

# SECTION I: FEMTO lab POLICIES, PROCEDURES AND RESOURCES

## General chemical safety information

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## *FUME HOOD USE*

### **Rules:**

- The following solvents may be used in the fume hood:
  - Acetone
  - Ethyl alcohol
  - Isopropyl alcohol
  - Methanol
  - Methylene Chloride (dichloromethane)
  - Wafer bond remover
- None of these may be heated. Care should be taken around hot plates.
- No other chemicals may be used in the fume hood (except DI water) without permission from the lab manager and consultation with the chemical safety officer.
- Beakers left out without supervision should be labeled with the user, date, and chemical.
- Liquid waste should be disposed of in appropriately labeled waste bottles. Each bottle should have an EH&S hazardous waste label and be capped when not in use. Do not pour solvents down the drain. Request a pickup from EH&S when bottles become full or if they have been in use for more than 9 months.
- Do not block air flow by storing large objects in the fume hood. Do not lift the sash past the red arrow.
- Take appropriate (gloves, lab coat, and eyewear) safety precautions according to the chemical you are working with, as specified below.

## NON-HALOGENATED SOLVENTS

**Examples:** Acetone, isopropyl and ethyl alcohol, and methanol

### **Hazard Properties:**

- Repeated contact can cause the skin's protective fats and oils to dissolve, resulting in reddening, itching and blistering.
- Can be readily absorbed through skin, producing systemic toxic effects.
- In addition to irritation of the respiratory tract and mucous membranes, inhalation can cause dizziness, drowsiness, headache, lack of coordination and nausea.
- Exposure over a prolonged period of time may result in damage to the liver, kidneys, lungs, blood, nervous system, and other organs. Carcinogenic, mutagenic and teratogenic effects are not uncommon
- Unlike most halogenated solvents, most non-halogenated solvents are flammable or combustible (see the subsequent section on Flammable Materials).

### **Practices:**

- Use fume hoods to prevent inhalation of solvent and build-up of flammable levels of vapor. Minimize solvent vaporization by avoiding unnecessary open containers.
- Allow space for thermal expansion in containers; overfilling can cause rupture if they are filled nearly to the top with cold liquid and then stored in a warm area.
- Wear eye protection for all operations in which accidental splashing might occur.
- Substitute a less toxic solvent whenever possible.
- Avoid direct skin contact by using lab coat and solvent-resistant gloves. Appropriate gloves are kept in a marked drawer next to the fume hood. If supplies are running low, contact the lab member in charge of the fume hood.
- Dispose of solvent waste in a sealable container with an EH&S hazardous waste label. The container must be sealed when not in use.
- Store solvent bottles in the "flammable" cabinet below the fume hood. Do not store them in the fume hood, as this blocks air flow.

*Ketones and Aldehydes (Examples: acetone, methyl ethyl ketone, cyclohexanone)*

- These chemicals are generally highly flammable.
- Typical effects are those of respiratory tract irritation, anesthesia, and dermatitis.

*Aromatic Hydrocarbons (Examples: benzene, toluene, xylenes, styrene; none in lab)*

- Chronic exposure to a low concentration of benzene may damage the bone marrow, with resultant changes in blood cells. Benzene is considered carcinogenic, and has a relatively short latency period. Substitutes for benzene should be used.
- Aromatics defat the skin, and prolonged use causes drying, scaling and cracking. Readily absorbed through intact skin and may produce systemic toxic effects.
- The most commonly used aromatic solvents are flammable

*Aliphatic Hydrocarbons (Examples: hexanes, pentanes; none in lab)*

- Typically lighter aliphatics are highly volatile and flammable with low flash points.
- Although not typically very toxic, the aliphatic hydrocarbons do cause many of the common symptoms related to organic solvent overexposure.
- N-hexane is unusual among aliphatic hydrocarbons as it is particularly toxic to the peripheral nervous system.

*Ethers (Examples: ethyl ether, dioxane, glycol ethers; none in lab)*

- Many cause anesthetic effects and may be potent irritants and cause dermatitis.
- Glycol ethers may, in addition to the typical symptoms of organic solvent exposure, cause anemia (low red blood cell count) and have deleterious reproductive effects.
- The lower molecular weight ethers (e.g., diethyl ether) are highly volatile and are particularly hazardous flammable liquids.
- Can form explosive peroxides upon exposure to air

## CHLORINATED SOLVENTS

**Examples:** methylene chloride, chloroform, trichloroethylene, dichloroethylene

### Hazards:

- Most of these compounds have an **anesthetic or narcotic effect**, causing people to feel intoxicated if overexposed. This can be particularly dangerous when working around machinery, as judgment and coordination can be impaired.
- Some of the chlorinated solvents are strong **systemic poisons** which damage the liver, kidneys, nervous system, and other organ systems. These symptoms most often appear gradually, with nausea, loss of appetite, vomiting, headaches, weakness, and mental confusion most common.
- All chlorinated solvents can cause **dermatitis** (chapping, drying, rashes) on repeated contact with the skin, since they remove the protective fats and oils. Gloves appropriate for a particular chlorinated solvent should be determined by consulting a **glove reference chart**. Gloves are kept in a drawer next to the fume hood.
- Many of the compounds are highly **irritating** to the membranes around the eyes, and in the nose, throat, and lungs. Examples of chlorinated solvents which have irritating properties are ethylene dichloride and chloroform.
- In studies on laboratory animals, many chlorinated hydrocarbons have been linked to the development of **cancer** in animals; examples of these compounds are: ethylene dichloride, perchloroethylene, chloroform and methylene chloride. When excessively heated, chlorinated solvents can **decompose**, forming highly toxic fumes such as phosgene, hydrochloric acid, and chlorine.
- With few exceptions, most of the chlorinated hydrocarbons are **non-flammable**.

### Work Practices:

- As with all volatile hazardous materials, chlorinated solvents must always be used in a fume hood or with other local exhaust ventilation such as an approved snorkel. Inhalation of the vapors is not an acceptable work practice.
- Dispose of waste in a sealable container with an EH&S hazardous waste label. The container must be sealed when not in use. Chlorinated solvent waste should be kept in a separate container from non-chlorinated solvents.
- Methylene chloride should be stored in the “corrosives” cabinet below the fume hood (on the left).

## **FLAMMABLE MATERIALS**

Flammable and combustible materials are a common laboratory hazard. To minimize the risk of fire, all laboratory personnel should know the properties of the chemicals they are handling. MSDSs or other sources of information should be consulted for information such as vapor pressure, flash point, and explosive limit in air. In addition to fuel, an ignition source and an oxidizer are required for a fire to start. Users should be aware of any potential ignition sources in the immediate area including electrical equipment such as mechanical stirrers. A blanket of inert gas can be used to remove oxidizer (air) from the system. Some basic precautions for the safe handling of flammable materials include the following:

- Cap bottles and vessels when not in use. Use narrow-necked bottles and flasks for transferring to help reduce the release of flammable vapors.
- Never heat flammable substances with an open flame. Preferred heat sources include steam and water baths, oil baths, and heating mantles.
- Provide ventilation adequate enough to dilute the vapor concentration to below flammable levels rapidly. Working in a fume hood is an excellent way to achieve this.
- Use only refrigeration equipment that is certified for the storage of flammable materials.
- Metal containers and lines should be grounded to disperse static charges.
- Note that most flammable vapors are heavier than air and can travel long distances along bench tops and floors. Be aware of ALL potential ignition sources in the area, including those at a lower level than the work area.
- Know the location and proper use of laboratory fire extinguishers.

Flammable gases can rapidly produce an explosive atmosphere in the lab upon leakage or escape. Acetylene, hydrogen, ammonia, hydrogen sulfide, propane, and carbon monoxide are especially hazardous in this regard. Great care should be used when handling flammable gases. Precautions include working in a fume hood and enclosing larger cylinders in a ventilated gas cabinet. Installation of flash arresters on hydrogen cylinders is recommended. A reaction vessel should be triple flushed and purged with an inert gas prior to introduction of a flammable gas.

## CRYOGENS

Examples: liquid nitrogen, used with the Lakeshore cryostat and the photoluminescence setup

### Hazard Properties

- These materials are extremely cold (-100°C to -270°C) and, upon contact, can instantly freeze other materials. Serious tissue damage may occur upon exposure.
- Evaporating liquid nitrogen will displace the air within a non-ventilated space possibly leading to **suffocation**. Generally, labs have adequate ventilation to prevent this.
- Be aware of **ice that can plug or disable pressure-relief devices**. Ensure adequate pressure relief mechanisms are functional, i.e., never use tight-fitting stoppers or closures without pressure-relief devices.

### Practices

- Do not move an **over-pressurized container**. Evacuate and seal area, call EH&S (x3194) or dial 9-911.
- Avoid trapping cryogenic liquids between closed sections of an apparatus.
- **Dewar flasks** or other glassware devices should be taped on the outside or provided with shatterproof protection to minimize flying glass particles in case of implosion. Dewar flasks should be vented with a bored or notched stopper.
- Cool cryogenic containers slowly to reduce thermal shock and flashing of the material.
- Cryogen handlers should be protected by a **face shield or safety goggles, lab coat or apron and gloves or mitts**.
- When utilizing cold baths with solvents, use in a hood with a catch pan. Be aware of increased fire hazard. Be prepared for **vigorous solvent boiling** upon initial addition of solvent.
- Avoid **condensing oxygen** (blue in color) and/or contact with organic material when using liquid nitrogen. Flush cold traps with nitrogen or keep under vacuum to avoid condensation of oxygen from air within the trap. Condensed oxygen when contacted with organic materials can cause a powerful explosion.

Check the glassware and valves for cracks and other defects before beginning experimental work. Verify that systems assumed to be under vacuum are so, particularly when using liquid nitrogen. You should be on the lookout for the possibility of condensed air within the apparatus.

Skin contact with liquid nitrogen may lead to a frostbite burn. An occasional droplet of nitrogen, such as is encountered when filling a Dewar, often does not freeze the skin because of insulating film gaseous nitrogen, which forms immediately. However skin is readily frozen if the liquid nitrogen is held on a spot by clothing which is saturated with the refrigerant, or by any other means which leads to extended contact.

**Storage:** Storage of liquid nitrogen: use only approved low temperature containers. Make sure liquid nitrogen containers are vented to prevent pressure buildup. You must use extreme care when working with liquid nitrogen. Liquid nitrogen should not be stored in sealed containers, as tremendous pressure could result and an explosion is possible.

**Spill and accident procedures:** Flood the area (skin and eyes) immediately with large quantities of cool water, apply cold compresses. See a doctor immediately if the skin is blistered or if the liquid nitrogen came in contact with your eyes.

## VACUUM SYSTEMS

Vacuum systems have a variety of hazards associated with their operation. There are risks associated with implosion, as well as the release of toxic materials. The systems are typically complicated and require extensive training prior to use.

### General Safety

- Understand the type of vacuum pumps being used and their limitations. Always check with the manufacturer for the appropriate application.
- Prepare for **power outages** whether you are present or not. Some valves close upon loss of power, some open. Understand the effects that a series of valve openings and closings will have upon the system's integrity.
- Always replace the pump **belt guard** to prevent catching fingers or clothing in the mechanism.
- Be aware of the hot surface in **oil diffusion pumps**
- If a glass vacuum line is ever used **above ambient pressure**, it should be shielded from personnel to prevent glass shards from flying if the line were to shatter.
- Glass vessels that are evacuated should be round-bottomed and/or thick-walled and designed for low-pressure work. They should be regularly checked for star cracks and scratches.
- The use of safety glasses is mandatory.

### Traps and Venting

- Use of house vacuum systems must employ appropriate **traps** to prevent chemical, radioactive or biohazardous material from contaminating the building lines. Likewise, use of an aspirator should also employ a suitable trap to avoid contaminating the water stream.
- Mechanical vacuum pumps should be protected by **cold traps** – generally liquid nitrogen based.
- If hazardous materials are used with the vacuum system they should be located in, and **vented** to, a fume hood.
- Pump oil from vacuum system exhaust has been known to accumulate in building ductwork systems increasing the likelihood of fire spread. Pump exhaust should only be done **into the fume hood** proper, or if exhausted directly into building ductwork, an oil trap must be installed.
- Operation of low temperature traps must be thoroughly understood. Both the cooling and warming phases deserve undivided attention. For example, when using liquid nitrogen, the **condensation of air** due to an open valve may cause a serious explosion when the air vaporizes upon warming.



- **Dewar flasks are under high vacuum and are therefore subject to implosion.** They should be wrapped in tape or plastic sheathing.

### **Chemical Hazards**

- Mechanical pump oil can become contaminated with hazardous materials that were being pumped on. Upon maintenance, proper protective equipment must be employed. A ventilated area should be used for changing pump oil, as harmful vapors may be released. Clean or contaminated pump oil must be disposed of as hazardous waste via EH&S.
- Mechanical pump exhaust may require suitable scrubbing for volatile highly toxic materials. This may involve a relatively simple filter or liquid bubbler.

### **Practices**

Turning ON a High Vacuum System:

- Make sure all valves are closed.
- Turn on vacuum pump.
- Place Dewar around trap flask
- Submerge trap flask in liquid nitrogen. **Make sure system is under vacuum before cooling trap to avoid condensation of liquid oxygen.**

Turning OFF a High Vacuum System

- Remove all samples and experiments from vacuum line.
- Remove trap flask from Dewar. Allow to warm to room temperature
- Open vacuum system to atmosphere. **Do not do this while trap is cold to avoid condensation of liquid oxygen.**
- Turn off pump.

## LASERS AND OPTICAL AMPLIFIERS

High power lasers pose a threat to both eyes and skin. These guidelines are not meant to be an exhaustive reference on laser safety (UCSB has a laser safety manual and a laser safety officer for that), but rather a cheat sheet for common laser use in the FEMTO lab.

### General Safety

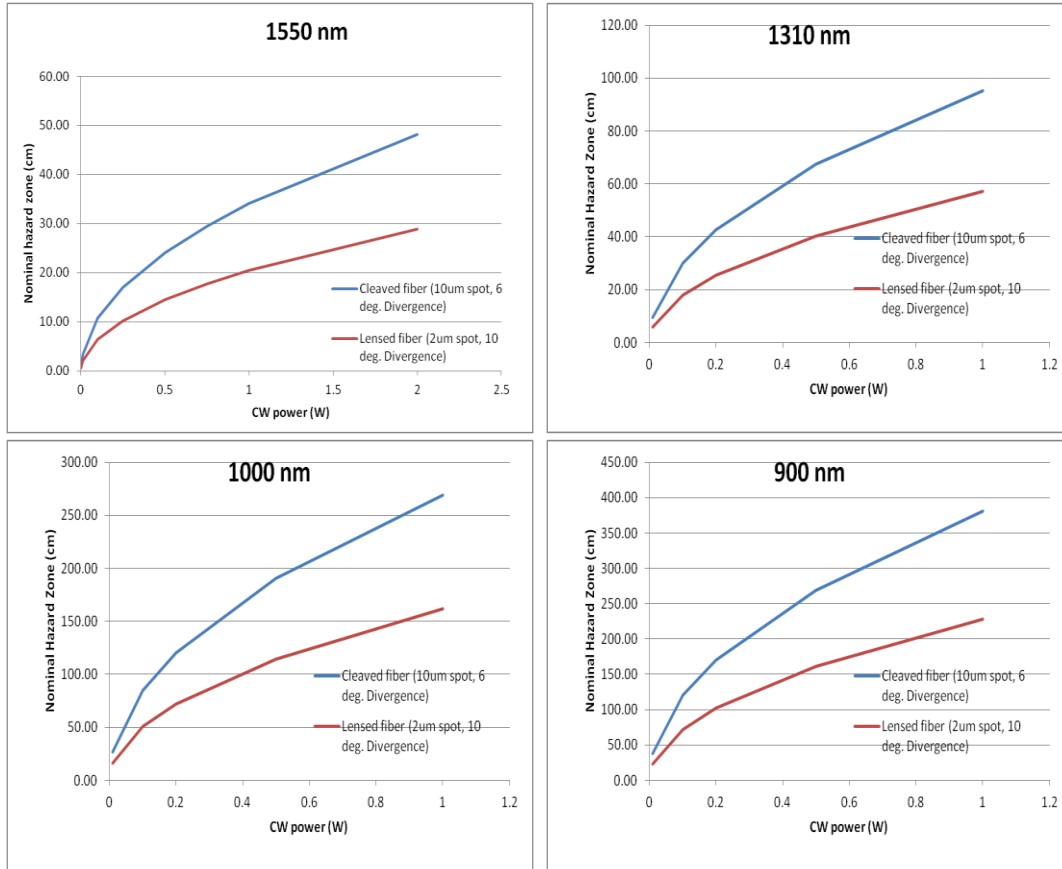
- Know where the beam goes before turning on the laser. Do not look directly into a laser beam or a fiber carrying light.
- Turn systems on from source to output: do not turn on an EDFA before a laser that pumps it.
- Know how much power comes out of the laser
- Align fibers at the lowest optical power possible

### Laser classification

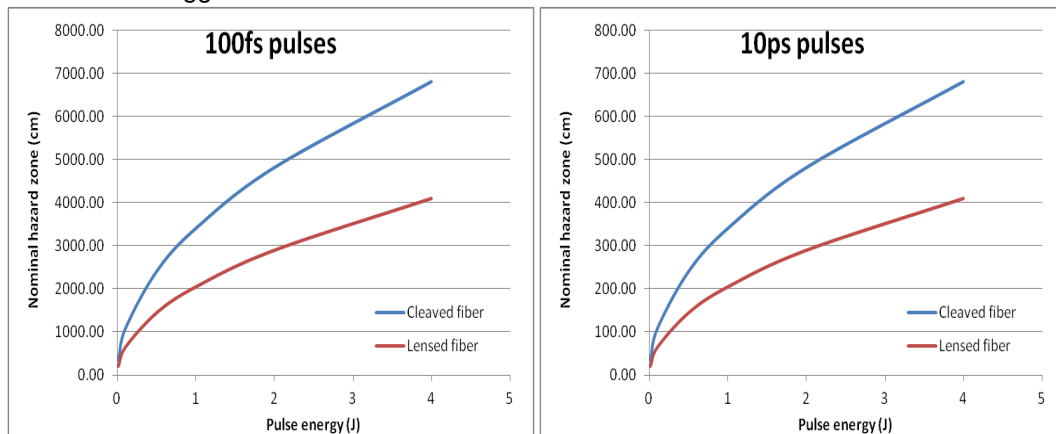
- The laser class is important and determines the safety precautions required. It is generally determined by the manufacturer and will be labeled on the laser or EDFA. As a rule of thumb, for 1550nm lasers the class is:
  - Class 4 if it is  $>500\text{mW CW}$  or  $>10\text{J/cm}^2$  pulsed
  - Class 3B if it is  $5\text{-}500\text{mW CW}$
  - Class 3A if it is  $1\text{-}5\text{mW CW}$
  - Class 1 if the light is carried in a fiber.
  - There are no additional regulations on IR light below  $1\text{mW CW}$ .

### Guidelines for commonly used laser configurations

- Collimated beams:
  - Do not use Class 4 collimated beams in the lab. Use Class 3B only when the beam can be covered. Align below at powers Class 3B.
  - Calculate the Nominal Hazard Zone (NHZ – calculation technique below). If it is greater than a few cm, consult UCSB's laser safety officer to ensure that you are in compliance with all laser safety rules.
- Lensed and cleaved fibers:
  - In general, there is no need to worry if the power is below:
    - $200\text{mW}$  at  $1550\text{nm}$
    - $10\text{mW}$  at  $1310\text{nm}$
    - $1\text{mW}$  at  $1000\text{nm}$
  - For higher powers, find the NHZ (in cm) from the chart and follow the same guidelines as for collimated beams (consult the laser safety officer if  $\text{NHZ} > \text{a few cm}$ ).
    - Only use these charts if the lensed or cleaved fiber is similar to the one for which the calculation was done. Otherwise, use the section below on how to calculate the NHZ.



- Modification for pulsed lasers
  - Calculate (or measure) the average power and calculate the NHZ using the charts above or the equation
  - Calculate the pulse energy and calculate the NHZ using the charts below or the equation
    - They are for 1550nm radiation – the NHZ will be larger for shorter wavelengths
  - Take the bigger number



### How to do Nominal Hazard Zone calculations

- First, find:
  - The beam diameter and divergence angle
  - The beam power (or pulse energy)
- Then look up the Maximum Permissible Exposure (MPE) for the relevant exposure time, wavelength, and pulse width:
  - There are charts in UCSB's laser safety manual, which can be found on the EH&S website. These values get updated as more medically relevant data becomes available, and so are not repeated here.
- Use the equation:

- $$NHZ = \frac{1}{\phi} \left( \frac{4\Phi}{\pi MPE} - a^2 \right)^{1/2}$$

- Where  $\phi$  is the full divergence angle (not the half-angle) in radians,  $\Phi$  is the flux (either  $W/cm^2$  or  $J/cm^2$ , depending on the units of the MPE) and  $a$  is the beam diameter. The NHZ is then in cm.