Top Ten Questions People Ask about the ALS

#10. How big or How Small?

How big is . . .

. . . the linac?
about 5 meters long

. . . the booster synchrotron?
about 70 meters around and 20 meters across

. . . the storage ring?
about 200 meters around and 60 meters across

. . . an undulator?
typically 4.5 meters long and, with its support structure, about 25 tons

. . . the average beamline?
typically about 30 meters long

How small is . . .

. . . the electron beam?
0.2 mm wide and 0.02 mm high.

. . . a photon beam?
When it hits a target, it's typically 1000 microns (1 mm) across, but it can be focused down to 0.1 micron (one ten thousandth of a millimeter).

#9. How much did it cost to build, and when did it start operating?

The ALS cost $99.5 million to build, and the first ALS light was delivered to an experiment in October 1993.

#8. How do you stop the electron beam in an emergency?

The electron beam in the machine can be stopped very quickly. This is done by turning off the accelerating chambers (rf cavities), which normally replenish the electrons' energy every time they go around the storage ring. Without this energy boost, but still under the influence of the bend magnets, the electrons will begin to spiral inward and collide with other electrons and the inner wall of the vacuum chamber. Each collision causes the electrons to lose energy until ultimately the beam is completely eliminated. The whole process of stopping the beam takes 10 milliseconds!

#7. How strong are the permanent magnets at the ALS?

To get a sense of their strength, imagine pulling a typical refrigerator magnet off your freezer door. For a pretty strong one, this takes a force of about 2.7 newtons (about half a pound, or the weight of a 0.27-kg object). By comparison, if the upper and lower magnetic structures of the wiggler installed on beamline 5.0 were placed 14 mm apart (their minimum gap), it would take a force of almost 170,000 newtons (38,000 pounds) to separate them—over 63,000 times as much force! ALS physicists and engineers don't even like to think about what would happen if we let the magnets touch—this could result in damage to their magnetic properties, so wigglers and undulators are engineered with sturdy structures to hold the magnets apart against extremely large forces.

#6. What are we doing to those electrons?

If you've ever wondered just what we are putting those electrons through in the ALS, here is an account of their energies, speeds, and cumulative distances traveled.

	At end of electron gun	At end of linac	At end of booster cycle	After 4 hours in storage ring
Time (s)	400 billionths	800 billionths	0.33	4 hours
Distance	1 m	5 m	98,000 km	4.32 billion km
Speed (%c)	59.5	99.9948	99.999994	99.999994
Energy (eV)	120,000	50 million	1.5 billion	1.5 billion

#5. How many times do the electrons go around in the storage ring?

They go around it 1.5 million times a second. The beam typically lasts for 4 hours, so the average electron goes around the ring 21.6 billion times.

#4. Why does the ALS spend so much time vacuuming?

When we check for vacuum leaks in the ALS, we look for leaks so small that if a car tire had one, it would take 10,000 years for the tire to go flat. Why? Well...the scattering cross section of a high-energy particle is so high that the ALS electron beam would move forward only a few meters in atmosphere because of the number of collisions with air molecules etc. the beam would experience. Thus, to maximize electron beam lifetime (i.e., keep collisions to a minimum), the ALS vacuum system is designed to maintain a very low pressure inside the vacuum chamber. In fact, the ALS vacuum chamber has fewer atoms per unit volume in it than there are in outer space, i.e., the pressure (approx. 1×10^{-9} torr) is about one trillionth that of the atmosphere. The ALS vacuum is so good that improving it would have almost no effect on beam lifetime; lifetime is chiefly limited by intra-bunch scattering of electrons, not by electrons scattering from gas molecules.

#3. How powerful is the ALS?

The heat flux from an ALS undulator beam is about equal to that inside a rocket nozzle. The following table shows approximate heat flux levels for various processes.

Process	Approximate heat flux (W/mm^2)
Meteor entering atmosphere	100–500
Sun's surface	60
Interior of rocket nozzle	10 ⟵ ALS

#2. Why do you need a tool the size of a football field to learn about things as tiny as atoms?

Scientists use many kinds of light as tools to look at things. With a light microscope, visible light can be used to see things as small as a biological cell, but we can't "see" the atoms that make up the cell wall. This is because the wavelength of visible light is bigger than the atoms (about 2 microns), and we can't look at things that are smaller than the wavelength of the light that we are using; the smaller objects simply can't reflect or scatter the light.

What we think of as light is really just a small portion of a wide spectrum of electromagnetic radiation (EMR). This radiation is produced when a charged particle (like an electron or proton) changes velocity. It can change velocity by changing either its speed or its direction—any change is called acceleration (or deceleration). The higher the energy (speed) of the particle, the smaller the wavelength of radiation produced. To look at things on the molecular and atomic level, we need EMR with shorter and shorter wavelengths, which in turn requires charged particles with higher and higher energies. At the ALS, electrons are accelerated in a ring with a circumference of 200 meters to achieve an energy of 1.9 GeV, so the synchrotron light they produce can have wavelengths as short as 10^{-9} meters.

And the number one question people ask about the ALS . . .

#1. What's the aluminum foil for?

The vacuum vessels of the ALS need to be kept spotlessly clean. Water and hydrocarbon molecules that get in when air enters the vessels can be driven off by heat in a process called "bakeout." The components are wrapped with layers of aluminum foil and electric heating tape. The inner layer of foil distributes heat from the heating tapes evenly over the surface of the vacuum vessel (aluminum is a much better conductor of heat than stainless steel) and prevents oxidation of the steel surfaces due to direct contact with the heating tapes. The outer foil layer insulates the equipment by reflecting infrared radiation (heat) back in toward the vacuum vessel being baked.