LCLS | Linac Coherent Light Source

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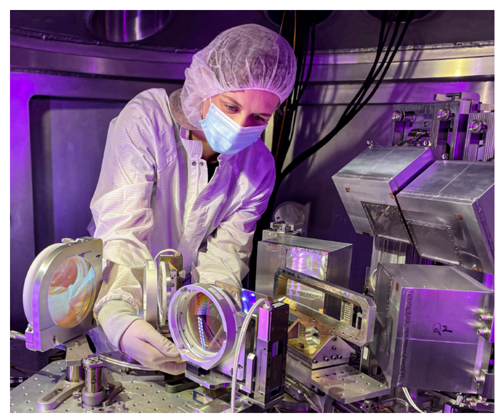
Linac Coherent Light Source (LCLS)

LCLS produces the world's brightest X-ray pulses. Like a high-speed camera with an incredibly bright flash, it takes X-ray snapshots of atoms and molecules at work, revealing fundamental processes in materials, technology and living things. These snapshots can be strung together into movies that show chemical reactions *as they happen*.

Facts

- Over 400 staff run the facility
- Over 3,000 scientists have conducted experiments at LCLS
- Users from 37 US states and internationally
- Approximately 30% first time users each year
- Over 2,000 peer-reviewed publications
- 9 experimental instruments
- Free access for non-proprietary research
- Huge demand, with over 4-to-1 oversubscription rate from users

A Unique Tool for Science



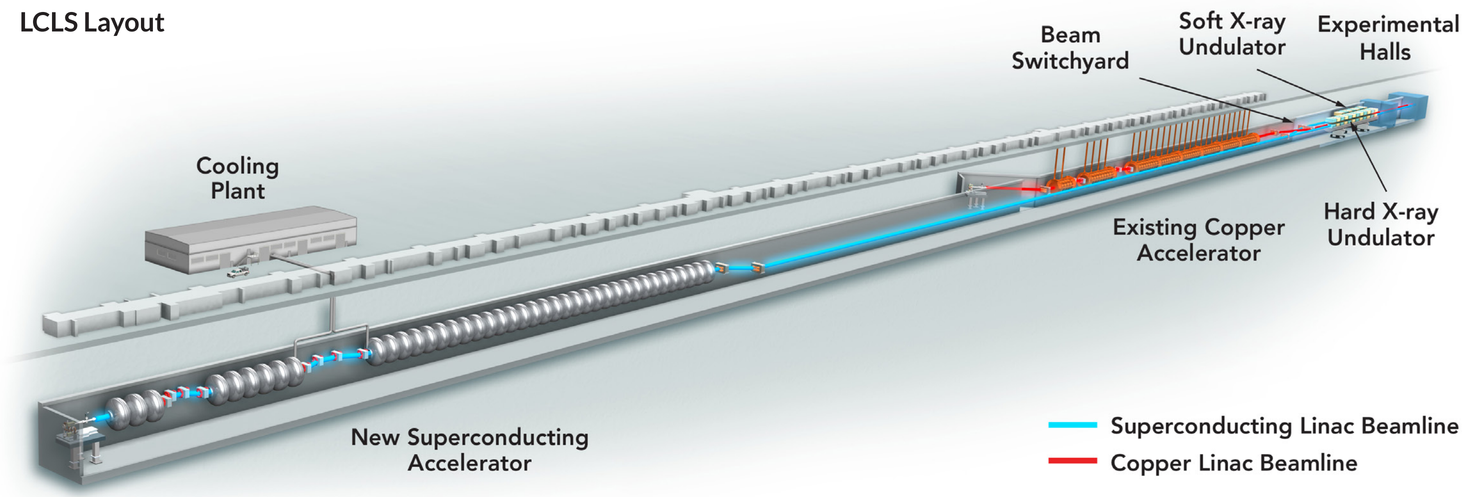
Hundreds of scientists use LCLS each year to catch a glimpse of nature's fundamental processes. When LCLS turned on in 2009, it was the world's first free-electron laser producing "hard," or very high-energy X-rays. Since then, similar light sources have sprung up around the world. A major upgrade to LCLS, completed in 2023, significantly boosts its power beyond anything else in the world, delivering beams that are 10,000 times brighter and pulses that arrive up to a million times per second. This continuous stream of X-ray laser pulses will transform our view of how nature works at the molecular scale and help advance technologies of the future, including novel electronics, life-saving drugs and innovative energy solutions.

Developing Future Electronics

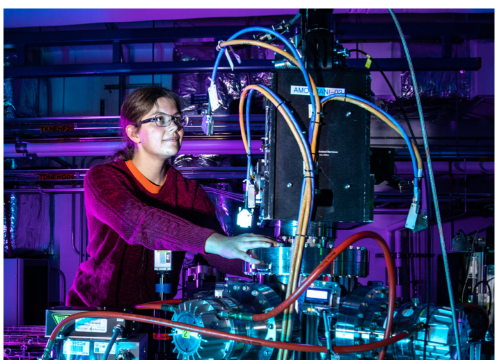
Scientists use LCLS to study interactions in quantum materials on their natural timescales, which is key to understanding their unusual and often counter-intuitive properties – which are used to build energy efficient devices and quantum computers and enable ultrafast data processing and other future technologies.

Above: The LCLS tunnel. (Jim Gensheimer/SLAC National Accelerator Laboratory) Right: A SLAC scientist sets up lasers for an experiment at the Matter in Extreme Conditions instrument at LCLS. (Jacqueline Ramseyer Orrell/SLAC National Accelerator Laboratory)

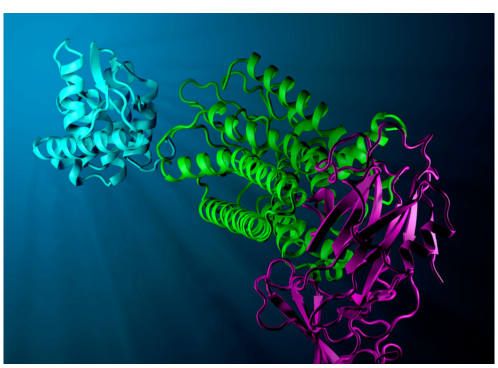
LCLS Layout



LCLS uses the last third of SLAC's 2-mile-long linear accelerator - a hollow copper structure that operates at room temperature. As part of the LCLS upgrade completed in 2023, the first third of the copper accelerator was replaced with a superconducting one. The new superconducting accelerator (gray/blue) is shown alongside the existing copper one (red). At the beam switchyard, electron beams from each linac will be directed to one of two undulators to produce hard or soft X-ray laser pulses. The pulses then travel to experimental halls where scientists conduct research. (Greg Stewart/SLAC National Accelerator Laboratory)



At the Time-resolved Atomic, Molecular and Optical Science (TMO) instrument, scientists produce ultrashort X-ray pulses that last for just several hundred attoseconds (or billionths of a billionth of a second). This allows scientists to investigate how electrons zipping around molecules jumpstart key processes in biology, chemistry, materials science and more. (Jacqueline Ramseyer Orrell/SLAC National Accelerator Laboratory)



Illustrating LCLS experimental results: The first 3D atomic-scale map of arrestin docked with rhodopsin, important signaling proteins in the body. (Greg Stewart/ SLAC National Accelerator Laboratory)

Clean Energy and Sustainability

By capturing snapshots of chemical reactions on attosecond and femtosecond timescales - the scale at which electrons move and energy flows across molecules - LCLS provides unprecedented insights into chemical and biological reactions. This will lead to more efficient and effective processes in industries ranging from renewable energy to the clean production of fertilizer and the mitigation of greenhouse gases.

21st Century Materials

At the intersection of physics, chemistry and engineering, materials science benefits substantially from the new capabilities of LCLS. The enhanced X-ray laser's potential to observe the internal structure and properties of materials at atomic and molecular scales is predicted to lead to breakthroughs in the design of new materials with unique properties and to impact a range of industries from energy storage to sustainable manufacturing and aerospace engineering.

Studying Matter in Extreme Conditions

LCLS allows us to study the behavior of extremely hot, dense matter that is typically only found at the centers of stars and giant planets. These experiments help researchers explore how planets form and sustain life, the impact of meteorite collisions, and how the fusion energy process that powers the sun could be harnessed here on Earth.

Revealing Life's Secrets

Life's processes occur at scales and speeds that have often eluded detailed study. The ability of LCLS to create 'molecular movies' can reveal these phenomena, revolutionizing our understanding of life at its most fundamental level. From the intricate dance of proteins and enzymes to the development of new types of pharmaceuticals and the machinery of photosynthesis, LCLS sheds light on biological systems in unprecedented detail.

The Linac Coherent Light Source at SLAC National Accelerator Laboratory is an Office of Science user facility operated for the Department of Energy by Stanford University.

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