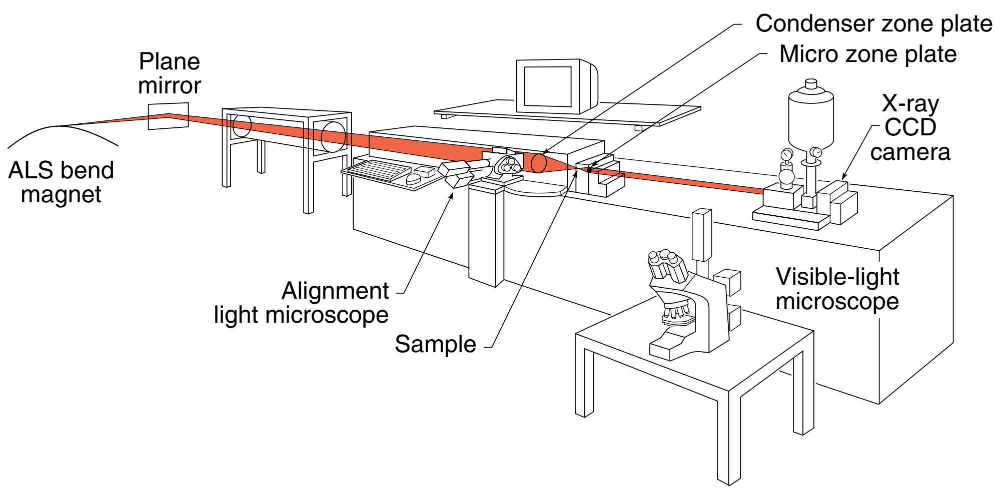
High-Resolution, Transmission X-Ray Microscope (XM-1) • Beamline 6.1.2

Berkeley Lab • University of California

Beamline Specifications

Photon Energy Range (eV)	Exposure Time (s)	Spectral Resolution (E/ΔE)	Spatial Resolution (nm)	Samples	Availability
300 – 800 (optimized) **250 – 950** (extended)	**3** (10^9 photons/image at 517 eV, 0.2% BW)	**500 – 700**	**25**	**Wet or Dry** (up to 10 µm thick; wet chamber in helium atmosphere)	**NOW**



Schematic layout of Beamline 6.1.2.

Beamline 6.1.2 is a PRT-owned bend-magnet beamline dedicated to a high-resolution, transmission x-ray microscope (XM-1) for imaging of biological structures, environmental systems, and materials.

Owned by the Berkeley Lab's Center for X-Ray Optics, XM-1 is a direct-imaging instrument that uses two Fresnel zone-plate lenses. The first is a condenser that focuses x rays onto the sample. The second is an objective (micro zone plate) that images the transmitted x rays onto a detector. In experiments with artificial test patterns, XM-1 has achieved a resolution of 25 nm with a zone plate of about 600 zones and an outer zone width of 25 nm. The goal is to achieve a higher resolution with improved zone plates.

Owing to the wavelength dependence of zone-plate focusing, the condenser zone plate in combination with a pinhole (nominally 10 µm in size) placed just before the sample acts as a monochromator with a resolving power (E/ΔE) of a few hundred (depending on the field of view). To select a wavelength for imaging, the condenser zone plate moves along the optical axis of the microscope. The current zone plates are optimized for experiments at photon energies from 300 to 800 eV but can operate from 250 to 950 eV. The extended photon-energy range covers the so-called water window

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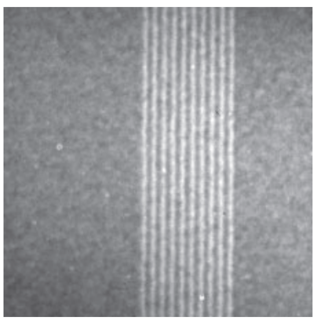
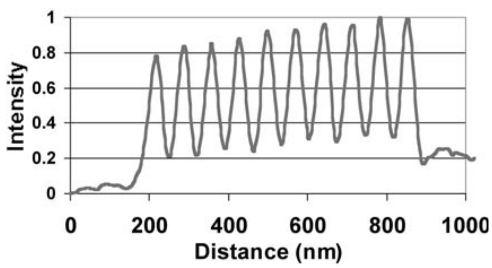
below the K absorption edge for oxygen (543.1 eV) but above that for carbon (284.2 eV), so that water is transparent but cellular structures containing carbon are not.

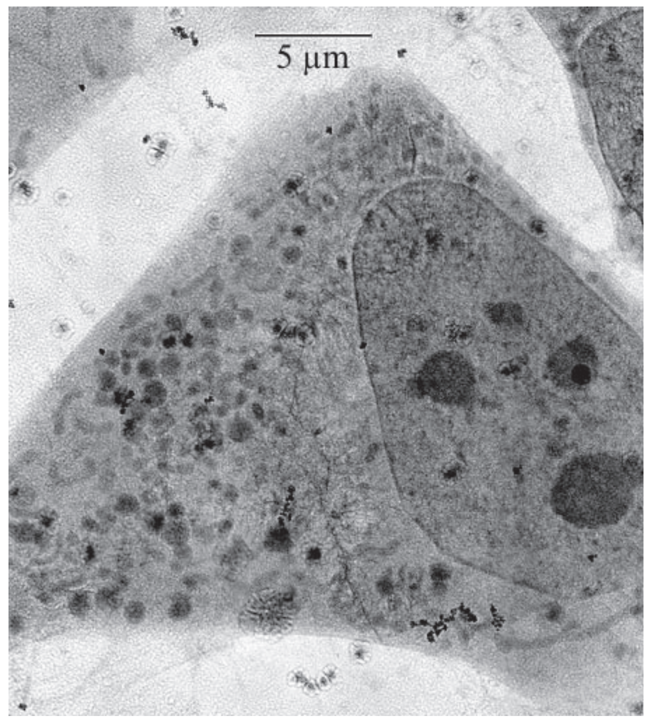
Imaging of biological and environmental samples in aqueous, near-natural environments is standard. The sample sits in a special holder at atmospheric pressure in a gap between the otherwise evacuated chambers for the microscope components. A charge-coupled device (CCD) camera records an image of 1000×1000 pixels with 1000 photons/pixel in 3 s. Readout of the recorded image takes about 2.5 s.

The microscope includes precise control of sample position and fully integrates two state-of-the-art visible-light microscopes. The first (external) microscope, for viewing the sample before mounting, is used to precisely map significant features and digitally store their locations. It permits a variety of contrast modes, including the use of phase-contrast or visible-light fluorescence for the location of significant features. The second (alignment) microscope is mechanically built into the x-ray microscope for viewing the sample after mounting. Visit *www-cxro.lbl.gov/microscopy* for more information. ■





Resolution test. *Test pattern of 15-nm lines with a 1:4 line-to-space ratio.*



Cryogenically fixed 3T3 cell. *The cryogenic system for XM-1 mitigates the effects of radiation damage in biological samples and eliminates the need for chemical fixatives. This allows for high-resolution imaging of delicate cell features. This cell was live and in its natural, hydrated state immediately prior to the freezing process. Many structures are clearly visible, including the cell boundary, nuclear membrane, nucleoli, lysosomes, and endoplasmic reticulum. This montage was constructed by combining many overlapping individual images. Data courtesy of C. Larabell, D. Yager, T. Shen, W. Bates, G. Denbeaux, L. Johnson, A. Lucero, and W. Meyer-Ilse (LBNL).*

This beamline is available to independent investigators with the concurrence of the PRT.

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