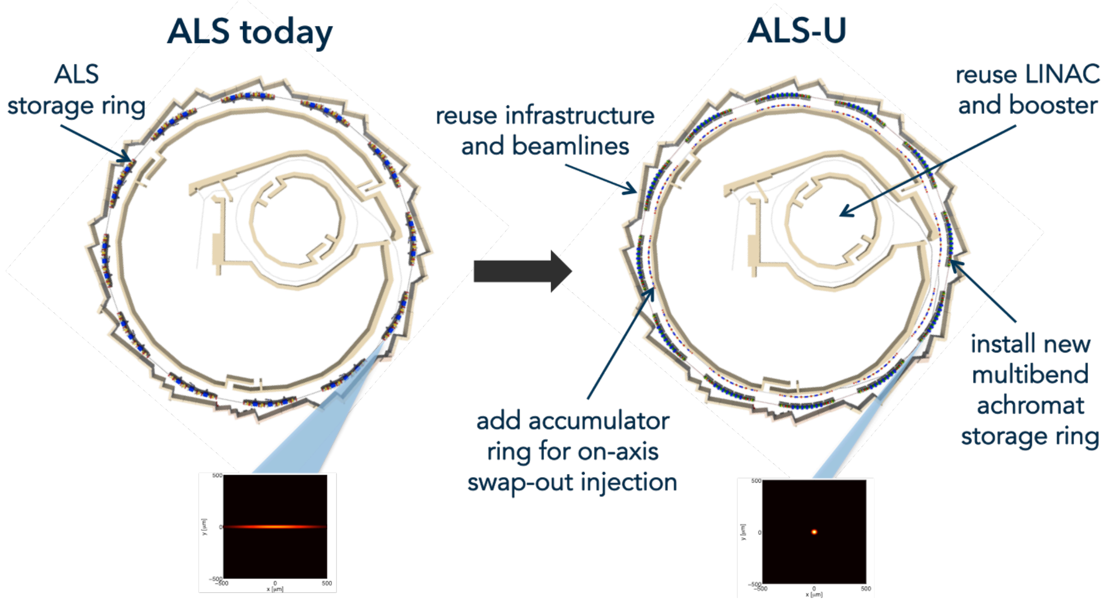
ALS-U FAQs

1) What's the big picture? Why is the ALS being upgraded?

The ALS was commissioned 23 years ago and has been regularly upgraded since that time to achieve the highest possible performance. However, the ALS magnetic lattice design has hit a natural limit and does not efficiently support experiments that require a fully coherent or an intense, nanofocused x-ray beam. To stay competitive with new or upgraded synchrotron x-ray sources around the world requires replacing storage-ring components, installing new undulator sources, and upgrading beamlines—a combination that will dramatically increase performance.

Recall that brightness is the metric that determines whether an experiment can be performed with a given spatial, spectral, and temporal resolution. The transition from 1st generation to 2nd generation and from 2nd generation to 3rd generation synchrotron radiation facilities each resulted in an increase in x-ray brightness of about a factor of 100, and in both cases the capabilities provided to the scientific communities were dramatically improved. Upgrading the ALS, the first 3rd generation x-ray facility commissioned in the United States, will result in a similar increase in brightness. Moreover, the upgrade will enable revolutionary new classes of science that utilize x-ray beams that are nearly transversely coherent, that is, beams with the smooth wave fronts one sees in textbooks.



Details of the ALS upgrade.

2) What are the proposed scope and schedule of the ALS-U project?

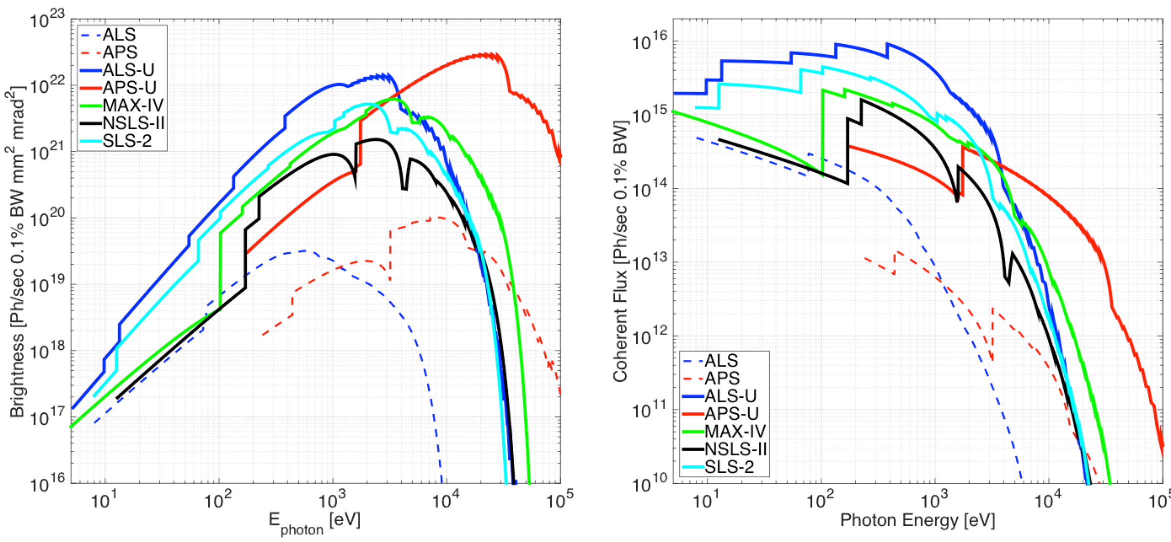
Although the details of the proposed ALS-U project are still being developed, the basic scope includes three components:

i. The bending and focusing magnets in the existing ALS storage ring will be replaced with an advanced multibend achromat (MBA) design retaining the same size and overall shape of the ALS storage ring but providing a much smaller horizontal electron beam size.

ii. To enable the smaller beam electron beam size, the injection system will be upgraded and a so-called accumulator ring will be installed concentric with the current ALS storage ring inside the "tunnel," i.e. the ALS storage ring concrete enclosure.
iii. Several undulators, beamlines, and many x-ray optics will be upgraded.

Conventional facilities will remain largely unchanged, though there will be small targeted upgrades for better temperature and vibrational stability.

The ALS-U project schedule is not yet set. Once project funding has started, ALS-U can be completed in about seven years, including less than one year of down time for installation and commissioning. Motivated by a positive recommendation from the Facility Upgrade Prioritization Subcommittee of the DOE Basic Energy Sciences Advisory Committee concerning ALS-U, we are now engaging the research community very strongly to determine the suite of tools that ALS-U should provide for maximum scientific impact.



Brightness (left) and coherent flux (right) of some current and planned x-ray sources.

3) What's an MBA lattice? How will the properties of the ALS-U source change from ALS?

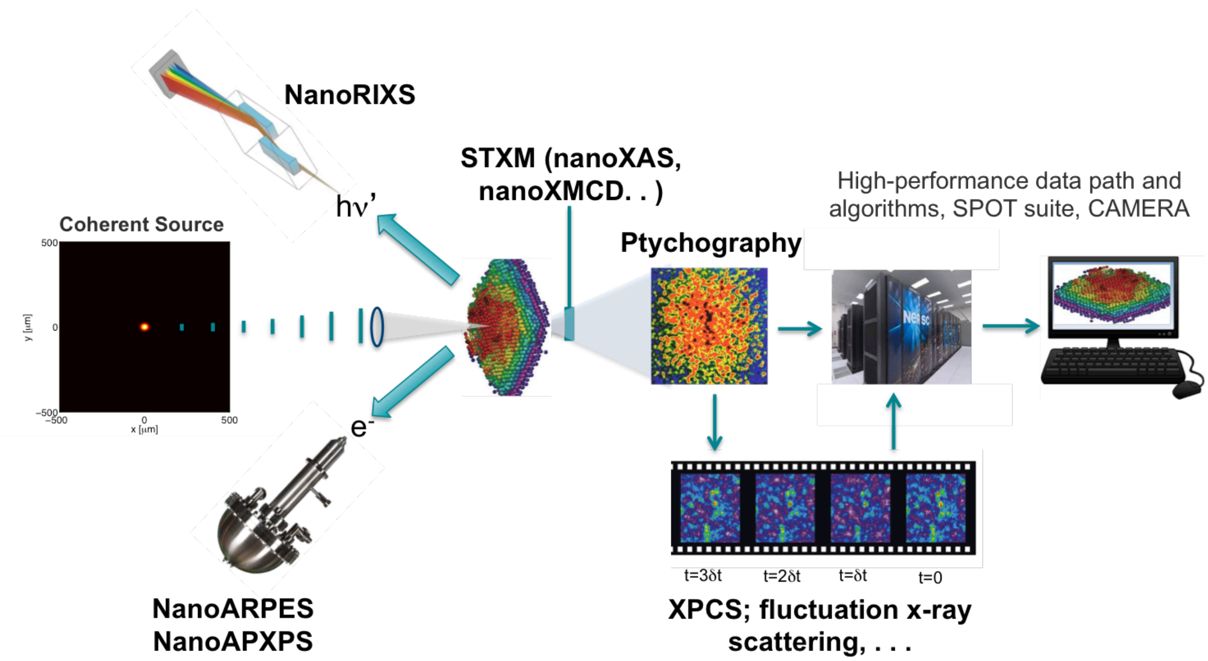
Today, the ALS has a triple-bend achromat lattice with three dipole magnets between the straight sections in each of the 12 ALS sectors. Quadrupole and sextupole magnets in each sector focus the electron beam and correct for chromatic errors. The upgraded MBA lattice at ALS-U will have nine (or possibly just eight) bend magnets in each sector interspersed with stronger focusing magnets. This will decrease the horizontal emittance—the product of horizontal spatial and angular extents of the electron beam—relative to the ALS by a factor of about 40, reduce the beta functions, which determine the ratio of size and divergence, and will also allow smaller undulator gaps as well as new classes of undulators. The combination will allow 100–1000x higher brightness and coherent flux in the soft and tender x-ray energy regime. The cross-section of the stored electron beam will change from an ellipse of high eccentricity at the ALS to an approximately circular beam at ALS-U with a diameter comparable to the current ALS vertical beam height. The source will have small enough horizontal and vertical emittance that undulator radiation will have nearly full transverse or spatial coherence, i.e., smooth wave fronts across the entire beam, up to a photon energy of about 2 keV.

4) This will be a brightness upgrade. Will the flux from undulators also increase?

ALS-U will maintain the same 500-mA ring current of the ALS, so the flux from existing undulators will remain about the same. Undulators with smaller gaps and more periods will be possible with ALS-U, and currently four new undulators are included in the project scope. Optimized undulators will generally increase flux by a factor of a few, particularly for photon energies above 1 keV.

5) What undulator-based ALS techniques will benefit from this upgrade?

The smaller horizontal source size of ALS-U relative to ALS will benefit experiments on nearly all beamlines, but undulator-based techniques that require transverse x-ray coherence will benefit most significantly. These include i) coherent diffractive imaging/ptychography, ii) nanoprobe techniques like STXM, nanoARPES, nanoAPXPS, nanoRIXS, etc., and iii) photon correlation spectroscopy (XPCS). We are also considering new and emerging techniques: i) interferometric concepts for high spectral resolution and detection of weak signals and ii) fluctuation x-ray scattering, a technique being developed at FELs to probe the structure of soft and biological systems in native environments. Of course, we will also be soliciting user input for other techniques that require very high x-ray brightness.



ALS-U tools that benefit markedly from high brightness and coherent flux

6) How will the performance of bend magnet beamlines be impacted?

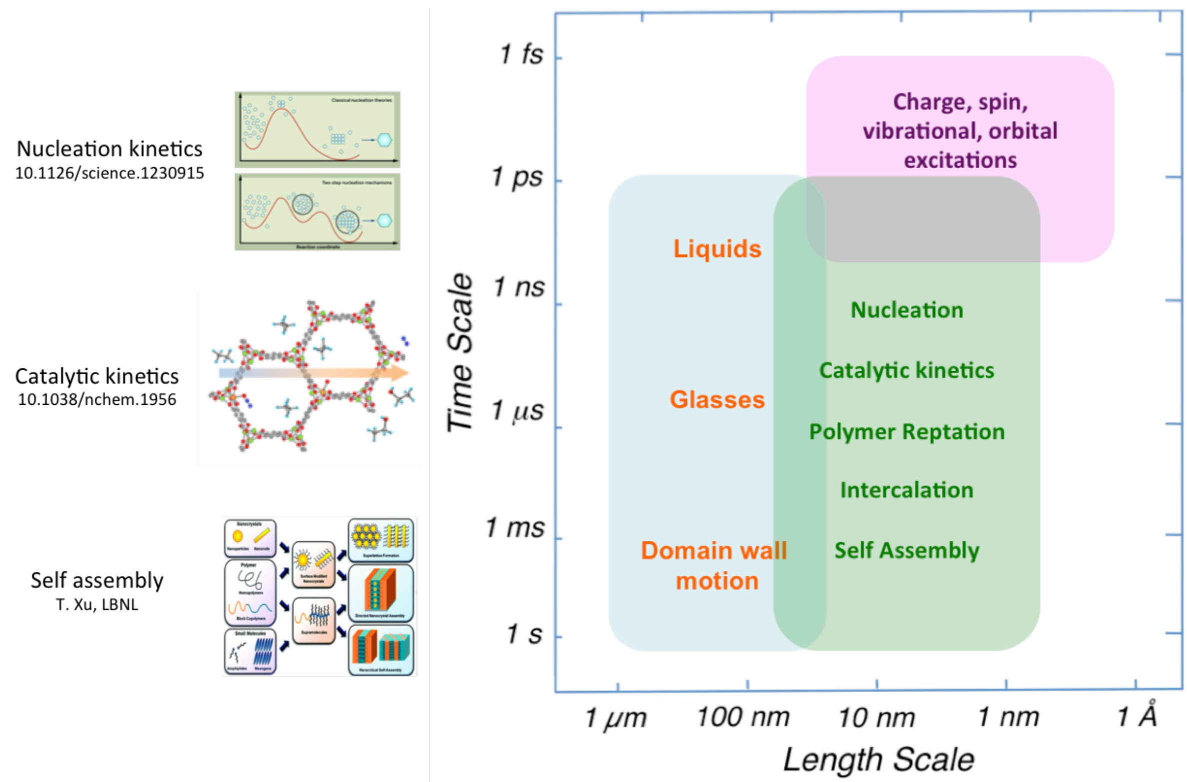
The flux from regular bend magnet sources will remain similar to that of the ALS, though the smaller horizontal source size means the brightness will be ~6x higher. Regular bend magnets at ALS-U will have slightly lower fields, leading to slightly lower critical x-ray energy.

7) What about hard x-ray beamlines? Will superbends be possible on ALS-U?

High harmonics from ALS-U undulators will be extremely good sources for crystallography and small angle scattering, e.g., on the GEMINI beamline presently under construction. The ALS-U superbend design is still evolving, but current plans foresee a critical energy and flux comparable to existing ALS superbend beamlines, with ~6x higher brightness.

8) What will be the time structure of ALS-U? Will dynamics experiments be possible?

Details of possible timing modes of ALS-U are not yet fully determined. To compensate for increased intrabeam scattering due to the smaller emittance of ALS-U in multibunch operation, the electron bunches will be lengthened in time from the present ~70 ps to ~120–200 ps. The repetition rate will remain nominally 500 MHz. An operational mode similar to two-bunch operation at the ALS could be offered at ALS-U; however, because of the much stronger intrabeam scattering, the brightness improvement compared to ALS would be much smaller than in multibunch mode.



ALS-U tools will be an ideal for probing systems at natural length and time scales

Pump–probe dynamics experiments presently done at the ALS will be possible with ALS-U. However, in multibunch mode, ALS-U will have a duty cycle (ratio of bunch length to bunch spacing) of almost 10%. This time structure will be ideal for repetitive probing, e.g., to measure spontaneous material and chemical kinetics ranging from the second to the nanosecond or shorter time regime, using time-resolved x-ray microscopy or correlation spectroscopy. Advanced RIXS concepts will also be easier with a small source size, and these provide dynamical information complementary to XPCS.

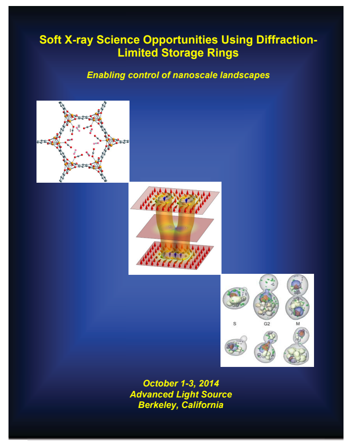
9) What new and upgraded beamlines and endstations are planned for ALS-U?

We will be actively seeking user input to develop a balanced plan for new and upgraded tools needed to provide an optimal suite of ALS-U capabilities. Several existing undulator beamlines will receive upgraded optics to take full advantage of the brighter source. A few new beamlines will be part of the ALS-U project and these will be planned in close collaboration with the ALS user community. ALS beamlines will generally be able to use/operate with the new sources with minor modification, new optics, and/or realignment.

10) Will ALS undulators need to be changed to function at ALS-U?

Existing ALS undulators will continue to work at ALS-U, but they are not optimized to take full advantage of the reduced electron beam size. The cross-section of new ALS-U undulator vacuum chambers will be smaller and in some cases round, with an inner diameter as small as 4 mm! This will allow narrower undulator gaps and thus undulators with more and shorter periods. Also, undulator magnets will be able to surround the vacuum chamber, enabling new undulator concepts that are being actively considered.

11) How can I find out more about ALS-U science opportunities?



A report from the workshop *Science Opportunities with Diffraction-Limited Soft X-Ray Beams* held at the ALS in October 2014 is available at http://www-als.lbl.gov/images/stories/News_and_Publications/General_Publications/sxr_workshop_report.pdf. Informational pages are also available on our website (als.lbl.gov). We will also be posting slides describing initial thoughts about early science opportunities at ALS-U, with complementary information about the tools needed to realize these opportunities.

12) How can I get involved in planning the ALS-U scientific program?

ALS-U science opportunities will be actively discussed at the ALS User Meeting on October 3–5, 2016, both in the plenary sessions and in some of the workshops. At the User Meeting, we will be asking users to think about and provide information concerning ALS-U science opportunities. Finally, we will host an ALS-U workshop in January 2017 to start identifying what new and upgraded beamlines and endstations should be part of the ALS-U project.

Have more questions? Contact Steve Kevan, ALS Deputy for Science, at SDKevan@lbl.gov.