Next Generation Light Source

an X-ray Laser Array at the Berkeley Lab

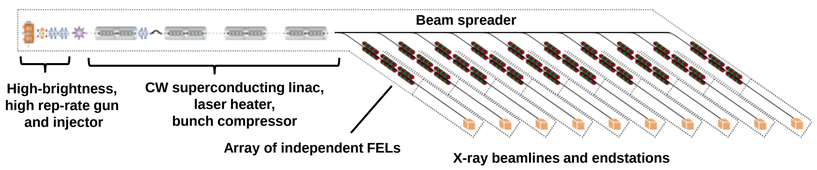
BERKELEY LAB
Lawrence Berkeley National Laboratory

NGLS

NGLS Capabilities

LBNL is developing design concepts for a multi-beamline soft x-ray FEL array powered by a superconducting linear accelerator, operating with a high bunch repetition rate ~1 MHz. Electron bunches are distributed from the linac to the array of independent FEL beamlines with nominal bunch rates up to 100 kHz in each FEL, and with even pulse spacing. Individual FELs may be configured for different modes of operation, including self-seeded and external-laser-seeded, and each may produce high peak and average brightness x-rays with a flexible pulse format, and with pulse durations ranging from sub-femtoseconds to hundreds of femtoseconds.

- ~2.2 GeV CW SC LINAC
- 3 initial FELs (seeded, 2 color, SASE) 280 eV – 1.2 keV, expandable to 10 independent FELs

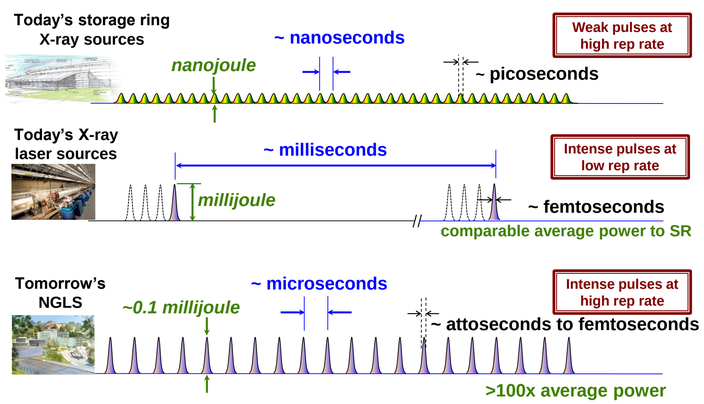


High repetition rate soft X-ray laser array
- Up to 10^6 pulses per second
- Average coherent power up to ~100 W

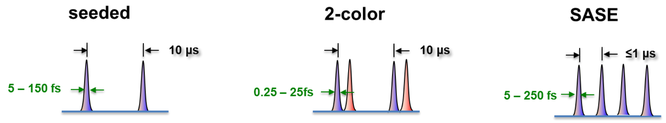
Spatially and temporally coherent X-rays (seeded)
- Ultrashort pulses from 250 as – 250 fs
- Narrow energy bandwidth to 50 meV

Tunable X-rays
- Adjustable photon energy from 280 eV – 1.2 keV - higher energies in the 3rd and 5th harmonics
- Polarization control
- Moderate to high flux with 10^8 – 10^{12} ph/pulse

Expandable
- Capability, Capacity



Three initial FEL beamlines - span the science case

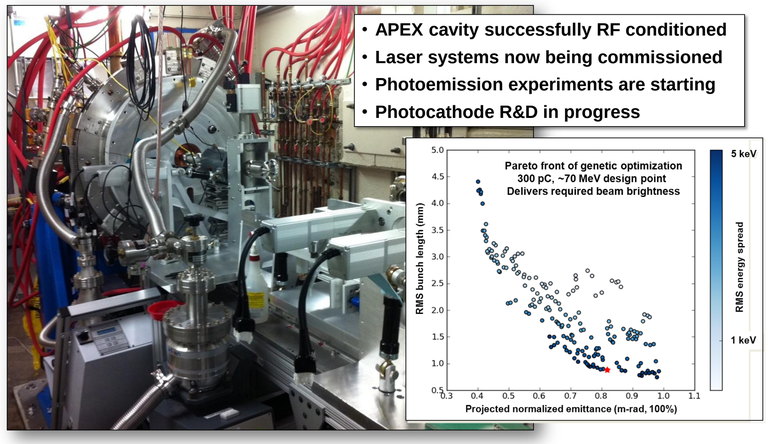


seeded	2-color	SASE
• High resolution (~Fourier limit) • 10^{-3} – 5×10^{-5} bandwidth • 10^{11} – 10^{12} ph/pulse	• Ultrafast 250 atto • 2 color • 10^8 ph/pulse	• Highest rep rate • 10^{11} - 10^{12} ph/pulse • 100 W
• *High-resolution spectroscopy* • *Diffractive imaging (with harmonics)*	• *Multidimensional X-ray spectroscopy*	• *Diffractive imaging (at highest rate)* • *Photon correlation spectroscopy*

Feasibility Studies for Siting in Berkeley

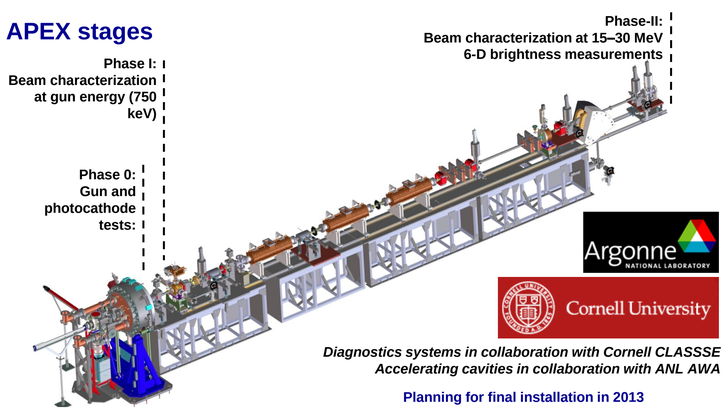
Light Source R&D

APEX Gun: High-brightness MHz Electron Source



- APEX cavity successfully RF conditioned
- Laser systems now being commissioned
- Photoemission experiments are starting
- Photocathode R&D in progress

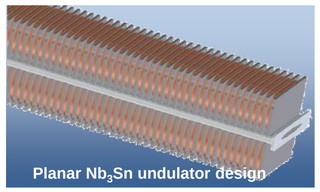
APEX stages

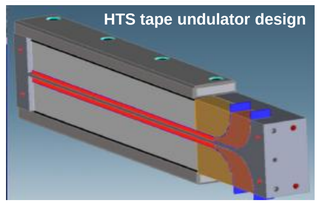


Diagnostics systems in collaboration with Cornell CLASSSE
Accelerating cavities in collaboration with ANL AWA

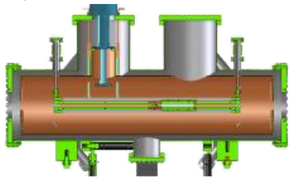
Planning for final installation in 2013

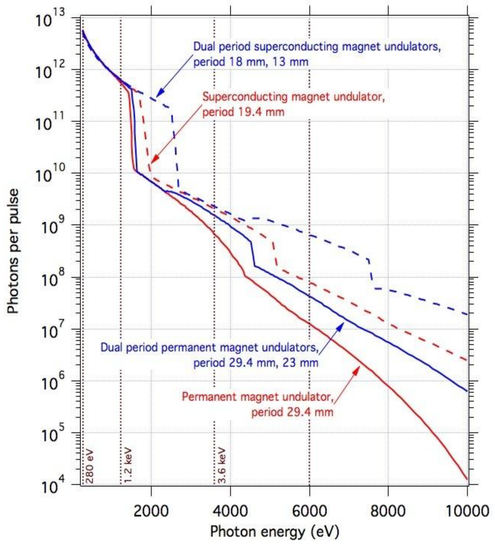
Superconducting Undulator R&D





Cryostat for test and measurement





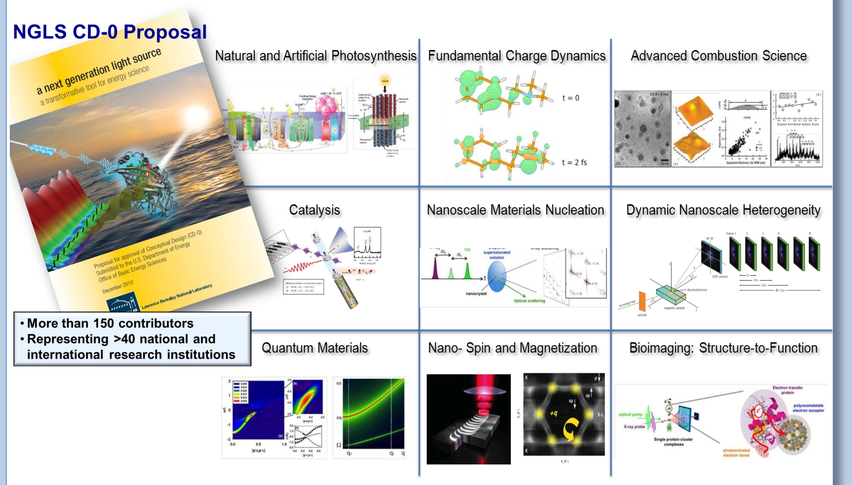
- **Linac design and beam dynamics modeling "start to end"**
- **HHG Laser Seeding R&D, combined with HGHG**
- **Soft X-ray Self-Seeding R&D in collaboration with SLAC/LCLS**
- **SCRF Linac collaboration with Fermilab**

SLAC
Fermilab

NGLS Science Drivers

Broad Range of Energy Science Uniquely Enabled by NGLS

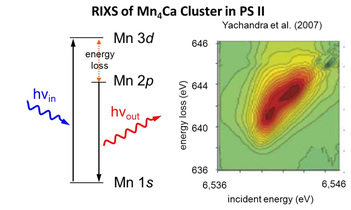
NGLS CD-0 Proposal

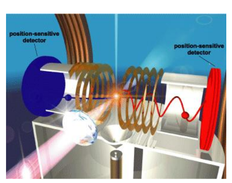


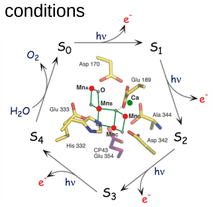
- More than 150 contributors
- Representing >40 national and international research institutions

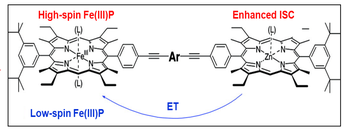
Example: Charge Dynamics in Molecular Complexes

- Capture charge transfer processes, transient oxidation states, molecular bonding, and molecular structure
- Two-color time-resolved X-ray absorption, X-ray emission spectroscopy (XAS, XES),
- Molecular reaction microscope (COLTRIMS) capture core PES and ion fragments in coincidence ⇒ time-resolved, ⇒ complex molecules
- Time-resolved resonant inelastic X-ray scattering (RIXS) - under physiological conditions









Example: Time to do Experiments - Photosynthesis

Sample Replacement: 10^5 Hz

Flux reqd.	10^{17}	photons
Flux limit(1)	10^8	ph/pulse
Rate limit(2)	10^5	Hz

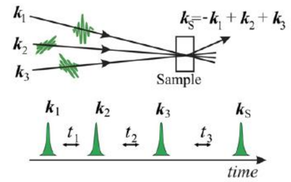
	Max. ph/pulse	Rep. rate [Hz]	Time to do experiment Ph Req. / Ph/Pulse / Rep. Rate		Time resolution
NSLS-II(3)	10^5	5×10^8	$10^{17}/10^5/10^5$	**100 days**	100 ps
LCLS(4)	10^{10}	10^2	$10^{17}/10^8/10^2$	**100 days**	~fs
NGLS(4)	10^9	10^6	$10^{17}/10^8/10^5$	**3 hours**	~fs

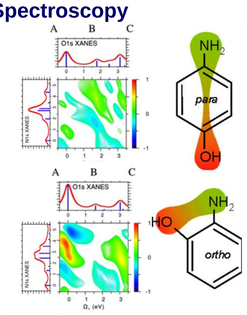
(1) damage threshold
(2) sample replacement rate
(3) 100 meV BW - with 10x mono losses
(4) Few fs pulse duration, low-charge mode

Storage rings: limited to study of cryo-trapped states, ***or*** liquid samples replaced at ~100 kHz (single bunch)

From Spontaneous Raman to X-ray Multidimensional Spectroscopy

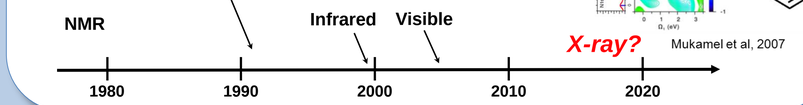
multidimensional spectroscopy has revolutionized fields of science





1991 Nobel Prize multidimensional NMR

multidimensional electronic spectroscopy



Mukamel et al, 2007