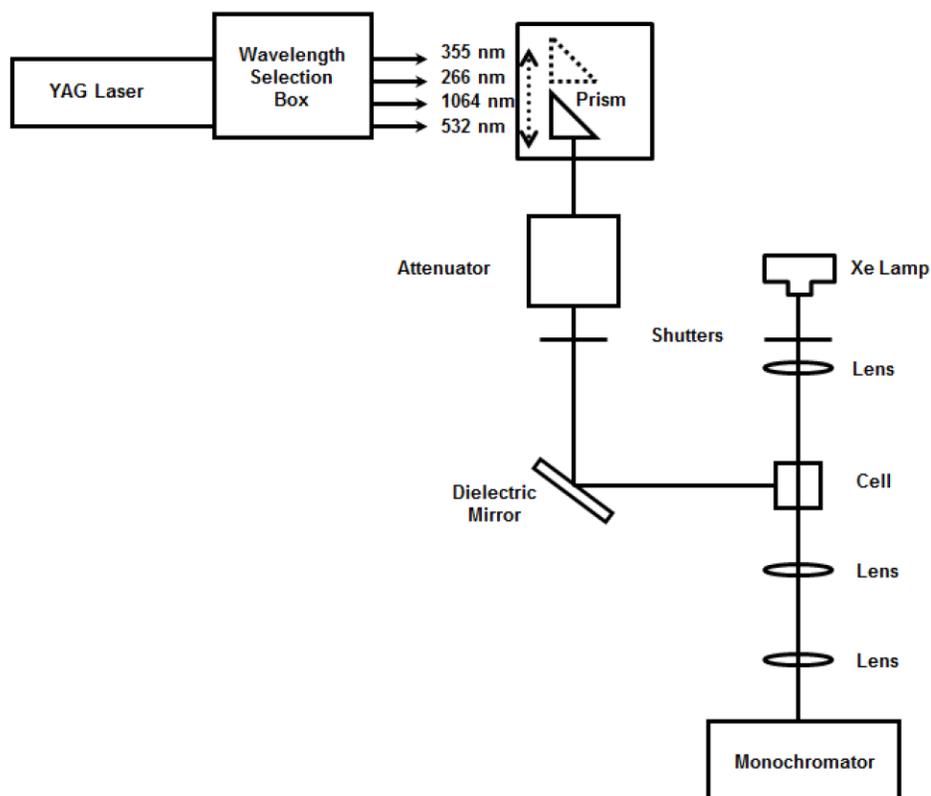
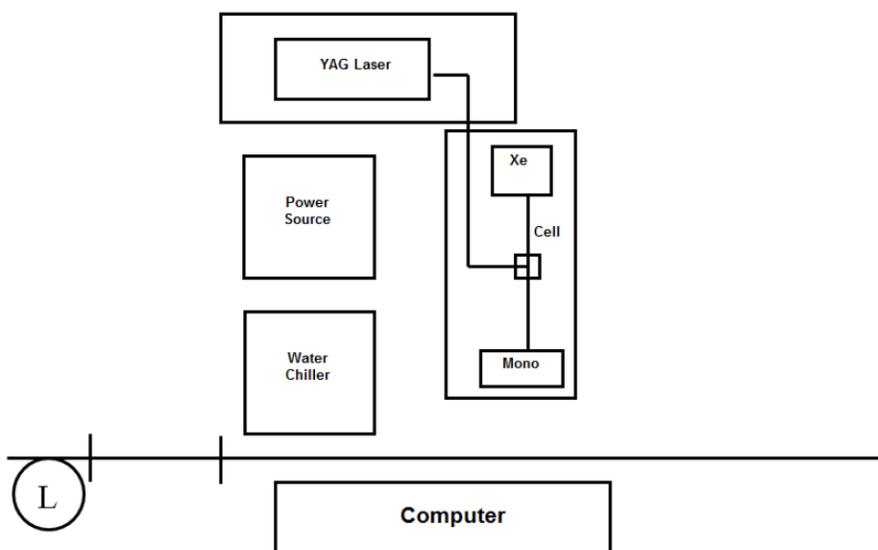
All emergency situations and injuries should be reported to the management team after first aid issues have been dealt with. The names of the management team are listed on the yellow posters in the hallways.



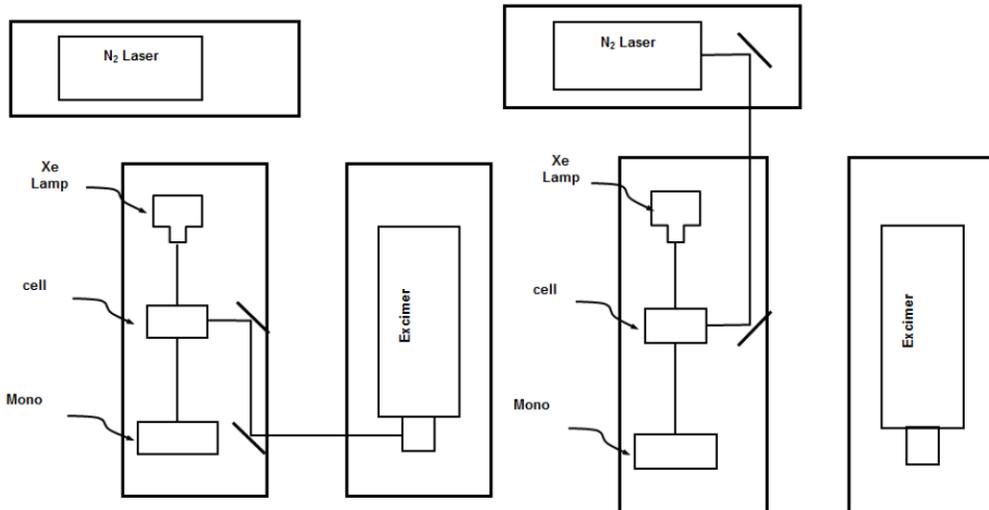
# Appendix A



## Appendix C – Nd:YAG Setup and Alignment



## Appendix D- Alignment for N2 and Excimer Lasers



## **Appendix E: Nd:YAG laser Startup and shut down procedures**

### **Starting up the YAG and its Detection System (draft 3-6-12)**

Turn on the YAG laser's Cooling water located in room 013

Please sign the YAG log sheet on the door to room 015

#### Turning on the Xenon lamp

(1) Before igniting the Xenon lamp

- (a) Make sure that all of the electronics in the detection system is turned off.
- (b) Make sure the YAG Control Box is turned off
- (c) Make sure the knife switch is OPEN. (Knife switch is inside the small shop-made metal box attached to the lamp housing.)

(2) Turn on the lamp power supply, bottom unit in the stack

(3) Ignite Xenon lamp by depressing and releasing the toggle on the frame of the shop-made metal box attached to the lamp housing.

(4) Close knife switch inside the small metal box

(5) Turn on lamp pulser supply

(6) Turn on lamp pulser

#### YAG Laser Start Up (after turning on the cooling water in 013)

(1) Turn on the key switch of the YAG's power supply unit

(2) Turn on rear toggle switch on the YAG Control Box – location of the switch at the right rear (when facing the front panel)

(3) When the monitor screen of the YAG Control Box lights up, depress the black square button below POWER ON – depress this button until a beep is heard

(4) System Self Test (watch monitor screen) takes some seconds to complete

(5) Eventually QSWITCH ENABLE – QSWITCH OFF – LAMPS OFF – POWER OFF

labels will appear on the bottom line of the monitor screen

(6) Check monitor screen to see that the two indicator bars, one just above OscPFN and

the other above AmpPRN, show some white which indicates that the lamps in the YAG are ignited

(7) Laser is now ready and awaits further startup of the controls at the operator's desk

#### On the Optical Table

(1) Turn on the shutter control box – the metal box resting on the wooden support

#### Behind the Operator's Desk

(1) Turn on Power Strip Unit #1 attached to the wall behind the operator's desk

(2) Turn on Power Strip Unit #2 attached to the wall behind the operator's desk

#### On Operator's Desk – in Wooden Cabinet

(1) Turn on PMT power supply (upper compartment of the wooden cabinet)

(a) Depress Power button on the right side of the front panel

(b) Hit '0' (zero) on the numeric key pad of the front panel

(c) Hit the ENTER button

(d) Turn on the 3-position High Voltage toggle located on the far left of the front panel. Make sure it is all the way on so that the light shows red

(2) Turn on DG2 (Delay Generator, located in the second from the top compartment of the wooden cabinet) – Power button on the right of the front panel

(3) Wait to turn on the 10-Hz Line Sync Box (fourth compartment from the top of the wooden cabinet) until the YAG laser program has finished initialization (otherwise the program can stall during initialization of the monochromator)

### Other Units on the Operator's Desk

- (1) Turn on the LeCroy – Power button located to the lower left of the front panel
- (2) Turn on the metal “Delay Box” located just to the left of the Wooden Cabinet and to the right of the LeCroy – an ON/OFF toggle is located to the rear and to the right of the black fuse (roughly in the middle of the box)

### Computer

- (1) After the computer screen lights up, hit ‘esc’ on the keyboard
- (2) Run the program Spex Check – as a precaution to make sure the communication to the monochromator is clear
- (3) Run YAG Facility to start the normal program

### Running the YAG laser

- (1) After the YAG Facility program has successfully initialized, Turn on the 10 Hz Line Synch box (in the fourth from the top shelf of the wooden cabinet on the operator's desk)
- (2) On the YAG Control Box depress the black square button below QSWITCH ENABLE showing on the bottom line of the monitor screen of the Control Box
- (3) The monitor screen of the YAG Control Box should, then, sequentially display the messages ‘Ramping Oscillator’ and ‘Ramping Amplifier’
- (4) After these rampings, on the monitor screen, both of the lamp-indicator bars and the pulse-indicator bar (top indicator bar) should show significant amounts of white.

### Notes on checking operation of the YAG Facility program

- (1) After launching the laser program, make sure that ‘I zero’ changes and is not stuck at a value of ‘1’ (one).

- (2) After clicking RUN, do not click on REPEAT or the program will freeze and require restarting – bug in the software.
- (3) If possible, change to 20 microseconds per division when using the program. The shorter time scales work, but the 20 microsecond and higher time scales are more thoroughly debugged.

**Shutting down the YAG and its Detection System** (draft 3-6-12)

- (1) Quit the YAG Facility program from the File menu
- (2) On the YAG Control Box push and hold the black square button below the screen of the monitor at the position of QSWITCH OFF
- (3) Turn off the 10 Hz line Synch, located in the fourth compartment from the top of the wooden cabinet on the operator's desk.
- (4) On the YAG Control Box, turn off the lamps with the black square button below the monitor screen under LAMPS OFF.

On the Optical Table

- (1) Turn off the shutter box

At the Operator's desk

- (1) Turn off the LeCroy
- (2) Turn off the metal "Delay Box" with the rear ON/OFF toggle
- (3) Turn off the PMT power supply in the top shelf of the wooden cabinet on the operator's desk
  - (a) Hit '0' zero on the numeric key pad (the program must be exited for this to work)
  - (b) Hit ENTER on the key pad
  - (c) Turn off the High Voltage toggle at the far left of the front panel

- (d) Turn off the POWER button at the far right of the front panel.
- (4) Turn off the DG2 (Delay Generator) on the second shelf of the wooden cabinet
- (5) Turn off the Power Strip #2 on the wall behind the operator's desk
- (6) Turn off the Power Strip #1 on the wall behind the operator's desk

Back at the YAG Control Box

- (1) Hit the black square button below POWER OFF on the monitor screen of the YAG Control Box
- (2) Turn off the toggle ON/OFF switch on the rear of the YAG Control Box

At the YAG Power Supply

- (1) Turn off the key

At the Xenon Lamp

- (1) Turn off the pulser power supply
- (2) Turn off the pulser
- (3) Turn off the lamp power supply
- (4) Open the knife switch

On the door to room 015

Please sign the YAG log sheet on the door to room 015 if you have not done so already.

In room 013

Turn off the YAG laser's Cooling water located in room 013

## **Appendix F: Excimer and N2 laser startup and shut down procedures**

### **Starting up the Excimer and its Detection System (draft 3-6-12)**

Please sign the NITROGEN/EXCIMER log sheet on the door to room 013

- (1) Before igniting the Xenon lamp, make sure that all of the electronics in the detection system are turned off.
- (2) Before attempting to ignite the Xenon lamp, make sure the knife switch is OPEN.  
(The knife switch is in the shop-made metal box attached to the lamp housing.)

#### **Xenon Lamp Ignition**

- (1) Turn on lamp power supply (bottom unit)
- (2) Ignite Xenon lamp by depressing and releasing the toggle in the shop-made metal box attached to the lamp housing
- (3) Close knife switch in this metal box
- (4) Turn on lamp pulser supply
- (5) Turn on lamp pulser

#### **Excimer Laser Start Up**

- (1) Make sure that dual laser-triggering box is set to trigger the Excimer, and not the Nitrogen laser. (The small box is located on the top of the Nitrogen laser's chassis.)
- (2) Turn on 'key switch' to Excimer located on the end of the laser's frame
- (3) Turn on 'Mains' switch on the end of the Excimer's frame
- (4) Wait for warm-up period shown on the laser controller's key pad
- (5) Following time-out of the warm-up period – hit the RUN/STOP key on the laser controller's key pad
- (6) Hit the EXE key on the laser controller's key pad

- (7) Open laser's output shutter on Excimer's frame
- (8) To produce the lasing action, switch the OPERATE/STOP toggle to OPERATE on NDRL Crate after the Crate is turned on (see below)

#### Turn on Detection System on Optical Table

- (1) Turn on Monochromator
- (2) Turn on power supply for PMT enclosure (box on optical table to the left of the monochromator)

#### Turn on Detection System located on the Detector Table

- (1) PMT Power Supply
  - (a) Depress POWER button on the right side of the front panel
  - (b) Hit '0' (zero) on the numeric key pad of the front panel
  - (c) Hit the ENTER button
  - (d) Turn on the 3-position High Voltage toggle located on the far left of the front panel. Make sure it is all the way on so that the light shows red
- (2) Turn on the NDRL Crate by switching upward the toggle switch located at the rear, in the middle right
- (3) If you want to use the dose, turn on the BNC Portanim located on top of the NDRL Crate
- (4) Turn on the Printer – the ON/OFF toggle is on the right side of the printer's frame
- (5) Turn on the LeCroy – ON/OFF push button is on the lower left of the front panel

#### Turn On the Computer

- (1) Depress the Master Switch on the Master Switch Box on the lower shelf of the Computer Table

## Notes on checking operation of the two different laser programs

- (1) After launching the laser program (either the standard program or the laser program using the optical trigger) make sure that 'I zero' changes and is not stuck at a value of '1' (one).
- (2) After clicking RUN, do not click on REPEAT or the program will freeze and require restarting – bug in the software.
- (3) If possible, change to 20 microseconds per division when using the program. The shorter time scales work, but the 20 microsecond and higher time scales are more thoroughly debugged.

### Program Options (with or without optical triggering of the LeCroy)

- (1) If using the laser program with optical triggering:
  - (a) Make sure that the quartz plate immediately behind the laser's shutter is properly adjusted so that there is a reflected laser beam striking the active head of the photodiode.
  - (b) Make sure that the optical-triggering cable is triggering the LeCroy
  - (c) Run the Excimer laser at 1 Hz because optical triggering does not work at 10 Hz (use 1 Hz/10 Hz toggle (middle toggle of three) at upper left of front face of the NDRL Crate).
  - (d) Optical triggering also does not work with time scales shorter than 20 microsecond per division
  - (e) TBdelay is about 470
- (2) Using the standard laser program - no optical trigger of the LeCroy
  - (a) Make sure the LeCroy is triggered with the cable coming from the NDRL Crate.

(b) TBdelay is about 1960

**Shutting down the Excimer and its Detection System** (draft 9-23-14)

(1) Stop the lasing action by switching the OPERATE/STOP toggle to STOP on the NDRL Crate

(2) QUIT the laser program from the File menu

At the Excimer Laser

(1) Stop the laser by hitting the RUN/STOP key on the laser controller's key pad

(2) Turn off the Mains switch on the end of the laser frame

(3) Turn off the key switch on the end of the laser frame

(4) Close the shutter at the laser's exit window on the laser frame

On the Optical Table

(1) Turn off the monochromator

(2) Turn off the power to the PMT enclosure

At the Xenon Lamp

(1) Turn off the pulser power supply

(2) Turn off the pulser

(3) Turn off the lamp power supply

(4) Open the knife switch

Turn off Detection System located on the Detector Table

(1) Turn off the PMT Power Supply

(a) Hit '0' zero on the numeric key pad (the program must be exited for this to work)

(b) Hit ENTER on the key pad

(c) Turn off the High Voltage toggle at the far left of the front panel

- (d) Turn off the POWER button at the far right of the front panel.
- (2) Turn off the NDRL Crate by switching downward the toggle switch located at the rear, in the middle right
- (3) If you used the dose, turn off the BNC Portanim located on top of the NDRL Crate
- (4) Turn off the Printer – the ON/OFF toggle is on the right side of the printer's frame
- (5) Turn off the LeCroy – ON/OFF push button is on the lower left of the front panel

#### Computer Shutdown

- (1) Shutdown the computer, but wait for prompt to turn off the AC power
- (2) Turn off AC Power using the Master switch on the master switch box below the computer's keyboard

If degassing was used

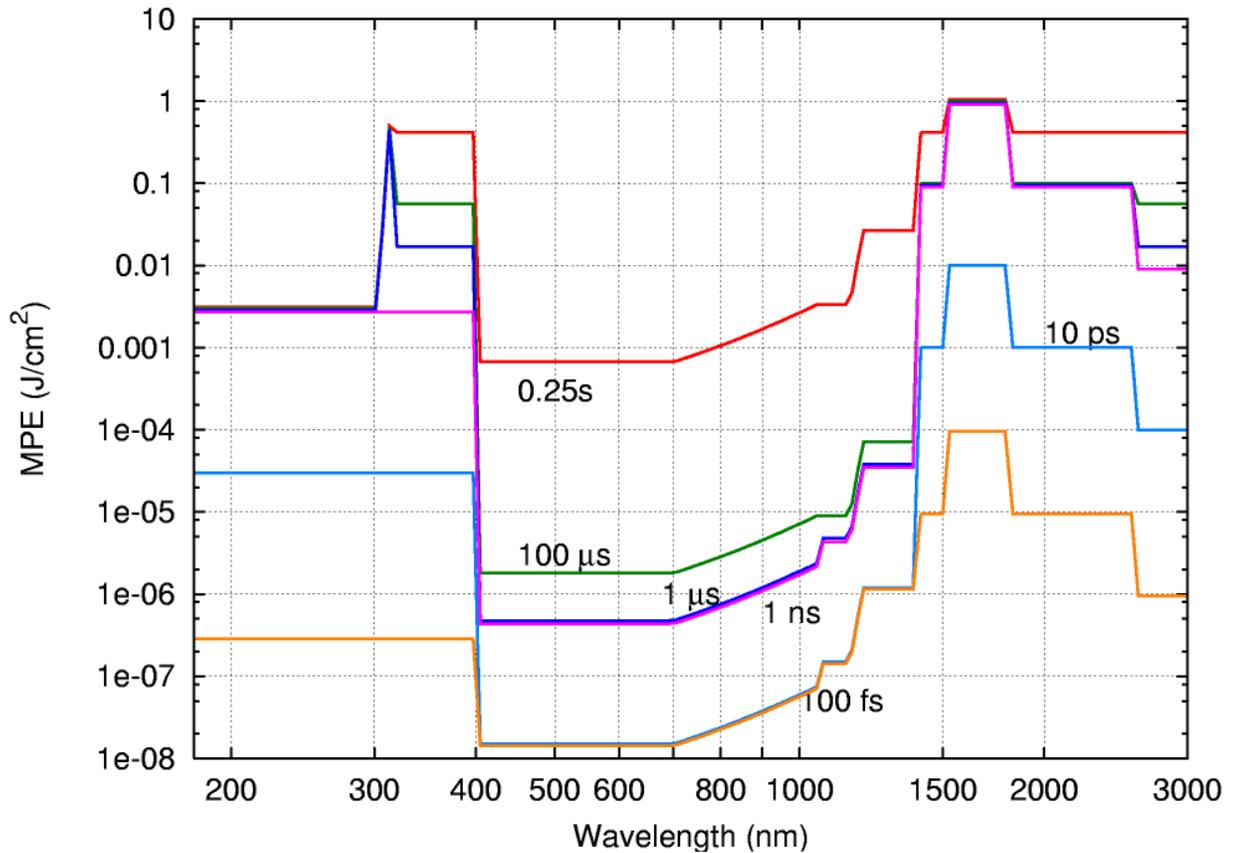
Turn off gas cylinders

On the door to room 013

Please sign the NITROGEN/EXCIMER log sheet on the door to room 013 if you have not done so already.

## Appendix G- OD calculation

The maximum permissible exposure per pulse (the exposure where no eye damage will occur) for different pulse widths and wavelength is presented in figure 1 (found in ANSI Z136.1). The MPE per pulse is lower for shorter pulses due to the large amount of power delivered in a short timeframe. Due to this the required OD is often high compared to a continuous laser.



**Figure 1: Maximum Permissible Exposure for beams of a particular wavelength and pulse width.**

Exposure times for visible laser radiation are limited to the blink reflex (0.25 s) and for non-visible radiation 10 s. Thus, from the laser repetition frequency and the wavelength we can find the number of pulses per exposure for each possible wavelength in the LCA. The max frequency associated with these systems is 10 Hz, so for visible lasers exposure is 2.5 pulses and for non-visible lasers 100 pulses. According to ANSI

Z136.1 the final MPE for pulsed systems operating under 55 kHz will be found by multiplying the MPE for a single pulse (found in the figure rounded down to 1 ns pulses) by  $n^{-1/4}$  (where n is the number of pulses exposed to). The MPE calculated this way for each laser wavelength is listed in table 1.

The needed OD is the log base 10 of the attenuation factor (Energy exposed: MPE). The laser energy the eye is exposed to is simply the maximum energy density per pulse (energy per pulse/area of the beam) multiplied by the number of pulses during exposure. The calculated values are found in table 1.

Wavelength (nm)	MPE (J/cm <sup>2</sup> )	Power Density (mJ/cm <sup>2</sup> )	Number of pulses	Exposure Power (J/cm <sup>2</sup> )	Attenuation Factor	Required OD
YAG 1064	1.18 e-5	500	100	50	1.1 e6	6.6
YAG 532	5.59 e-7	260	2.5	0.65	1.1 e6	6.0
YAG 355	2.98 e-5	1500	2.5	3.75	3.0 e5	5.1
YAG 266	1.18 e-5	520	100	5.2	4.4 e6	6.6
Excimer 308	1.18 e-5	200	100	20	1.7 e6	6.2
N2 337	1.18 e-5	6	100	0.6	5.0 e5	5.7