LINAC COHERENT LIGHT SOURCE

For more than 40 years, the 2-mile-long linear accelerator at the SLAC National Accelerator Laboratory has produced cutting edge science. Now, SLAC will continue this tradition of discovery by using part of the linac to create an entirely new kind of x-ray source. It will be used much like a super-high-speed strobe flash, enabling scientists to take stop-motion pictures of atoms and molecules in motion, illuminating the fundamental processes of physics, chemistry, and biology.

An aerial view of the 3-km-long linear accelerator at the SLAC National Accelerator Laboratory. LCLS in its initial phase utilizes one third of the linac to drive an x-ray laser.

An X-ray Laser

The Linac Coherent Light Source (LCLS) will produce ultra-short, intense pulses of x-rays, billions of times brighter than any other x-ray source. LCLS will exploit the free-electron laser (FEL) process, in which a pulse of high-energy electrons generates a laser beam of x-rays. The SLAC linac is uniquely capable of producing the intense, high-energy electrons required to drive such an x-ray source, and LCLS will be the first x-ray FEL facility.

Probing the Ultra-small and Capturing the Ultra-fast

Since their discovery in 1895, x-rays have been primarily used for studying structures, such as broken bones and the atomic arrangements in the proteins that drive biological processes. Their short wavelength and penetrating power make x-rays particularly useful for probing the ultra-small world of molecules and nanostructures. Increasingly, scientific attention is turning to the dynamics of these ultra-small materials—how they move and change under the influence of outside forces or their own interactions. Unfortunately, the time scale for change in the ultra-small world is incredibly fast--so fast that standard x-ray studies catch only a blur. LCLS will be the first x-ray source to offer both the intensity necessary to probe complex ultra-small structures and the ultra-fast pulse required to freeze their motions. It will capture images with a "shutter speed" of less than 100

Long History of Imaging Breakthroughs

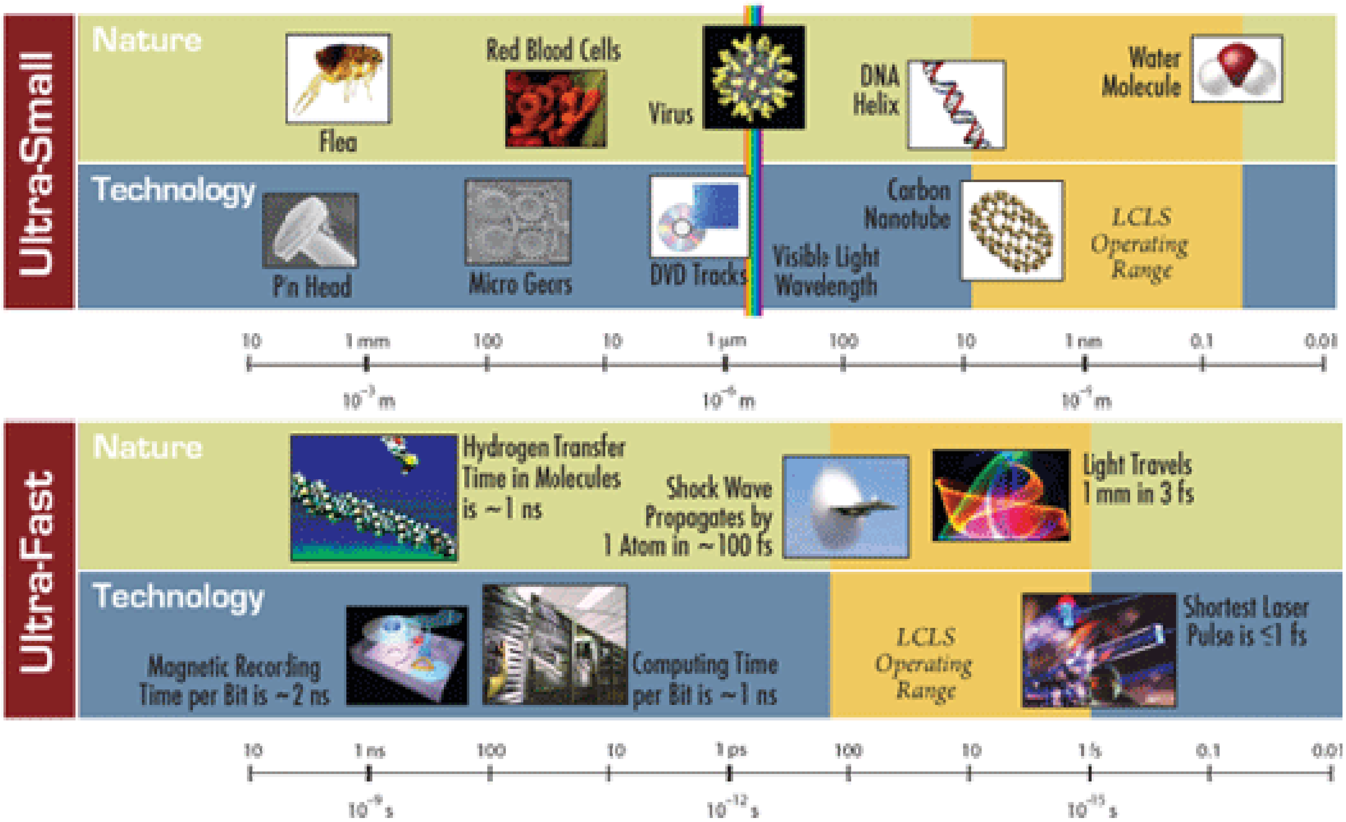
The LCLS will photograph atomic motion much as a "strobe" flash is used to photograph the motion of a bullet in flight. This latest advance in stop-action imaging at Stanford has roots going back more than 100 years. Around 1872, Eadweard Muybridge started making stop-motion photographs of people, animals, and trains in motion on Leland Stanford's farm. He is famous for showing that all four of a horse's feet leave the ground during a gallop. To be able to click a shutter fast enough to show each stride a horse makes when galloping required tremendous engineering ingenuity. The LCLS will provide X-rays of such shortness and precision that stroboscopic experiments can be done with materials on the nanoscale, and even with individual molecules and atoms.

How Fast Is a Femtosecond?

2.4 seconds: The time it takes light to travel the distance to the moon and back—about 480,000 miles.

100 femtoseconds: the time it takes light to travel the width of a human hair.

femtoseconds (less than a tenth of a trillionth of a second). Photosynthesis is an example of an ultra-fast chemical process; x-ray pulses from LCLS could capture the details of the sequence of chemical structures involved in this reaction. A better understanding of photosynthesis—a highly efficient use of the sun's energy—has implications for future energy sources and for agriculture.



LCLS plans to increase the range of biological materials whose structures can be studied, and also to enable the study of ultra-fast dynamics at the atomic scale.

User Experiments Begin in 2009

Groundbreaking for the LCLS took place in October of 2006. Transforming SLAC's venerable linear accelerator into a next-generation x-ray light source has benefited from the efforts of hundreds of scientists from all over the world. The LCLS construction project involves a collaboration including three Department of Energy laboratories (SLAC, Argonne, and Lawrence Livermore national laboratories). LCLS is currently in the final stages of construction and expects to begin producing FEL x-rays in 2009. Experimental instruments for LCLS will be added over several years, with the first user experiments scheduled for late 2009.

The LCLS will accelerate pulses of electrons to nearly the speed of light, and use them to create extremely intense, coherent pulses of x-rays through the free-electron laser process.