CHESS & LEPP

Impact of a Future Energy Recovery LINAC X-ray Source on Nanoscale Science

Joel D. Brock*
School of Applied and Engineering Physics
Cornell University, Ithaca, New York
jdb20@cornell.edu

* on behalf of the ERL team of I.V. Bazarov, S.Belomestnykh, D. Bilderback, J.D. Brock, E. Fontes, K.D. Finkelstein, S.M. Gruner, G. Hoffstaetter, A.Kazimirov, M. Liepe, Y.Lin, H.S. Padamsee, D.Sagan, V.Shemelin, Q. Shen, K.Smolenski, C. Sinclair, R. Talman, M. Tigner, V.Veshcherevich, Cornell University; and L. Merminga & G. Krafft of J. Lab

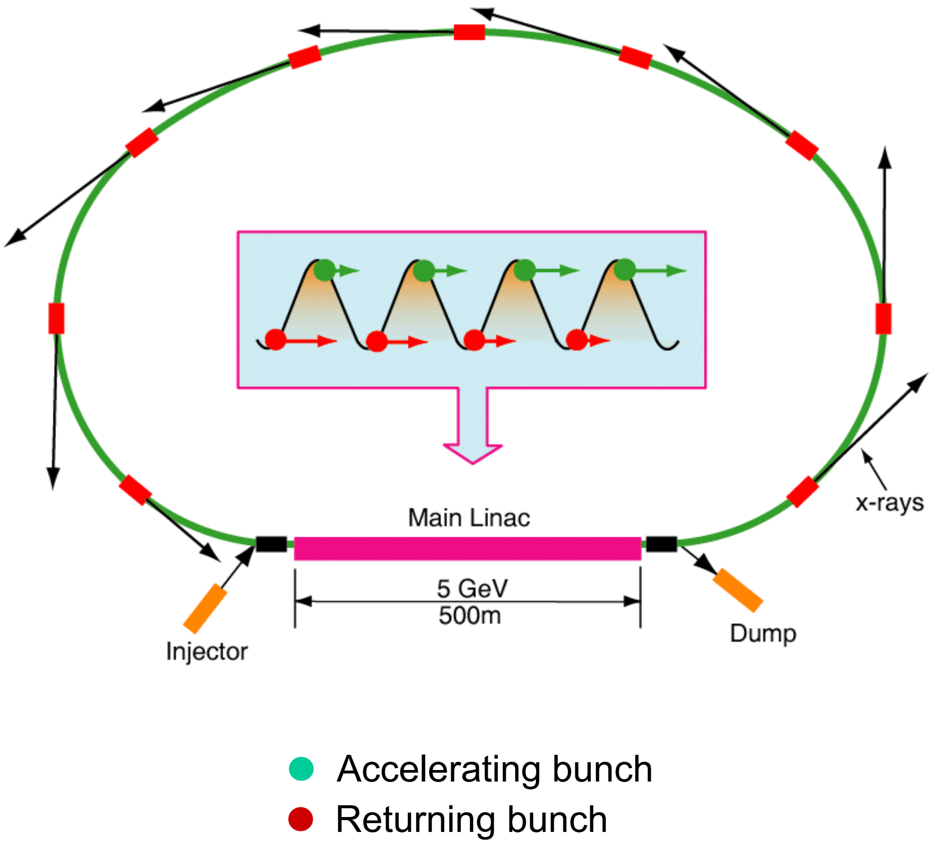
Energy Recovery LINAC

CHESS & LEPP

Injector: high-brilliance electron bunches generated by a laser-driven photocathode are accelerated to ~10MeV

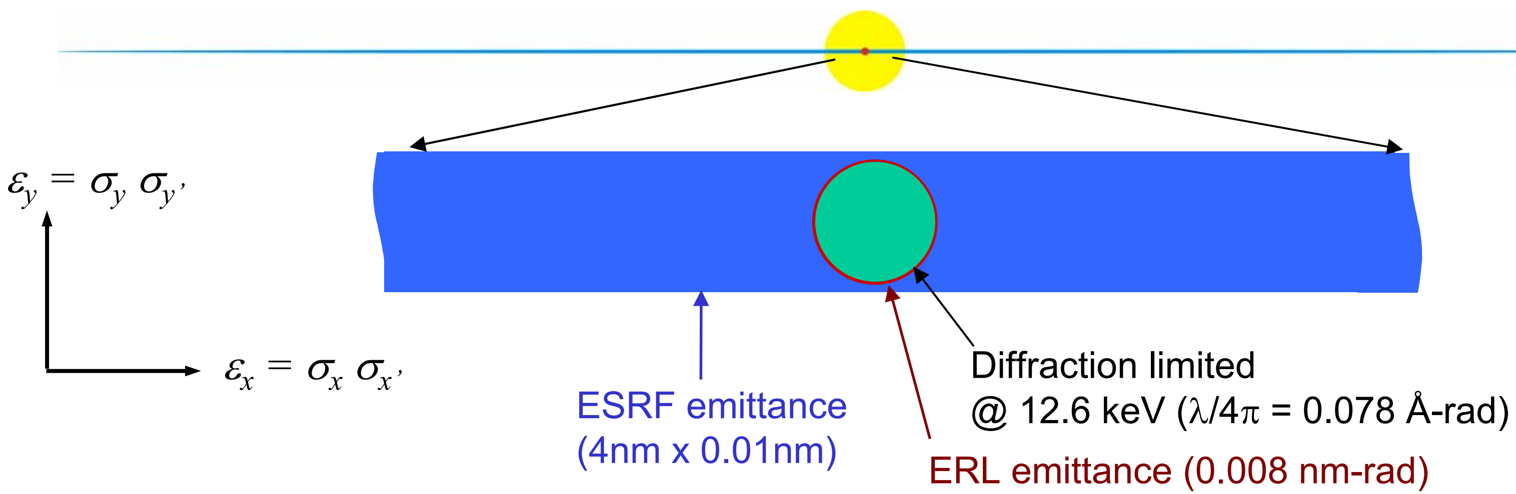
Main Linac: superconducting cells accelerate electron bunches to 5 GeV, and recover energy from returning bunches (180º out of phase)

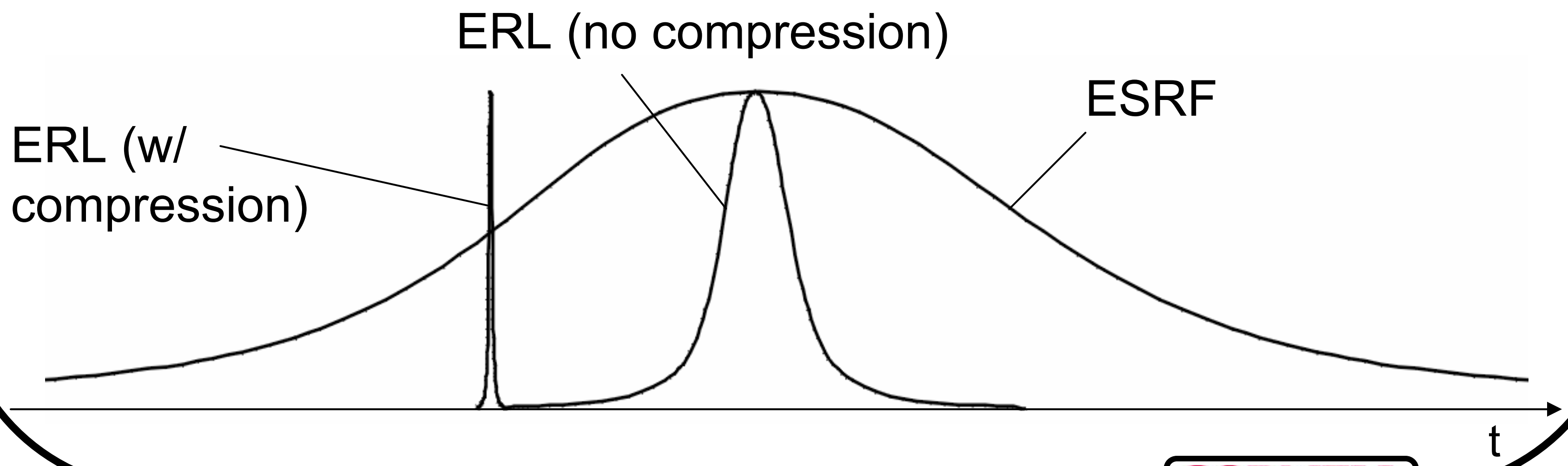
Transport loop: produces high-brilliance x-ray beams through undulators, and re-injects electrons into main linac for energy recovery



Electron Beam Size/Shape

CHESS & LEPP





Advanced Photon Source compared with Energy Recovery Linac

CHESS & LEPP

Parameter	APS 3rd generation storage ring	Energy recovery linac	Gain factor
Electron source size in microns rms	239(h) x 15(v)	2(h) x 2(v)	1/900 in area
Micro x-ray beamsize	100 nm to 1 micron (planned 30 nm)	**1 nm**	100 to 1000
Coherent flux x-rays/sec/0.1% bw	3×10^{11}	9×10^{15}	3,000
Pulse duration (rms)	32 ps	<100 fs	more than 320 times shorter

Conclusion: the ERL machine will be transformational!

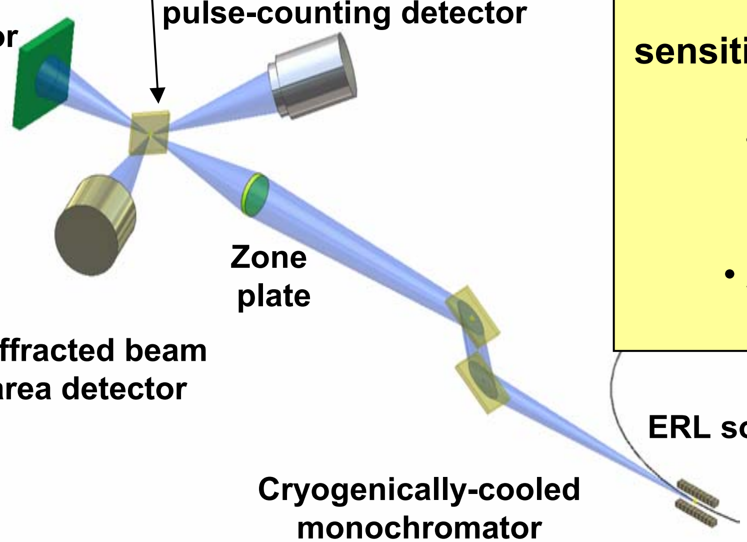
CORNELL UNIVERSITY

ERL Will Provide Unprecedented Nanobeams

CHESS & LEPP

Storage ring nanobeam flux limited by source size, shape, and divergence.

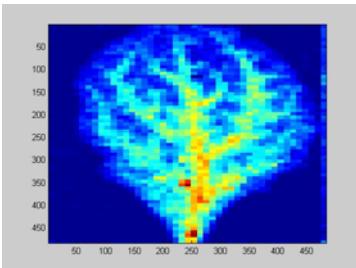
- Intense 1-10 nm probe size (rms), 1-10 keV beam allows study of nanostructures and molecules
- Quantitative atomic-scale structure, strain, orientation imaging
- Increase fluorescent trace element sensitivity from present 10^{-19} g to single atom (10^{-24} g)
- Sensitive to chemical state via XAFS at at ultra-low concentrations
- Ability to penetrate thick layers, nasty gas environments, etc. (as opposed to EM)



ERL source with electron beam size of 2 microns rms for 1 m long undulator and 0.5 m beta function demagnify by 2000x to make 1 nm beam size, etc.

Microbeam X-ray Science

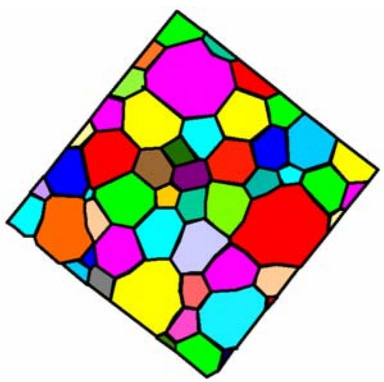
CHESS & LEPP



Zinc distribution in plant leaf by SR x-ray fluorescence

few cm scale object (CHESS data)

Centimeter scale

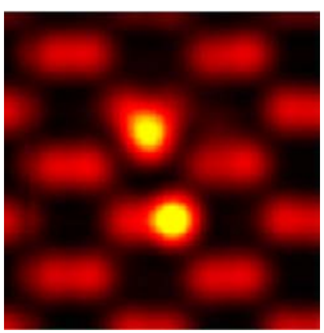


Hot-rolled Aluminum

SR x-ray diffraction. Map grain orientation and stress in real samples of 10^4 cubic microns at 1 micron resolution (APS data)

Micron scale

Nanometer scale



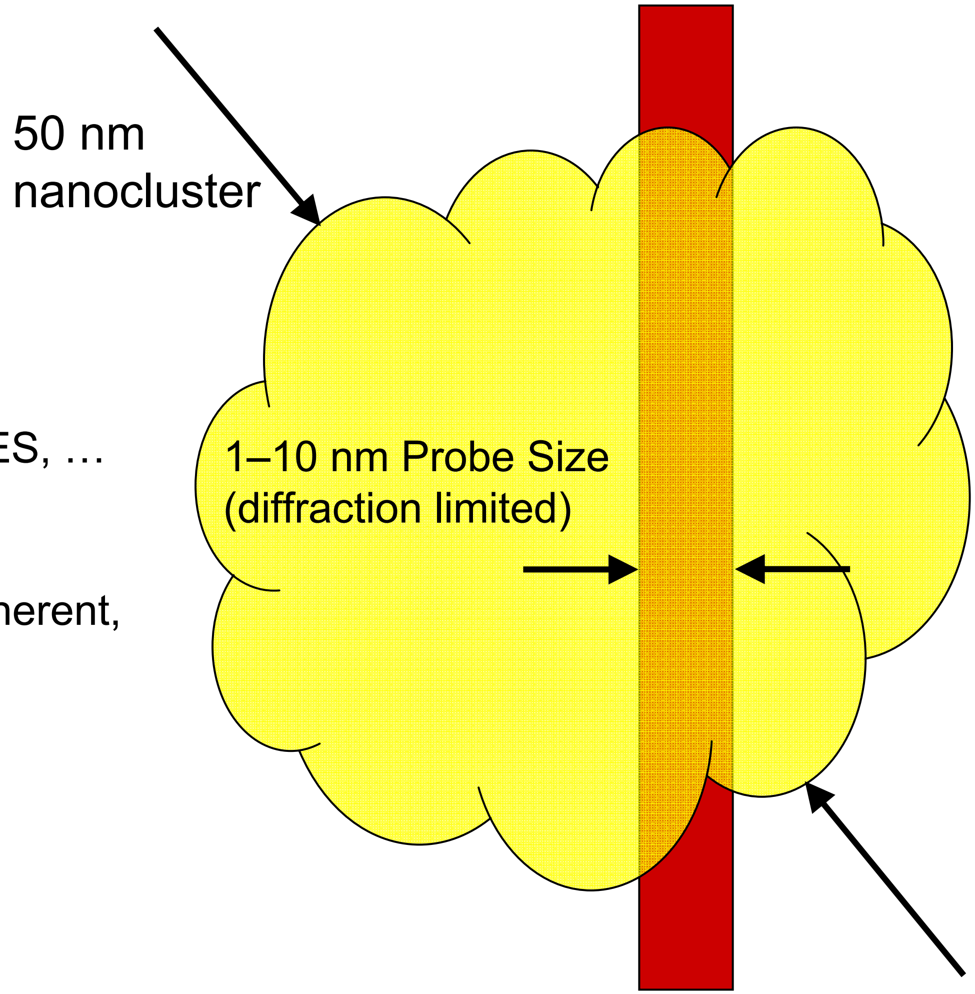
Two impurity atoms (yellow dots) in silicon crystal

TEM with 200 keV electrons can see individual atoms on samples a few atoms thick (Voyles, Lucent Technologies)

Atomic scale

Future of X-ray Nano-Characterization

CHESS & LEPP



Techniques

- Diffraction, Scattering, …
- Spectroscopy: EXAFS, XANES, …
- Holography
- Tomography
- Imaging: Phase contrast, Coherent, and Fluorescent (single atom sensitivity, ~10^{-24} gm)

CORNELL UNIVERSITY