Advancing Towards the Next Generation of NSLS-II

Why Upgrade NSLS-II?

The National Synchrotron Light Source II (NSLS-II) is one of the world's premier synchrotron facilities, enabling cutting-edge science across disciplines using X-ray imaging, spectroscopy, diffraction, and scattering.

- **Today:** 29 operating world-class beamlines (with 15 more planned over the next decade).
- **Challenge:** Future scientific problems such as next-generation batteries, quantum materials, biological assemblies, and advanced catalysts—are heterogeneous, complex, and dynamic.
- **Need:** Characterization methods that span multiple length, time, and energy scales with ultrafast, nanoscale, and operando capabilities. Sciences examples include:
  - Microelectronics and Quantum information sciences: NSLS-IIU will map 2 nm transistors and quantum materials at atomic resolution.
  - Synthesis & Manufacturing: NSLS-IIU will reveal nanometer-scale growth in real time, transforming manufacturing.
  - Batteries: NSLS-IIU will unlock real-time, single-grain insights into Li-ion battery dynamics.
  - Biomolecules: NSLS-IIU will capture biomolecular dynamics in real time, revolutionizing structural biology.

A Whole-Facility Upgrade

The vision for the NSLS-II Upgrade (NSLS-IIU) is a **"source-to-sample" transformation,** optimizing every component of an experiment:

- The Source – accelerator upgrade delivering 100× brightness.
- Beamline Optics – higher resolution and sensitivity.
- Sample Environments – operando and in situ capabilities.
- Detectors – faster, more sensitive, optimized for dynamics.
- Data Infrastructure – advanced computing, storage, and AI/ML pipelines.
- Sample Processing & Preparation – enhanced ancillary labs for sample development. .

Engaging the Scientific Community

- Developed in close collaboration with the NSLS-II user community.
- Guided by strategic workshops, Users' Meetings, and science case discussions.
- Regarded by BESAC as *"absolutely central"* for addressing future challenges and maintaining U.S. global competitiveness.

Looking Ahead

The **NSLS-II Upgrade** represents the next leap forward:

- The brightest X-ray beams in the world.
- The most advanced instrumentation and detectors.
- The most powerful data infrastructure for multimodal science.

Together, these advances will empower discoveries that shape our scientific and technological future.

NSLS-IIU Source Parameters and Brightness

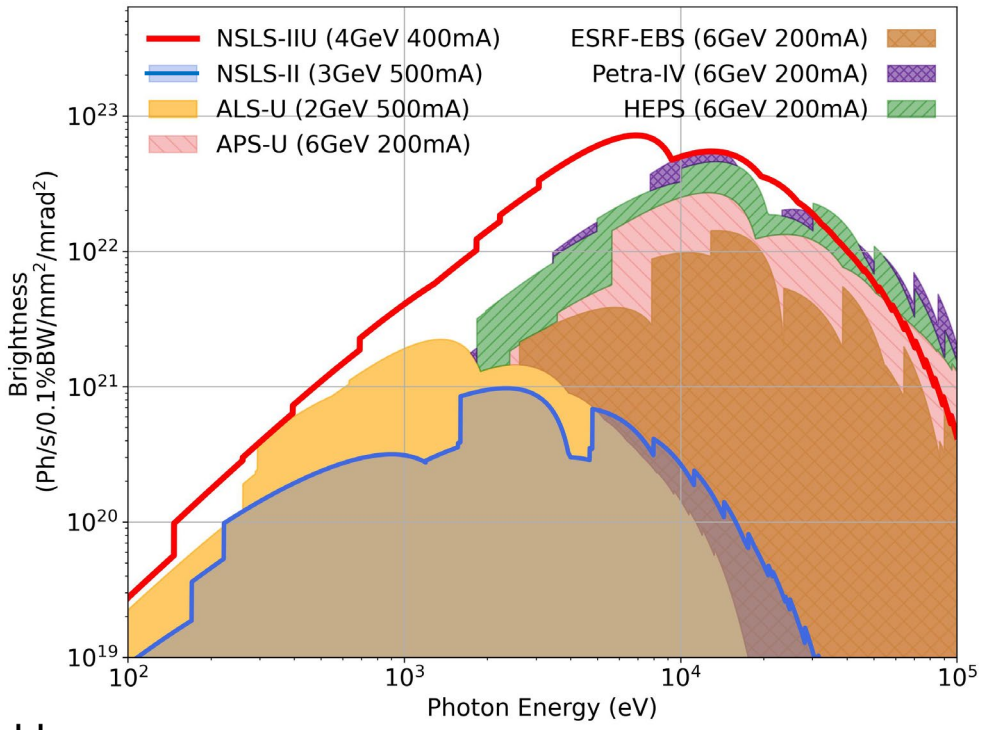
The NSLS-II Upgrade (NSLS-IIU) explores advanced lattice designs and optimized beam parameters. One key approach is the adoption of a complex multi-bend achromat lattice, which offers the advantage of preserving 8.4-meter straight sections for long insertion devices, while also maximizing the free space ratio relative to the ring circumference for accommodating other components.

Compared to NSLS-II, the emittance of NSLS-IIU is significantly reduced—from 1000 pm to approximately 35 pm. The optimized beam energy increases from 3 GeV to 4 GeV, while the beam current is adjusted from 500 mA to 400 mA. As a result, brightness gains across various photon energies range from a factor of 10 to over 100.

Key photon source parameters

Parameter	NSLS-II	NSLS-IIU
Energy (GeV)	3	4
Current (mA)	500	400
Emittance X (pm-rad)	1000	35
Emittance Y (pm-rad)	8 - 30	9

Brightness comparison of current and future synchrotron facilities



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