Understanding how the mechanisms for achieving high-temperature superconductivity could lead to much more efficient systems for producing, delivering, and using electricity.
X-Ray Light Sources

Millions of times brighter than medical x-rays, light sources generate high-quality, stable beams of x-rays and other electromagnetic radiation that can be used for numerous experimental techniques. Electrons are deflected as they pass through bending magnets along the circular path of a synchrotron or through other specially designed magnetic devices. This creates a continuous spectrum of radiation with various wavelengths and strengths (e.g., ultraviolet, light and hard or soft x-rays) that scientists can select to suit their particular experiment. These rays are then sent down pipes called beamlines to sophisticated instruments in work areas or end stations where experiments are conducted.

The Advanced Photon Source (APS) is the largest scientific user facility in the United States and one of the world’s most productive electron storage rings. By binding accelerated electrons into a circular path with magnetic fields, the APS produces ultrabright radiation in the hard x-ray range that can be focused onto small samples, allowing researchers to quickly gather large amounts of detailed data. With over 60 beamlines equipped with numerous instruments customized to particular research needs, the APS offers a broad range of experimental capabilities.

The Linac Coherent Light Source (LCLS) is an x-ray free-electron laser that is used much like a super high-speed strobe flash that produces very short pulses of electrons. The LCLS electron beam is linear, and the electrons travel through a 1-kilometer-long accelerator before emitting x-rays as they slam back and forth within the final 100-meter stretch of undulators. The wavelengths of the x-rays become much like a super high-speed strobe flash that produces very short pulses of light: a millionth of a billionth of a second.

Each 2-m-long, 1-ton undulator at LCLS contains many “teeth,” or alternating pairs of north-south magnets that force electrons to follow a wavy path, creating x-rays.

The ZNS chamber contains the central liquid mercury target that is bombarded by protons to produce spallation neutrons.

Electron-Beam Microcharacterization Centers

Researchers at Lawrence Berkeley National Laboratory are home to the Transmission Electron aberration-corrected Microscopy Beamline (EBC), a project of a collaboration among DOE electron-beam experts to develop the first electron microscope to surpass a spatial resolution of 0.05 nanometers, roughly half the diameter of a hydrogen atom. An electron gun atop the EBC instrument applies an intense electrical field and heat to emit electrons from a source material. The electron gun accelerates and focuses the electrons into a tight beam traveling at more than half the speed of light. The accelerated electrons behave like waves with very short wavelengths. Once shot from the electron gun, the beam is condensed and directed toward the sample. The electron waves zoom through the sample and into a series of magnetic lenses that magnify and focus them to form an image on a screen synchronously accelerated. As charge is transferred to magnetic lenses, some electron waves are bent at different angles, blurring the image. The TEM components correct these aberrations, giving this instrument its unprecedented capability of directly imaging subatomic distances with ultrahigh precision.

Neutron Scanning Facilities

Neutrons are produced for scientific experiments in a reactor or using an accelerator-based process called spallation. By bombarding a heavy-element target (e.g., mercury) with accelerated protons, spallation causes some neutrons to be knocked out or “boiled off” as the bombarded nuclei heat up. When the energetic protons collide with the heavy atomic nuclei in the target, about 20 to 30 neutrons are expected to scatter from just a single atom. These attributes make neutrons very useful not only for characterizing matter at subnanometer scales but also for capturing images of individual atoms within a sample.

The National Center for Electron Microscopy (NCEM) at Lawrence Berkeley National Laboratory is home to the Transmission Electron aberration-corrected Microscopy Beamline (EBC), a project of a collaboration among DOE electron-beam experts to develop the first electron microscope to surpass a spatial resolution of 0.05 nanometers, roughly half the diameter of a hydrogen atom. An electron gun atop the EBC instrument applies an intense electrical field and heat to emit electrons from a source material. The electron gun accelerates and focuses the electrons into a tight beam traveling at more than half the speed of light. The accelerated electrons behave like waves with very short wavelengths. Once shot from the electron gun, the beam is condensed and directed toward the sample. The electron waves zoom through the sample and into a series of magnetic lenses that magnify and focus them to form an image on a screen synchronously accelerated. As charge is transferred to magnetic lenses, some electron waves are bent at different angles, blurring the image. The TEM components correct these aberrations, giving this instrument its unprecedented capability of directly imaging subatomic distances with ultrahigh precision.


Electron orbital positions of protons in the surface revealed by a ray spectroscope.