How to design a room for a single-molecule work

by Steven B. Smith, April 2, 2008
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Water: It is handy to have a sink with running water to wash hands and dispose of harmless buffers. However placing a sink drain in a sub-basement can be a very expensive retro-fit if the floor sits on rock. You might need to go upstairs to wash your hands.

Compressed air: Building-provided compressed air is best to float optical tables or power pressure-driven fluidics (pressurized buffer bottles). Tables usually require 100 psi with a local regulator plus water trap and filter. No air is required for the miniTweezers optical trap.

Electricity: Specify lots of outlets with no heavy electrical equipment (like refrigerators) on the same circuits as the instruments.

Communications: Ethernet is nice but it is also possible to carry your data in/out on memory sticks or DVD media. Computers using old operating systems, like OSX 10.5 for the miniTweezers program, may be forbidden on your local network due to security issues.

Temperature control: After vibration, this is the most crucial and difficult problem,. Avoid rooms where sunlight shines in through windows and heats the room. Good temperature control requires a local thermostat and separate heat-exchanger for each room where a precision instrument is located. A digital controller running a programmable PID algorithm is most versatile. If the wall thermostat is far from the heat exchanger, it may be necessary to place an extra temperature sensor inside the heating duct near the exchanger. A good system should vary no more than +/- 0.5 deg. Celsius regardless of day, night, summer, winter, and changing equipment load (see below). The system must not oscillate. Going up 0.5 degrees and then down 0.5 degrees every hour is worse than going up 5 degrees and down 5 degrees every 24 hours. Check your system frequently or with a recording thermometer. For instance, see part# TEMP101A from Thermoworks. http://www.thermoworks.com/products/logger/logmaster_temp101a.html

Ventilation: Cold air falling down from above onto an instrument is a big disturbance due to temperature variations, refractive index changes and wind-force effects. Do not put your machine under a ceiling diffuser that delivers cool air. However, good air circulation is necessary to stabilize room temperature. It is best to bring in supply air at floor level e.g. under some tables or benches, and suck out the hot air at ceiling level. Snorkel exhausts may help eliminate localized heat but beware of blower noise.

Sound level: The common persistent noise in most labs comes from the ventilation system. I measure audible noise using a Center Technology model 325 mini sound level meter. This meter measures under two different frequency weighting functions, the A-weighting and C-weighting (see http://en.wikipedia.org/wiki/A-weighting) where the C-weighting is more appropriate to show what the instrument "hears". A noisy chemistry lab with lots of ceiling ventilation often registers 65-70 db-C whereas the quietest basement room I found at Berkeley measured 50 db-C. A duct silencer, McMaster Carr part# 2775K4, may be useful to lessen ventilation noise. The best strategy for designing new systems would be to use over-size ducts and under-speed fans.

Dust: Dust settles on optics, causing spurious diffraction and loss of transmission efficiency. Worse yet, dust particle drifting across optics beams will cause false signals that are hard to distinguish from single-molecule events. A box over the instrument protects from dust but may amplify the effects of audible noise at box-resonant frequencies. Foam rubber on the inner box walls reduces this effect. A HEPA filter installed over the room ventilation outlets will reduce dust and also reduce noise by reducing the air flow rate. See McMaster Carr part# 2153K73 for HEPA filter elements.

Vibrations: Building vibrations come from people walking down hallways, outside traffic, wind forces, building ventilator fans, water circulating or sump pumps and any machine with a large motor such as a vacuum pump. Floors in the lowest level subbasement are often on solid rock which is best to avoid vibration. Most vibrating machines are located on the roof of a modern building. One cheap way to check vibrations is to fill a petri dish with mercury and set it on the floor. Any continuous vibrations will establish a pattern of standing-wave rings on the mercury surface which you can see. Note that mercury is toxic, spills easily and is difficult to recover. A more "scientific" method would be to survey sites with a geophone such as part# HS-10 from the Geo Space Co. http://www.geospacelp.com Building vibrations can be largely avoided by suspending the miniTweezers instrument by an extension spring or bunge cord from the lab ceiling. Whereas air tables tend to oscillate at a 2-4 Hertz and thus amplify some vibrations such as walking footsteps, a miniTweezers head (mass= 8 kg.) suspended from a 4-foot rubber extension spring (McMaster Carr part# 8433K44) has a resonant frequency below 1 Hz which de-couples it from such problems. Also consider Home Depot steel extension spring 170733 with spring constant k=250 Nt/m.

Ceilings: The rubber spring mentioned above will double its length when stretched with an 8 kg weight. Therefore it attains a height of 8 feet above the instrument head, which itself is 4 feet above the floor when sitting on a table. Thus you would need a room with 12-foot ceilings to float the instrument. The metal spring however extends less and can be used with an 8-foot ceiling. Note the ceiling attachment should be to the solid floor above, not to a suspended ceiling tile. It is convenient to attach Unistrut channel (McMaster Carr part# 3310T614) to the ceiling in order to then attach a pulley for the extension spring and halyard.

Lighting: In optics labs, it is nice to dim the lights or else to turn on/off banks of lights rather than having all lights switched together. A dim light enables us to see laser beams with IR indicator cards. Note that lighting is a transient heat load which delivers several hundred watts to a room. Therefore expect the temperature to change when you turn on the lights. The time period for that change depends on the ventilation, walls and furniture but typically lasts a few hours.

Equipment: Any equipment that produces enough heat to need a fan should be placed outside the instrument room. Refrigerators and computers produce vibration, heat and electrical interference.

People: Most people produce about 100 watts of heat. Therefore we expect the temperature to rise when people enter a room. Some metrology labs require that visitors turn off a 100-watt incandescent bulb whenever they enter the controlled room, and turn it back on when they leave. Thus the heat load on the air conditioner system remains constant. Also, human speech is easily picked up by sub-nanometer instrumentation with fast data rates. It is better to simply keep visitors outside.

Laser eye safety: The miniTweezers optical trap contains two class 3B lasers, each operating at 808 nm wavelength (infrared) and capable of producing 200 mW of power. Therefore the instrument should be considered as experimental and potentially hazardous. Consult the laser-safety officer at your institution about possible requirements for warning signs, lockable doors and no windows.