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Insertion Device Possibilities

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U.S. Department of Energy

THE UNIVERSITY OF CHICAGO

Office of Science
U.S. DEPARTMENT OF ENERGY

A U.S. Department of Energy laboratory managed by The University of Chicago

Outline

Possibilities for customizing undulator output

1. Changing the electron beam properties
2. Changes to the straight section layout
3. Changes to the undulator

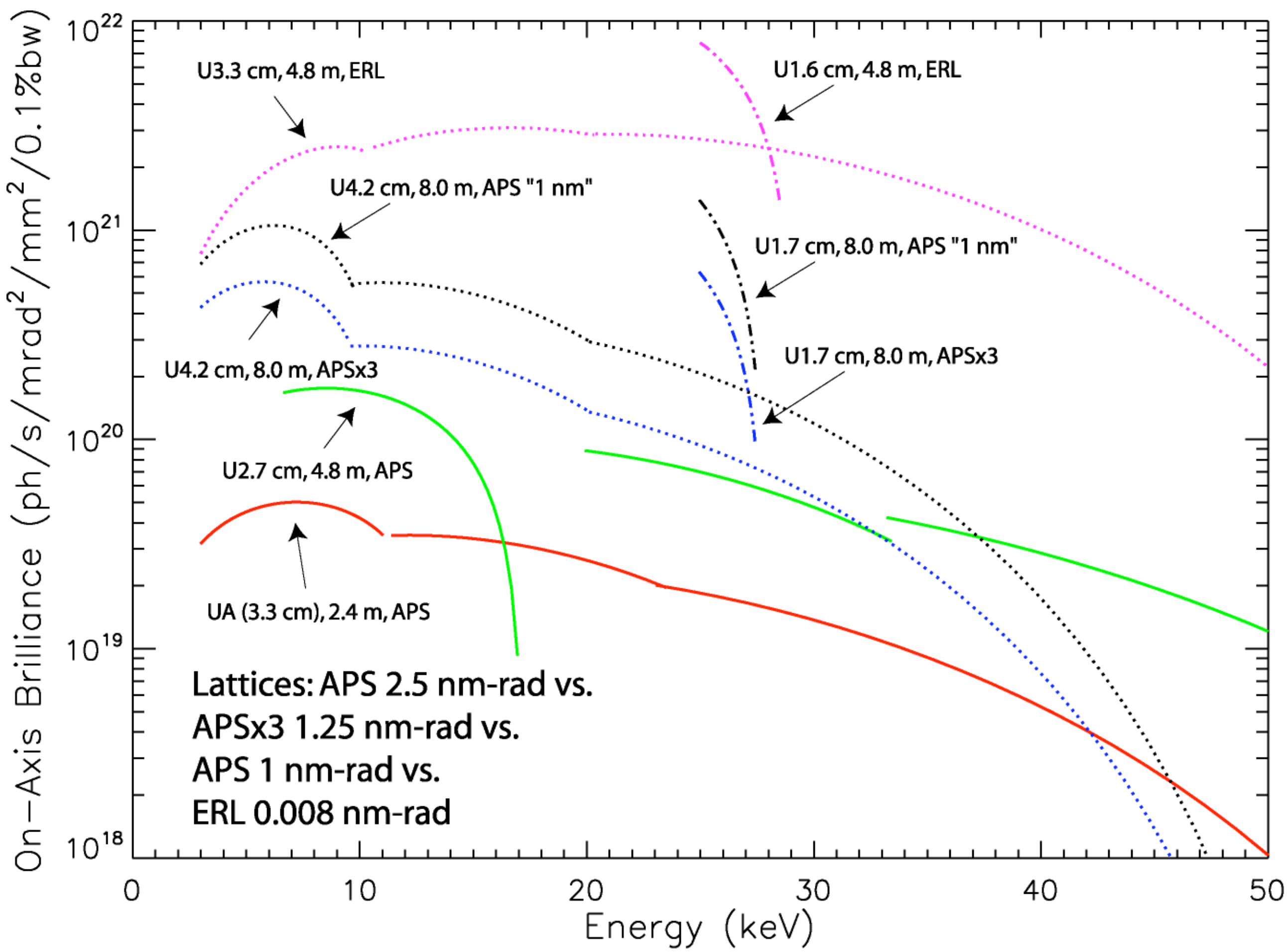
Some enhancements arise from ring redesign

Electron beam characteristics are key to the properties of the light that comes from undulators / insertion devices

- Smaller beam size results in higher brilliance
- Additional space in the straight section permits longer undulators; brilliance grows in proportion to undulator length (sometimes faster)
- Increase from 100 to 200 mA of stored beam gives higher brilliance

The different beam parameters from the three enhancement proposals result in different changes to undulator output.

On-Axis Brilliance Tuning Curves for New Options: APSx3 1.25 nm-rad vs. APS 1 nm-rad vs. ERL 0.008 nm-rad



- Beam Energy 7.0 GeV
- Beam Current 100 mA (APS), 200 mA (APSx3, APS 1 nm-rad), 25 mA (ERL)

Undulator parameters in previous graph were optimized

- With longer undulators and a higher beam current, power and power density become significant issues.
- Undulator period and total length were adjusted to produce highest brilliance at 3 keV and at 25 keV, without overtaxing the front ends.

Power density may be an issue in optimizing

For planar undulators, two routes to greater brilliance are: increasing the undulator length and decreasing the undulator period

- If length is increased, brilliance increases faster than power density
- If period is shortened, power grows faster than brilliance*

⇒ it makes sense to use the maximum undulator length, then decrease the period length until the power density is max'ed out.

For now, we use the maxima for the latest front end: 21 kW total power or 590 kW/mrad^2 on-axis power density. It is the power density that is the limiting consideration.

For 8-m-long undulators, we select the period length that gives the greatest brilliance at 3, 5, 10, and 25 keV. (The one for 25 keV would be a superconducting undulator.)

The tuning range may be limited (i.e. minimum gap may be larger) to restrict on-axis power density to acceptable levels, if necessary.

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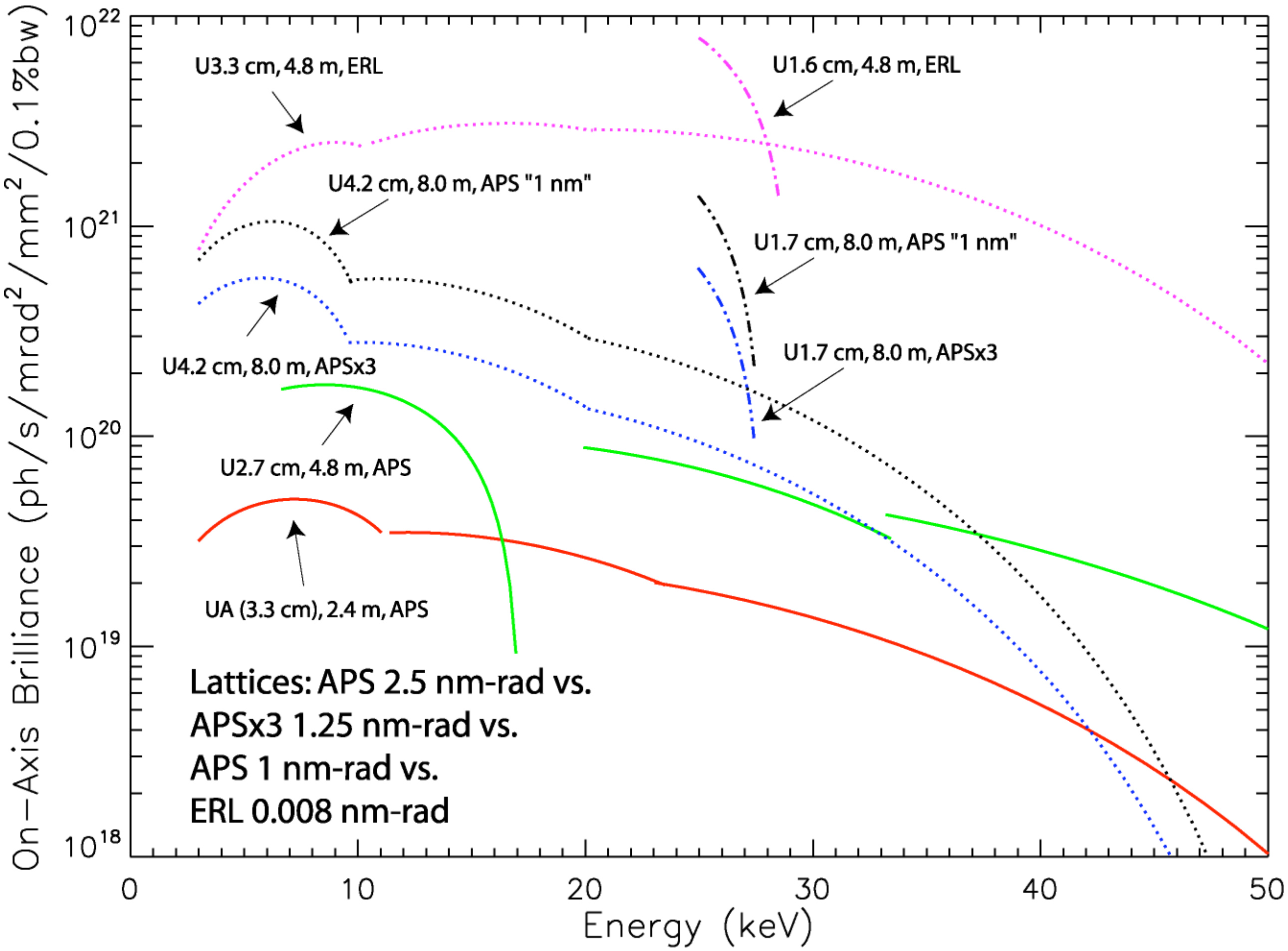
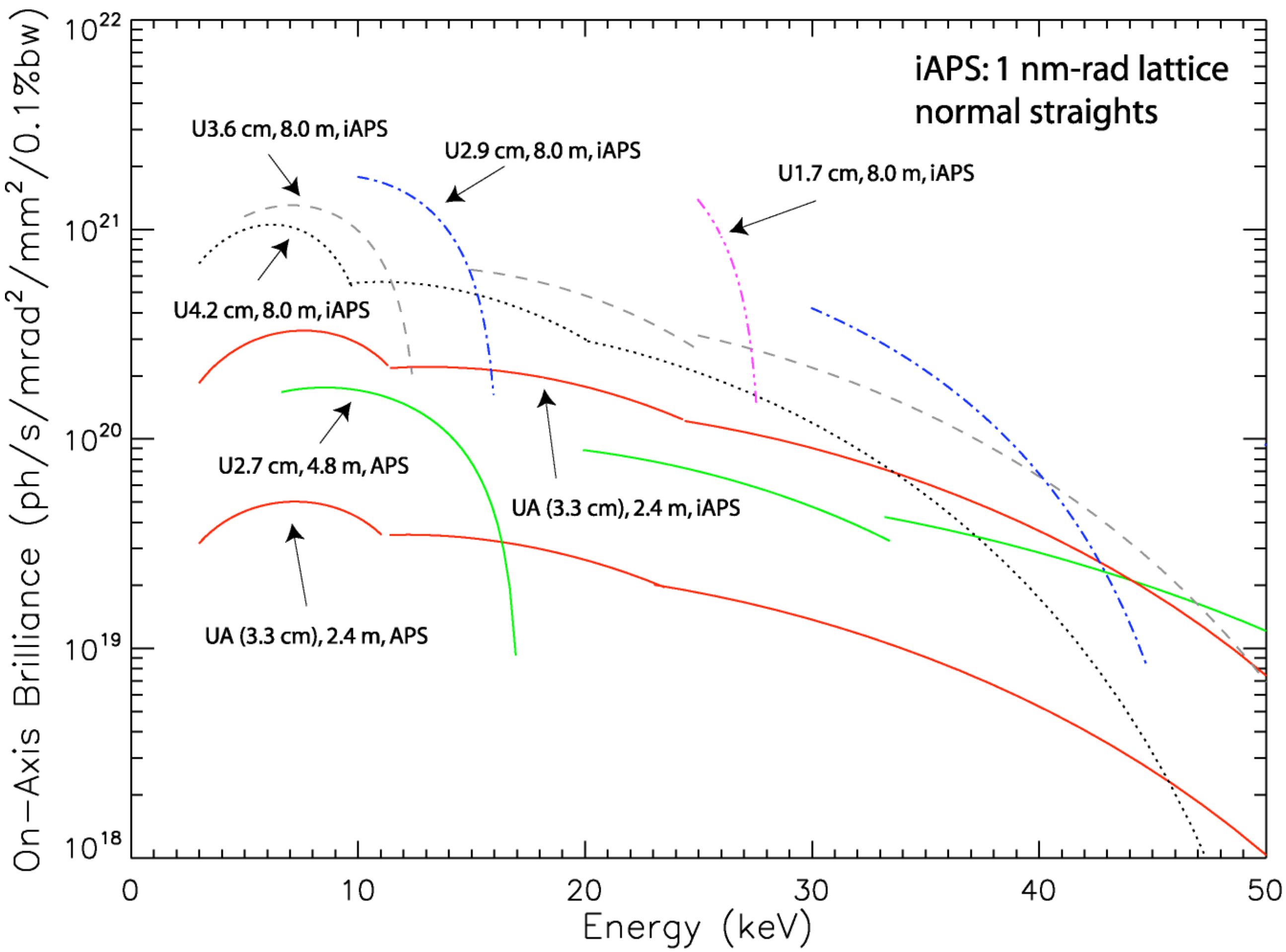
*(True for first harmonic and low-energy end of higher harmonics. May be different for higher energies or if comparing different harmonics. Thanks to D. Haeffner for pointing this out.)

On-Axis Brilliance Tuning Curves for New Options: APSx3 1.25 nm-rad vs. APS 1 nm-rad vs. ERL 0.008 nm-rad



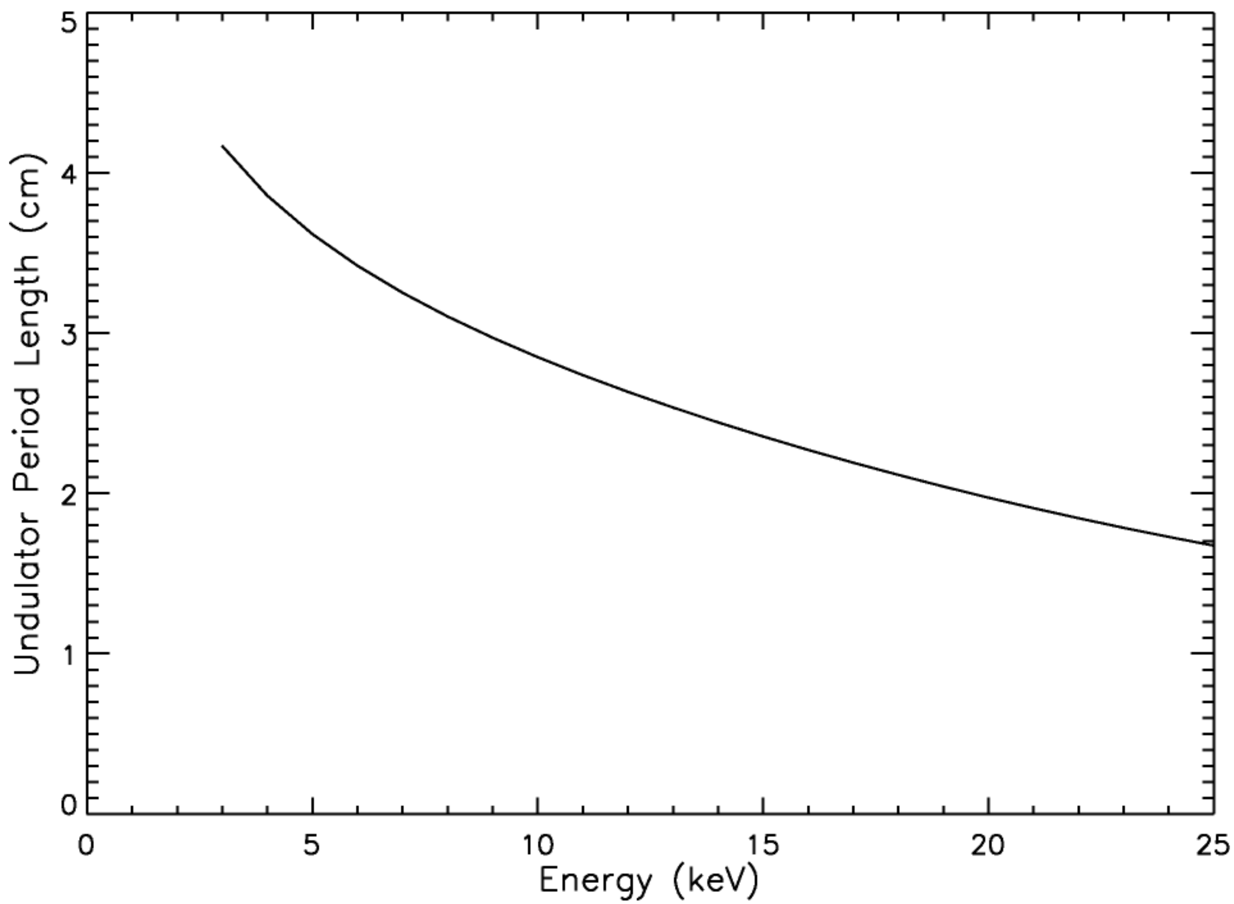
- Beam Energy 7.0 GeV
- Beam Current 100 mA (APS), 200 mA (APSx3, APS 1 nm-rad), 25 mA (ERL)

Tuning Curves for APS "1nm" Lattice Optimized at 3, 5, 10, and 25 keV



- APS "1 nm": 7.0 GeV, 200 mA
- APS: 7.0 Gev, 100 mA

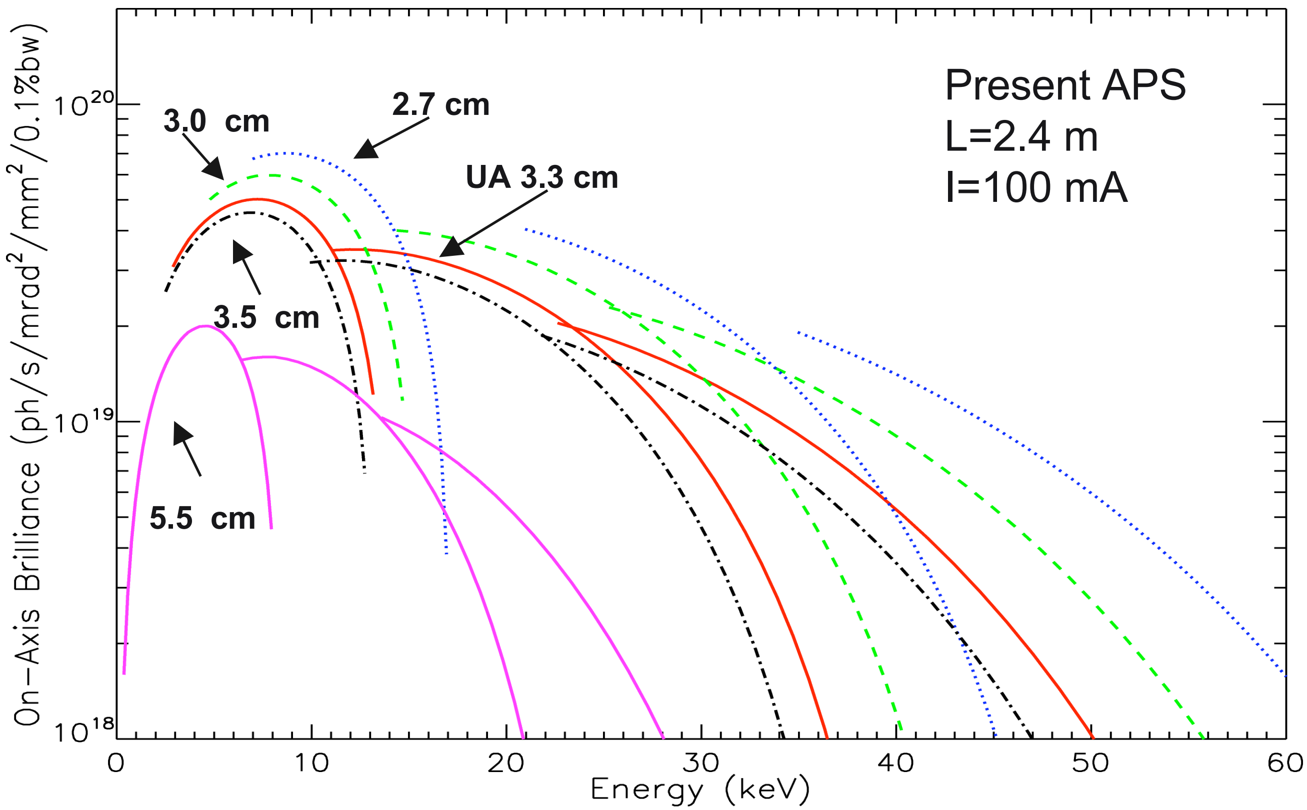
Optimized undulator period length vs. photon energy



Assumes 8-m-long undulator, 200 mA beam

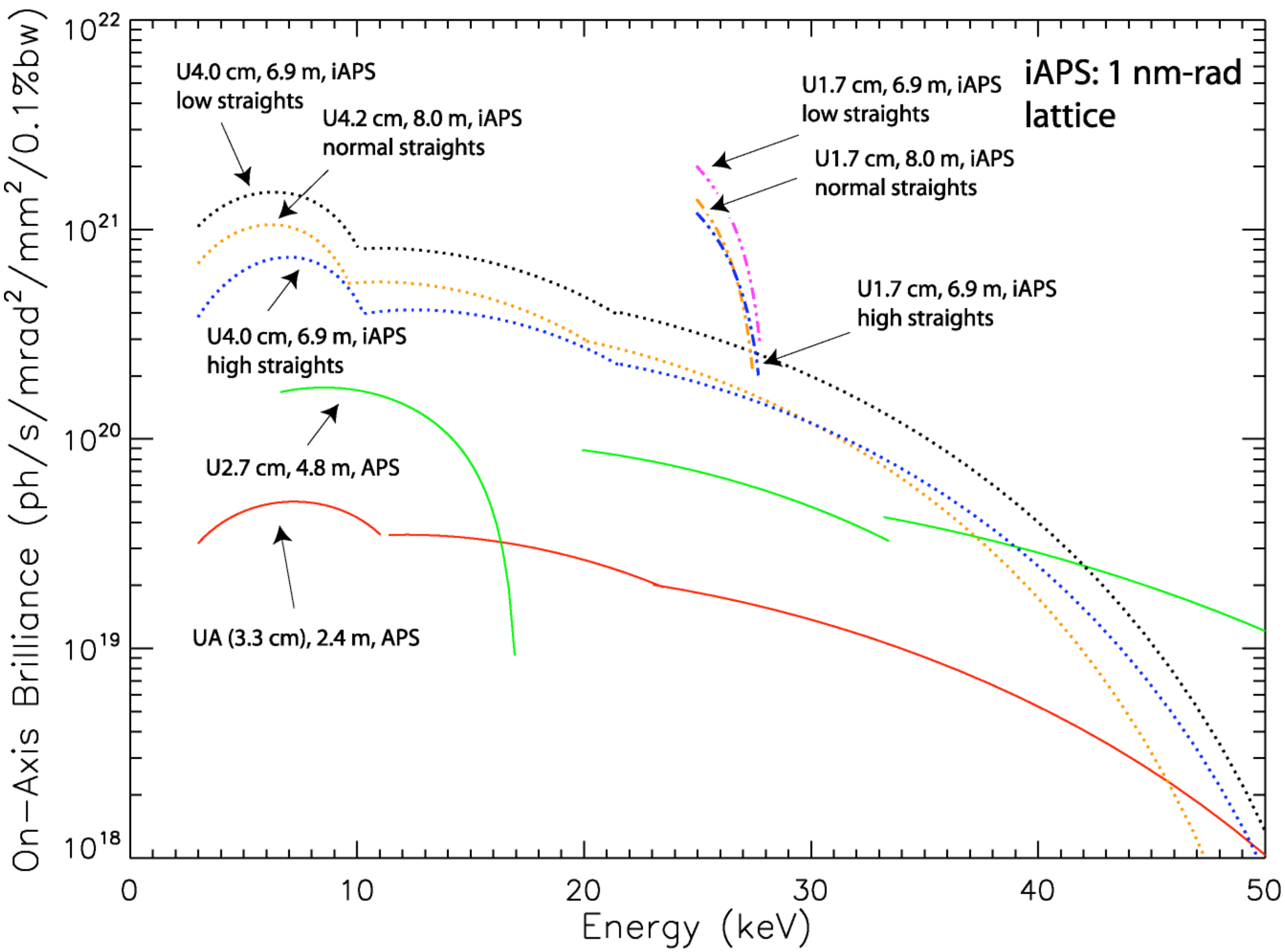
- Optimized period length determined from maximum allowed on-axis power density 590 kW/mrad^2
- Undulator gap > 10.5 mm

Customizing period length is already being done at APS



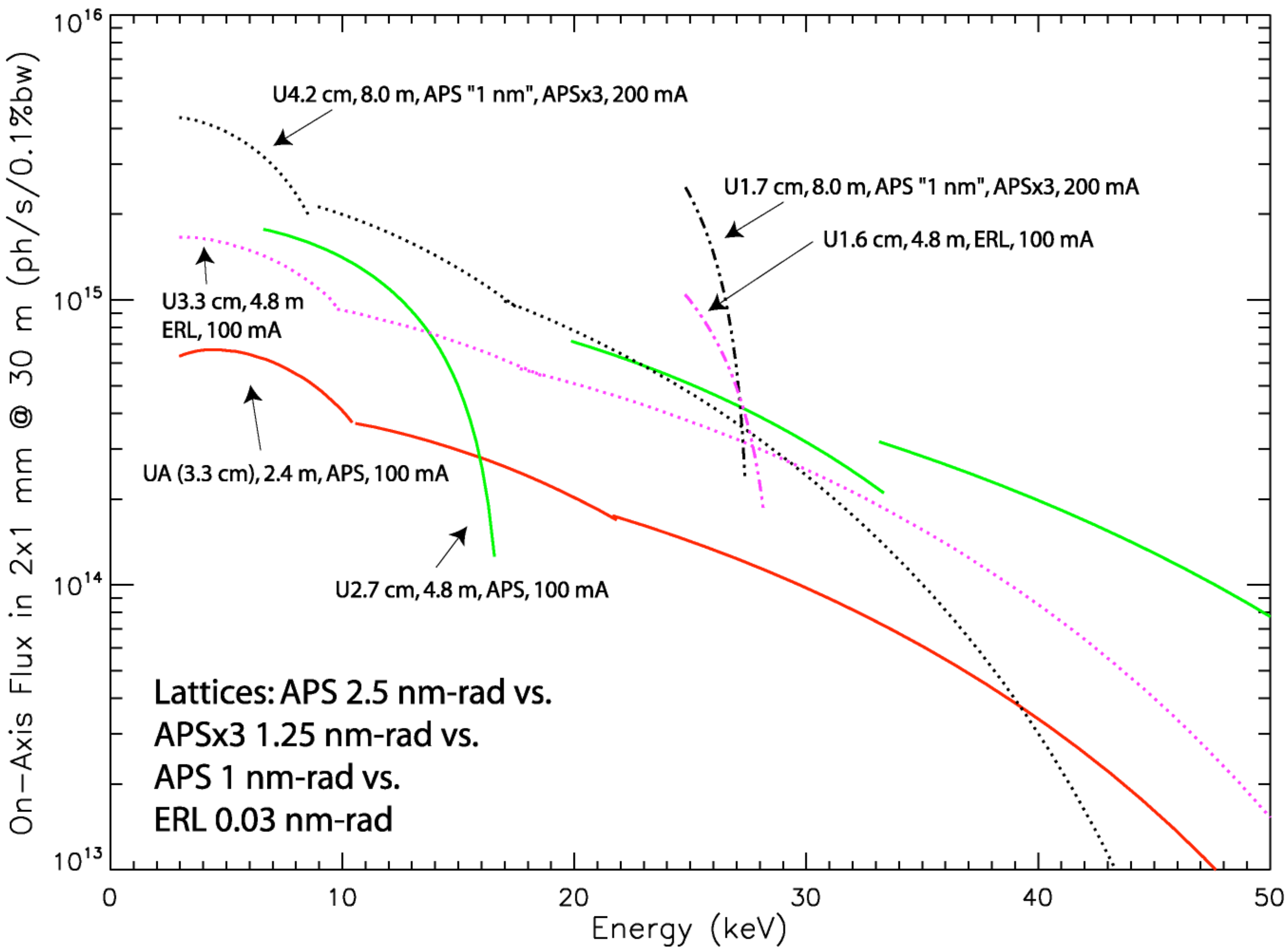
- Different period lengths can provide higher peak brilliance in different energy ranges.
- This type of customization is already being done (3.5 cm for Sect 4; 3.0 cm for Sects 21, 23, 24; 2.7 cm for Sects 3 & 14; 2.3 cm coming for Sect 14).
- We are glad to provide information to assist users in choosing.

APS "1 nm" tuning curves for normal beam, small ("low") horizontal size beam, and small divergence but large size ("high") beam



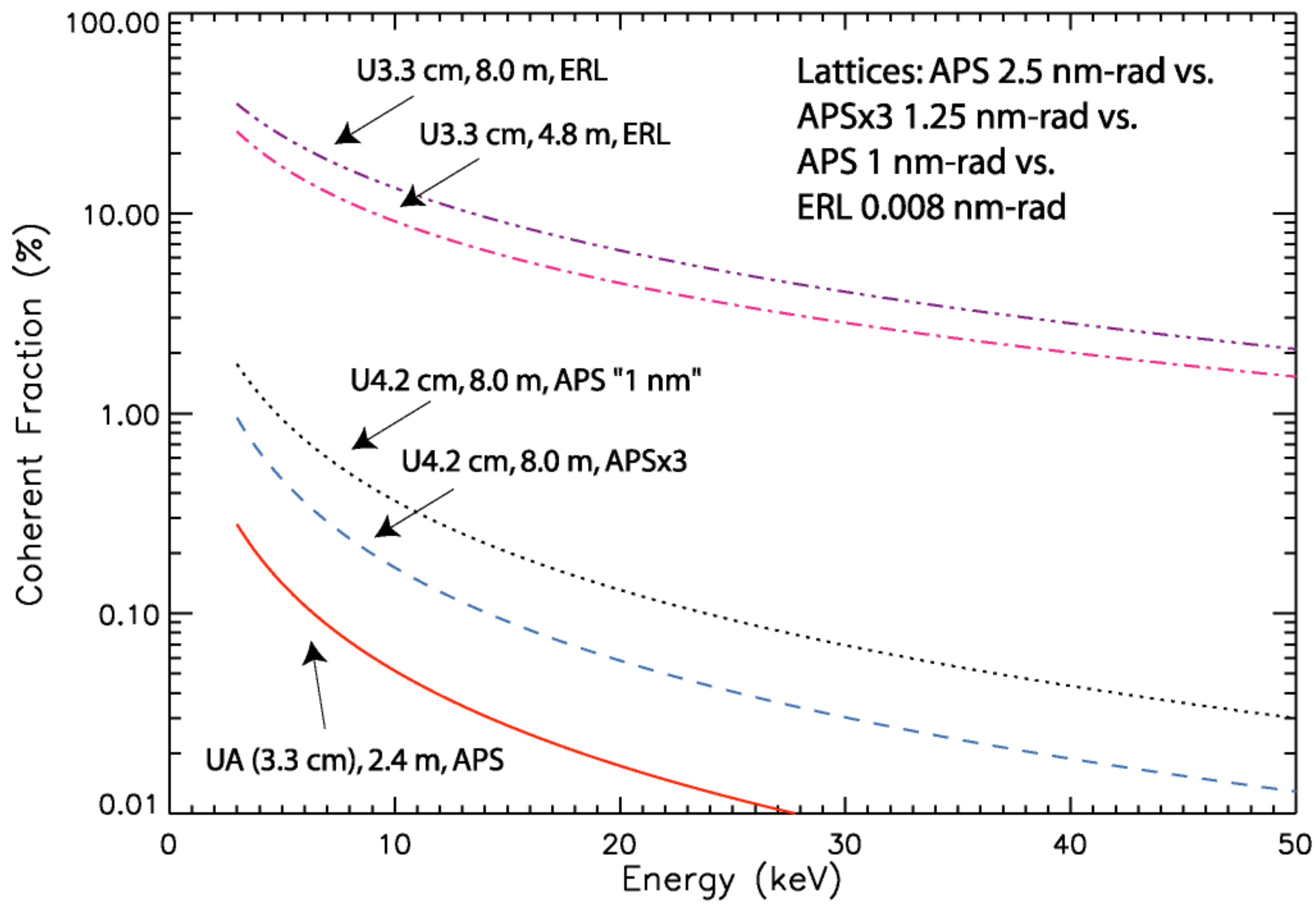
- Beam Energy 7.0 GeV
- Beam Current 100 mA (APS), 200 mA (APS 1 nm-rad)

On-Axis Flux Tuning Curves at 7.0 GeV for New Options: APSx3 1.25 nm-rad vs. APS 1 nm-rad vs. ERL 0.03 nm-rad



- Beam Current 100 mA (APS), 200 mA (APSx3, APS 1 nm-rad), 100 mA (ERL, "high-flux" option)

Coherent fraction of undulator output



- Coherent fraction of radiation in central cone > 10% for energies < 10 keV for the ERL high-coherence lattice (undulator length 4.8 m)

Beam parameters

	emittance (nm-rad)	beam current (mA)	straight section length (m)	beam energy spread (%)	sigma x (mm)	sigma y (mm)	sigma x' (mrad)	sigma y' (mrad)
Today's APS	2.5	100	4.8	0.096	0.275	0.009	0.0113	0.003
APS "1 nm"; normal straights	1	200	8	0.12	0.116	0.007	0.0093	0.0011
APS "1 nm"; high straight (small divergence)	1	200	6.9	0.12	0.245	0.006	0.005	0.0012
APS "1 nm"; low straight (small horizontal beam size)	1	200	6.9	0.12	0.035	0.007	0.022	0.001
APS x3	1.25	200	8 and 1.9	0.13	0.109	0.012	0.0137	0.0011
ERL, high coherence	0.008	25	4.8	0.02	0.011	0.006	0.0007	0.0014
ERL, high flux	0.03	100	4.8	0.02	0.022	0.011	0.0014	0.0028

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Possibilities for customizing undulator output

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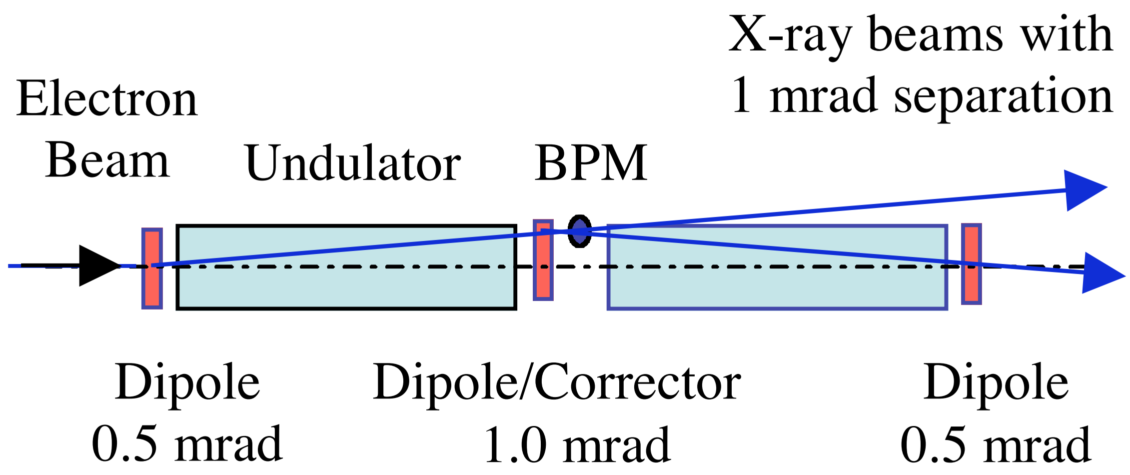
Changes to the straight section layout: canting or additional straights

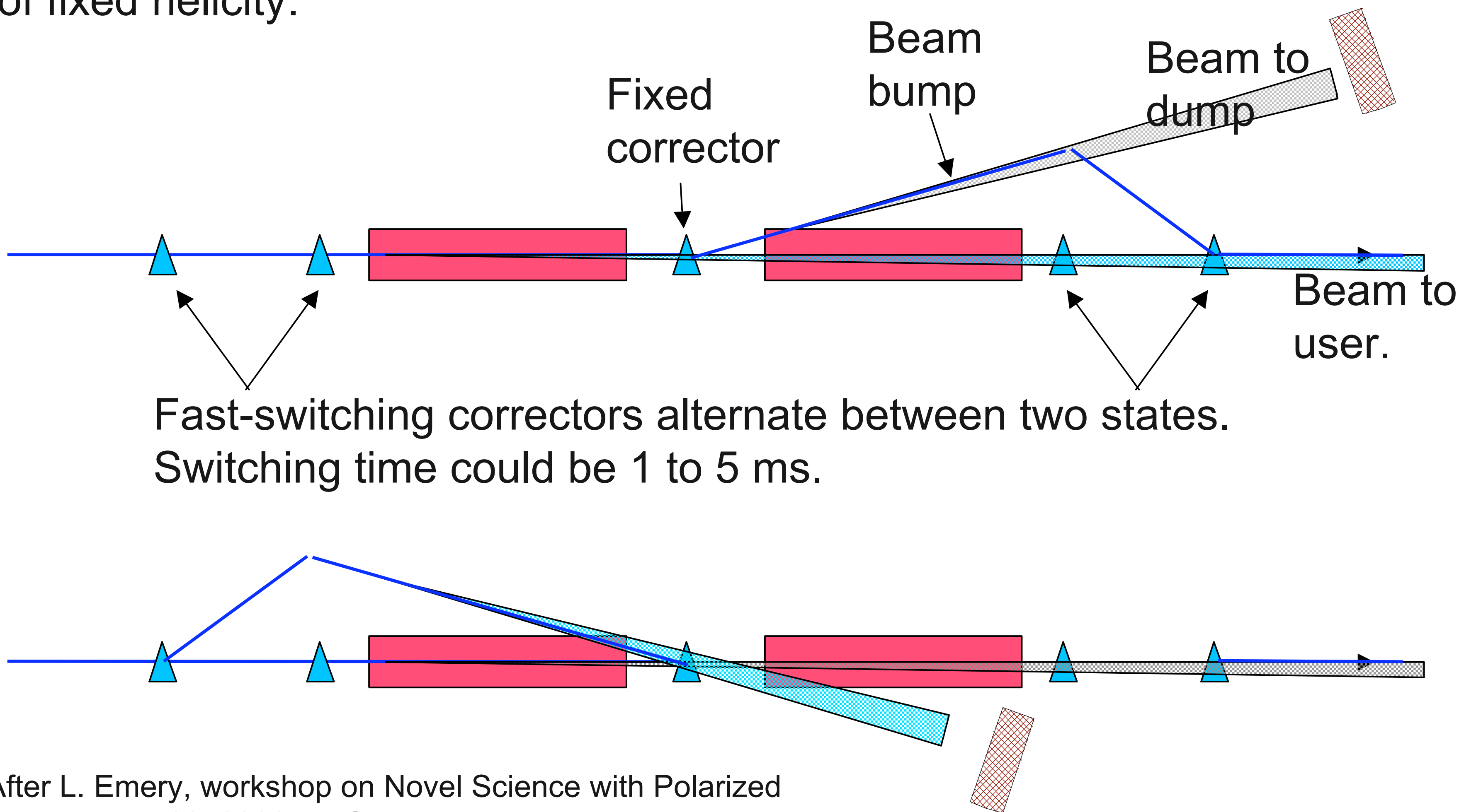


- Canting an undulator line (as has been done in Sectors 4, 21, 23, and 24) will still be possible.
  With 8 m of total space, three undulators 2.4 m long with steering dipoles between them could supply photons to 3 separate beamlines.

- The APSx3 option combines 8-m-long straights with two short straight sections where shorter undulators could be installed.

Fast Polarization Switching from a Long Straight Section

Use corrector magnets to switch the beams from two undulators of fixed helicity.



After L. Emery, workshop on Novel Science with Polarized X-rays, June 29, 2006, APS.

Outline

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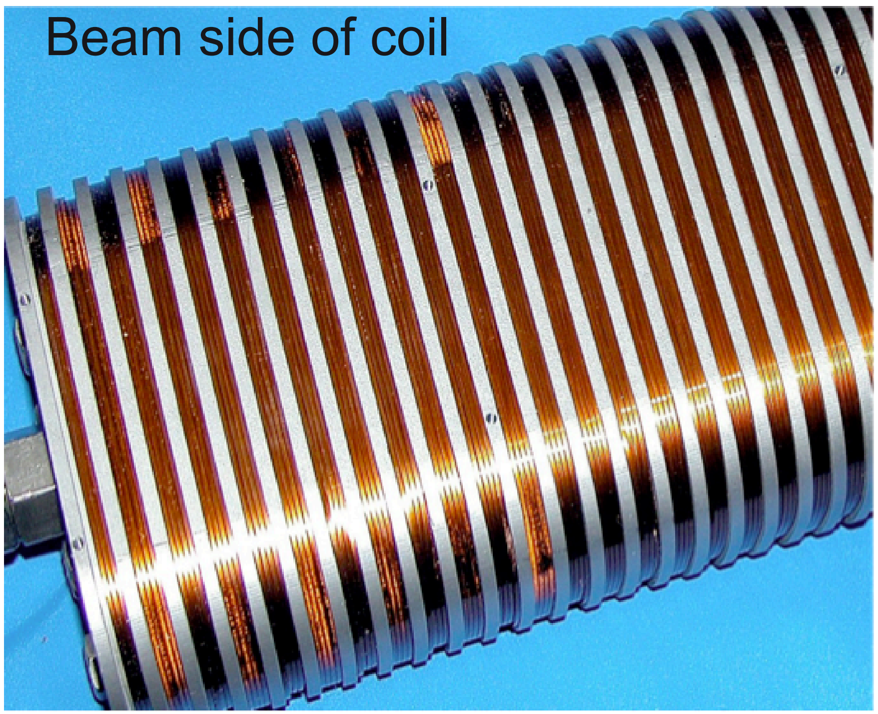
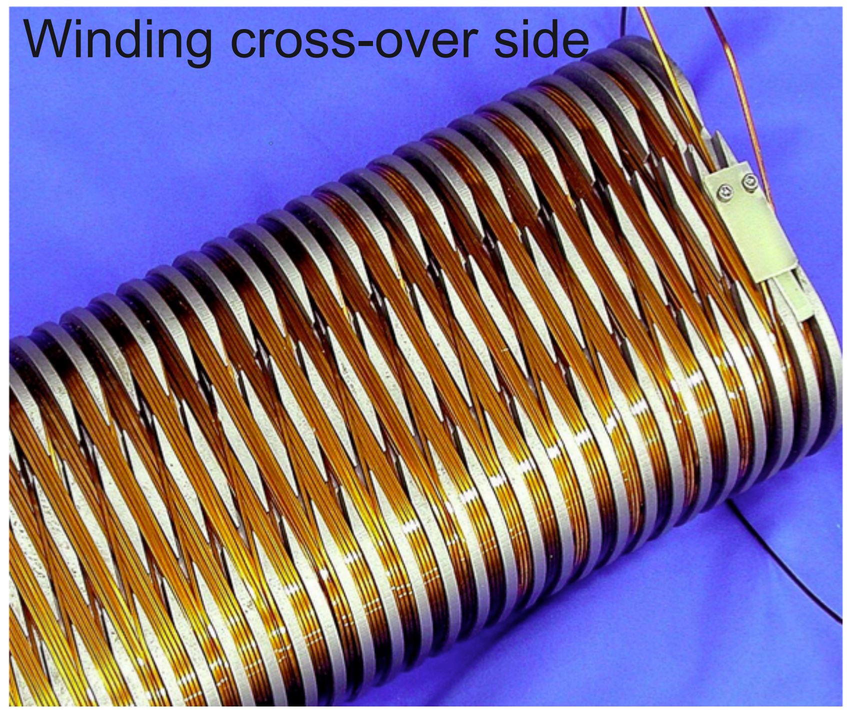
Changes in the undulator: superconducting undulator

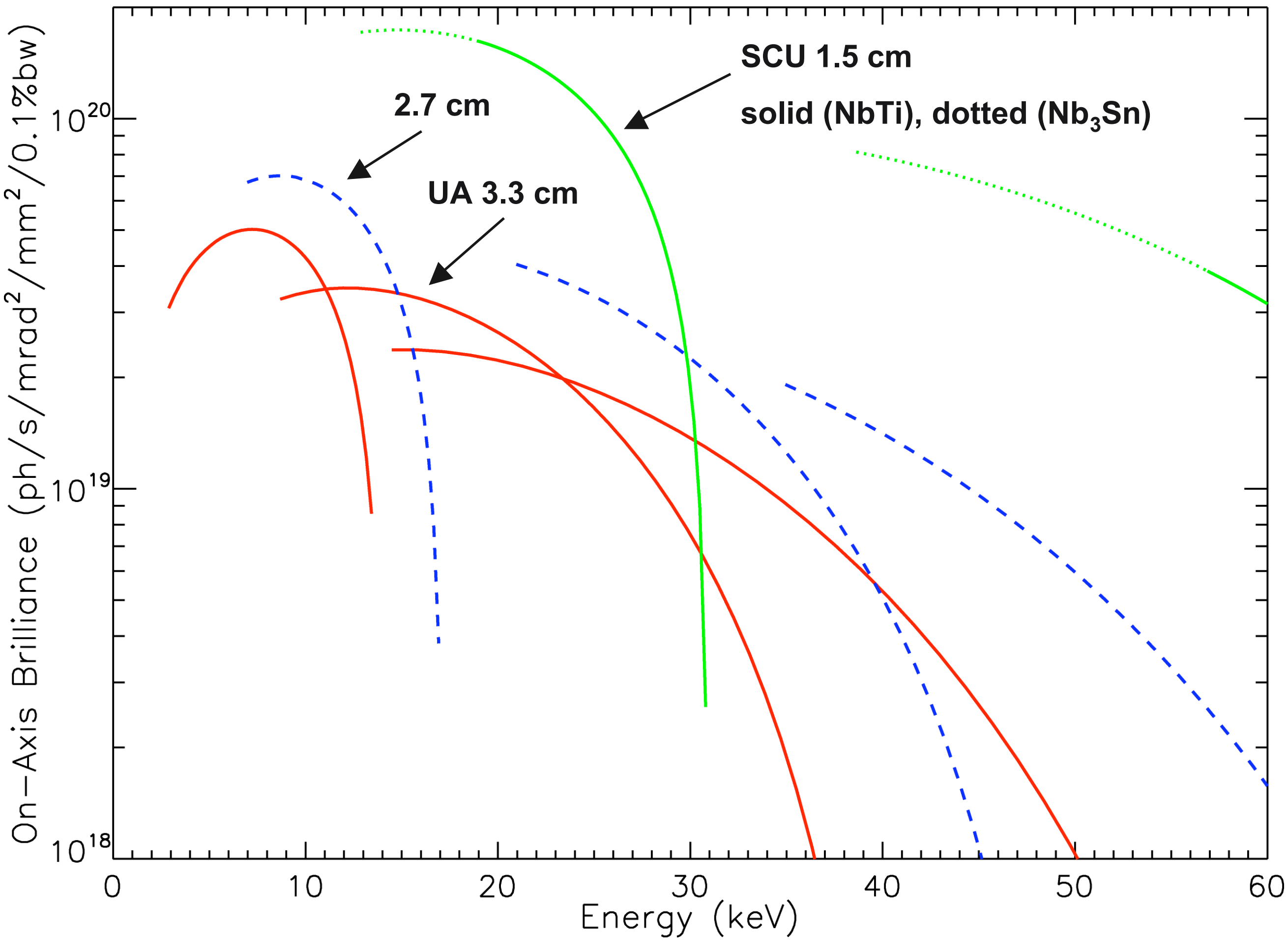
Research on building a superconducting undulator is underway

Goal is to achieve a tuning range of 20-25 keV in the first harmonic with a period length around 15 mm



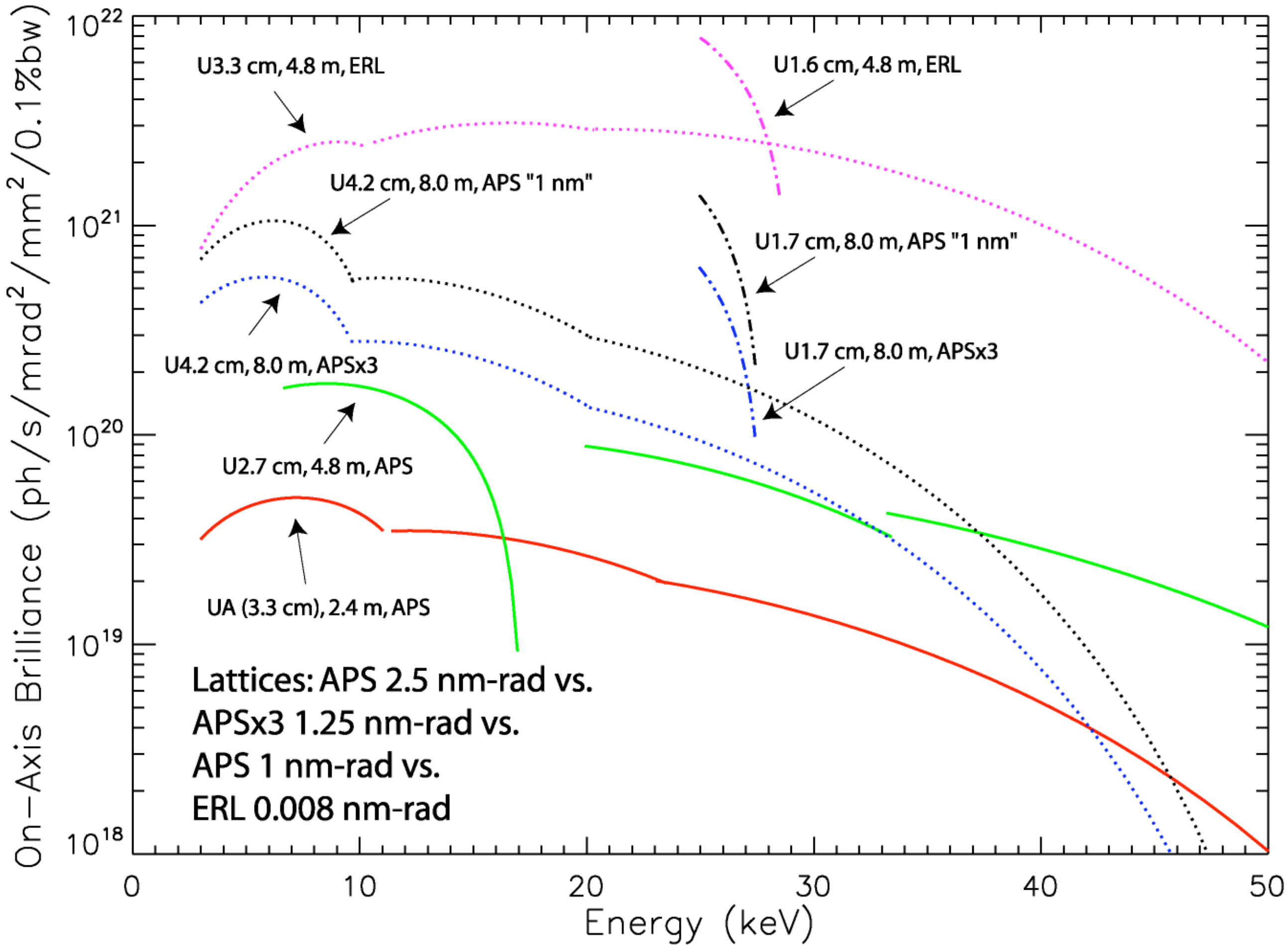


Superconducting undulator tuning curve



Superconducting undulators (SCUs) operate at a pole gap of 8 mm. The assumed magnetic fields on axis are 0.8 T for NbTi and 1.2 T for Nb_3Sn (all lengths 2.4 m).

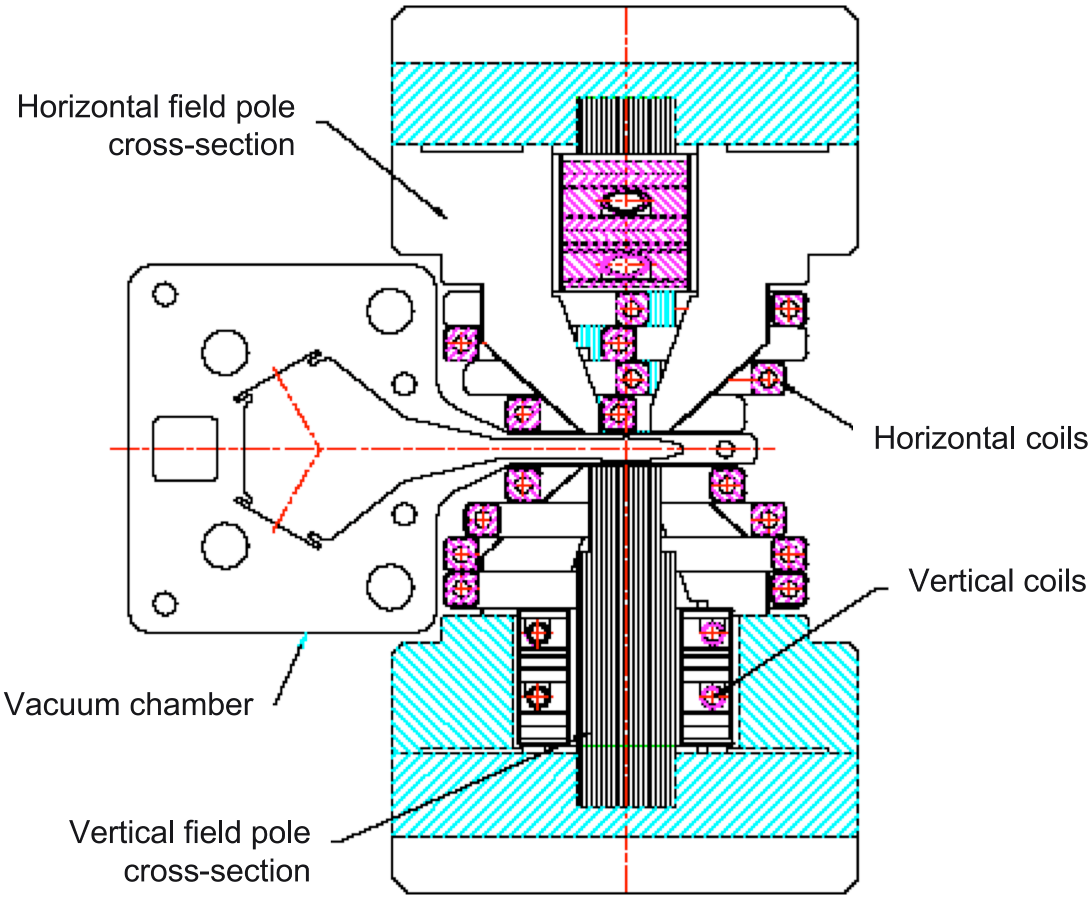
On-Axis Brilliance Tuning Curves for New Options: APSx3 1.25 nm-rad vs. APS 1 nm-rad vs. ERL 0.008 nm-rad



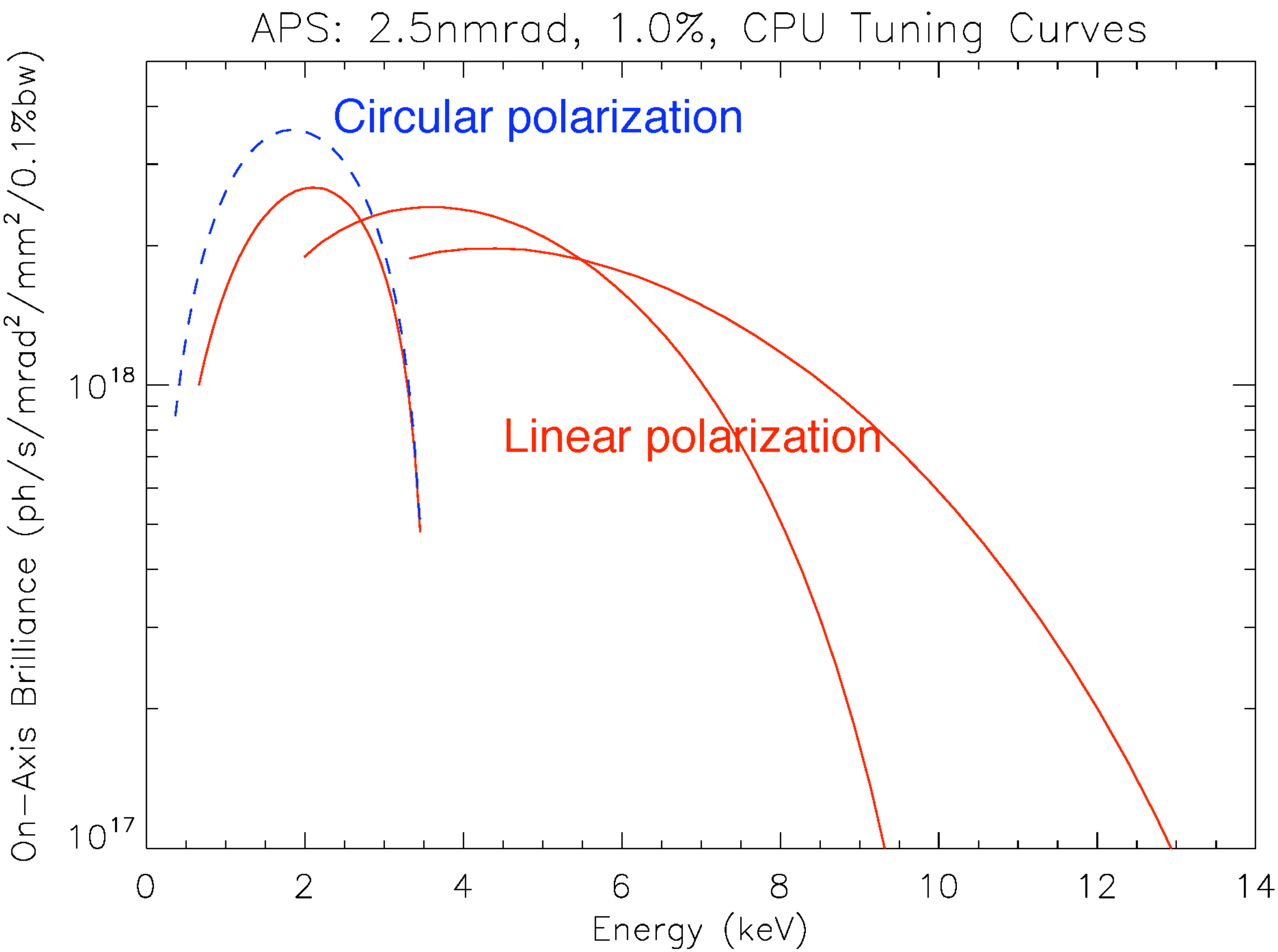
- Beam Energy 7.0 GeV
- Beam Current 100 mA (APS), 200 mA (APSx3, APS 1 nm-rad), 25 mA (ERL)

Circularly Polarizing Undulator (CPU) in Sector 4

- All electromagnetic
- 500-3000 eV output
- circular polarization, both left and right
- linear polarization, both vertical and horizontal
- switchable polarization
- compatible with standard ID vacuum chamber, so it can share a straight section
- open along one side for access by magnetic measurement probes



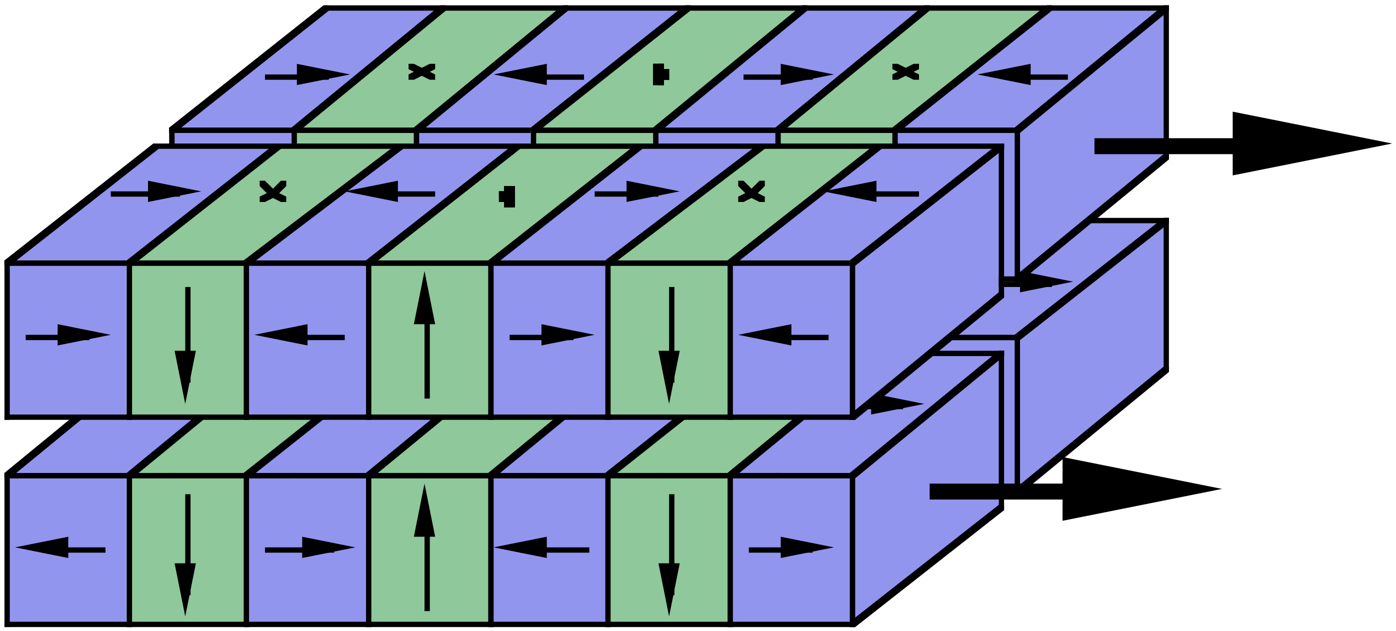
CPU Tuning Curves



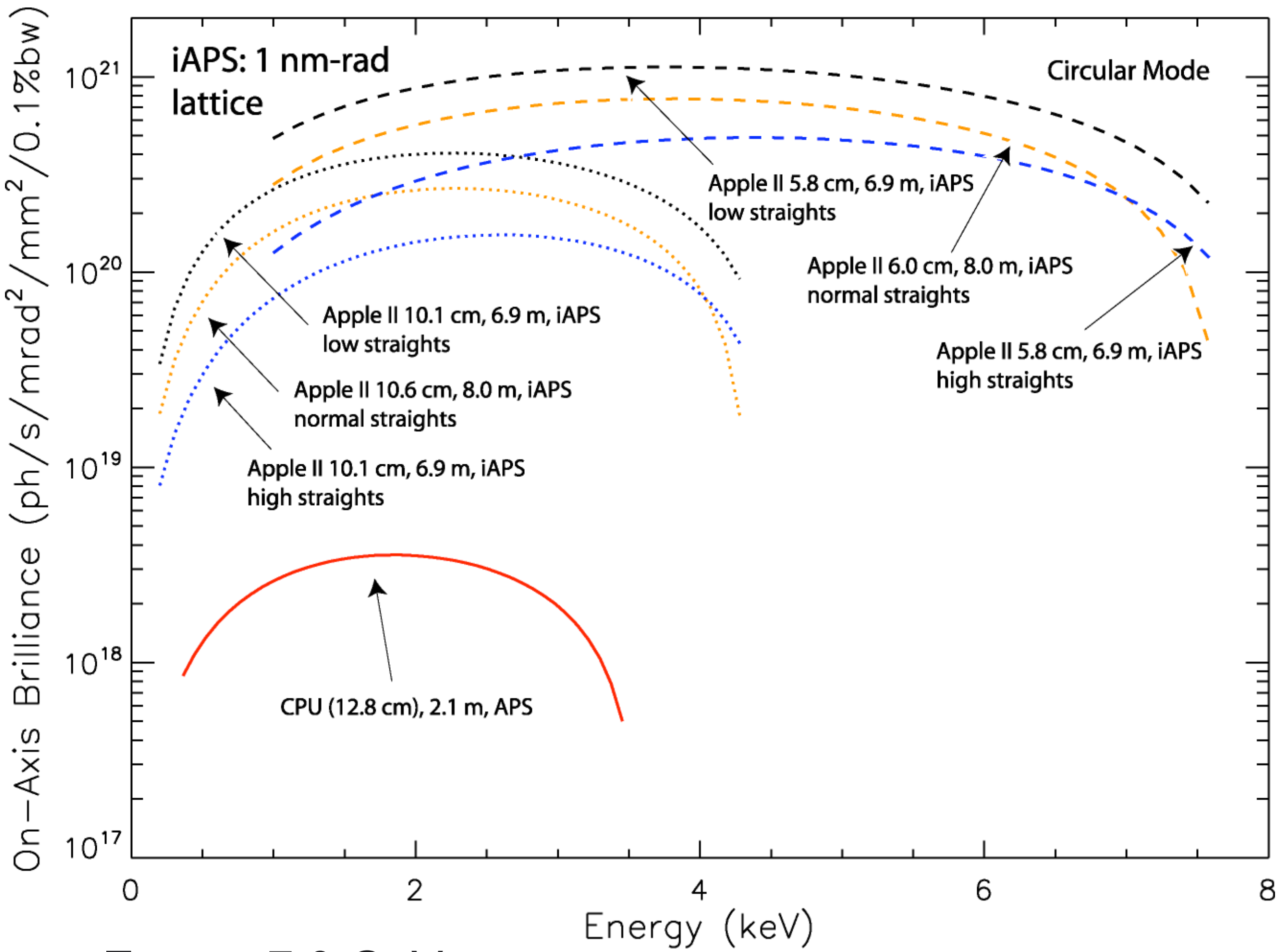
APPLE-type undulator

- **Magnetic Structure**

  Consists of pure permanent magnets

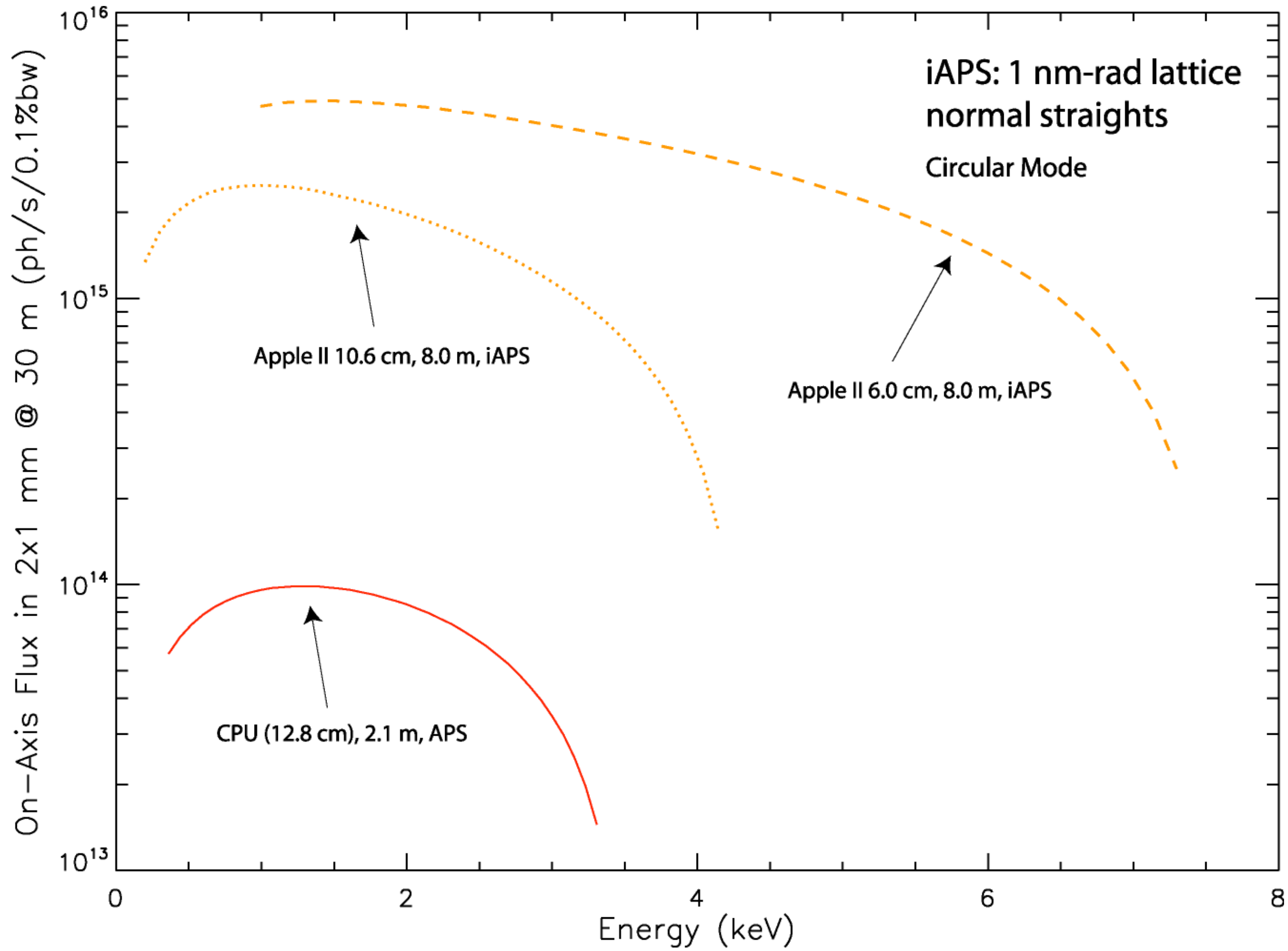


Tuning Curves for APS "1 nm" Lattice for Circular Undulators (various types of straight sections)



- Beam Energy 7.0 GeV
- Beam Current 100 mA (APS), 200 mA (APS 1 nm-rad)

On-Axis Flux Tuning Curves for APS "1 nm" for CPUs



- Beam Energy 7.0 GeV
- Beam Current 100 mA (APS), 200 mA (APS 1 nm-rad)

We will customize

There are many options for matching the insertion device(s) to the needs of the experimental program.

APS is committed to providing users with insertion devices that will enable them to do the best science.