Polarization control in a SASE FEL with crossed-undulator

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Science Drivers for
Hard X-Ray Upgrades
to LCLS

Scientific motivation

Polarization control (from linear to circular and from left circular to right circular) is highly desirable in ultrafast magnetic phenomena and material science.

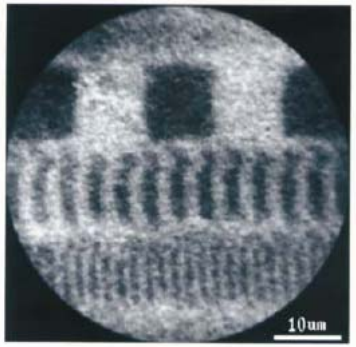
X-ray Magnetic Circular Dichroism **(XMCD)**

Magnetization dependent absorption of circularly polarized light

Polarization Dependent Imaging with X-Rays

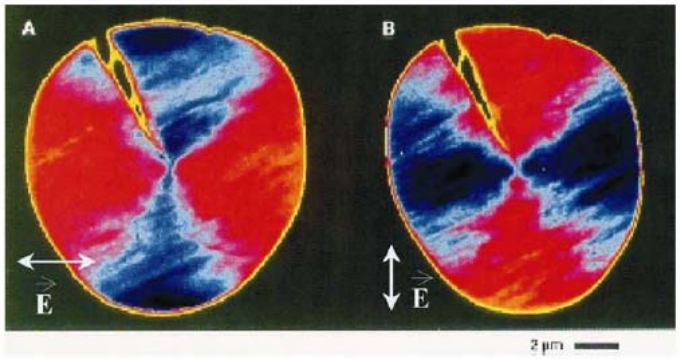
X-Ray Magnetic Circular Dichroism

Stöhr *et al.*, Science **259**, 658 (1993)



X-Ray Natural Linear Dichroism

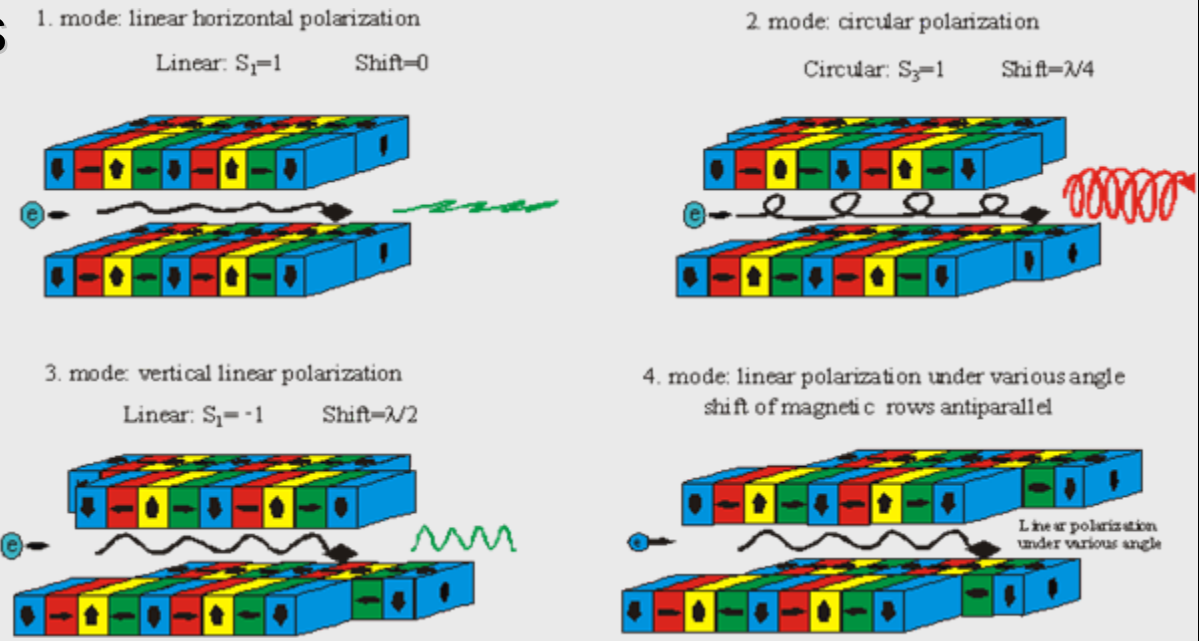
Ade and Hsiao., Science **262**, 1427 (1993)



(From J. Stohr's lecture)

How to control Polarization in FELs

- **Elliptical Polarization Undulators** (EPUs) are routinely used in spontaneous sources



But…

- For x-ray FELs, undulator tolerance is very demanding.
- Slow EPU mechanical movement pretends fast polarization switching

- **Crossed Planar Undulators**
- ……

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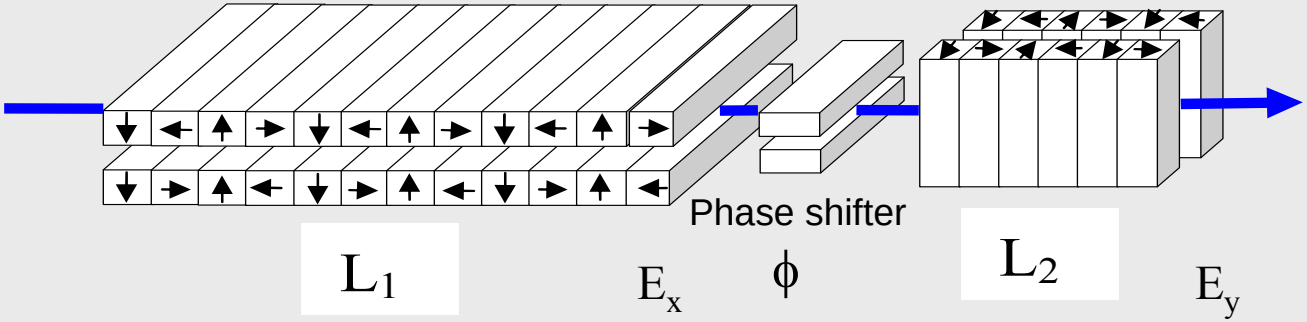
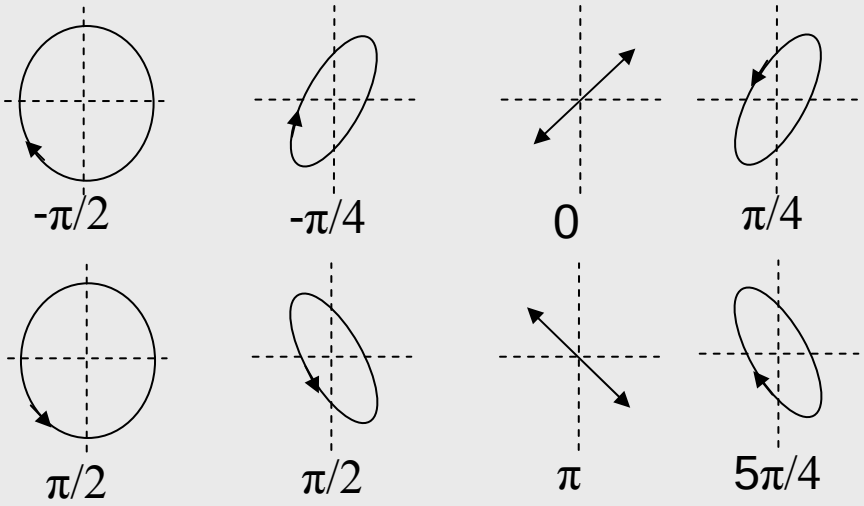
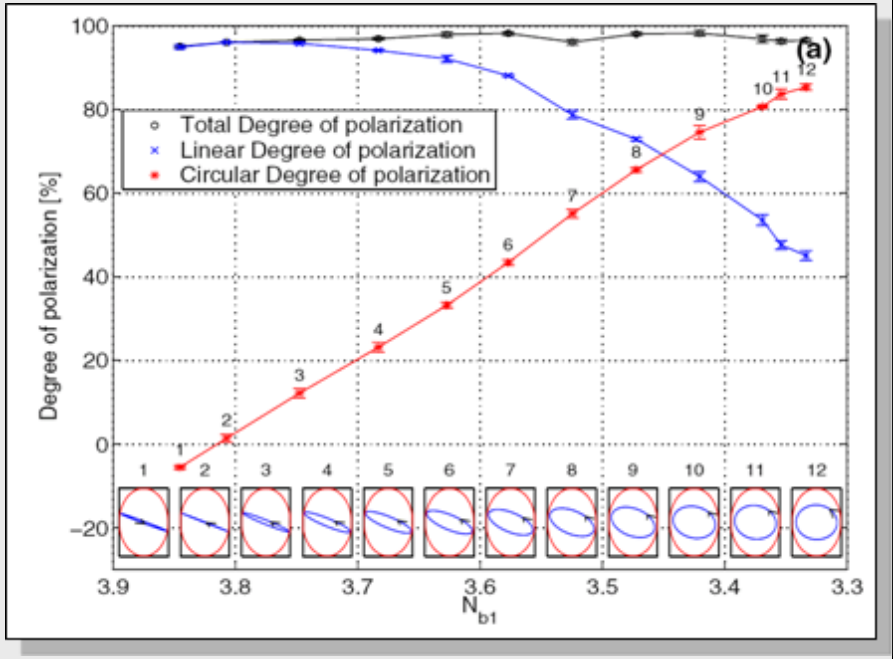
Crossed Planar Undulator



Proposed by K-J. Kim



Apply to FEL oscillator (DUKE)

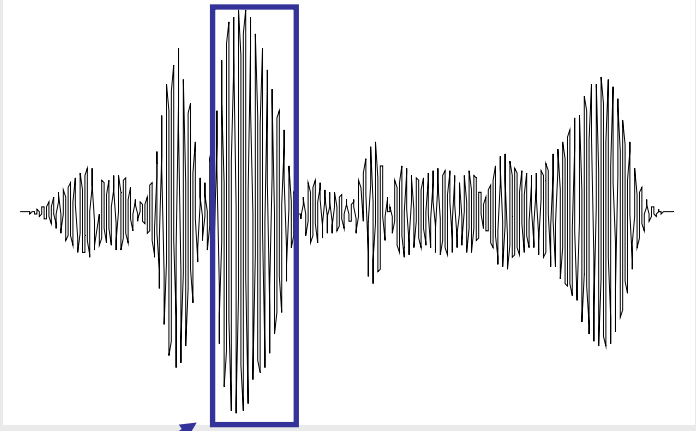


Y. Wu et al, PRL (2006)

How about SASE FELs ?

many intensity spikes due to poor temporal coherence;

- need to do a statistical analysis.



coherence time

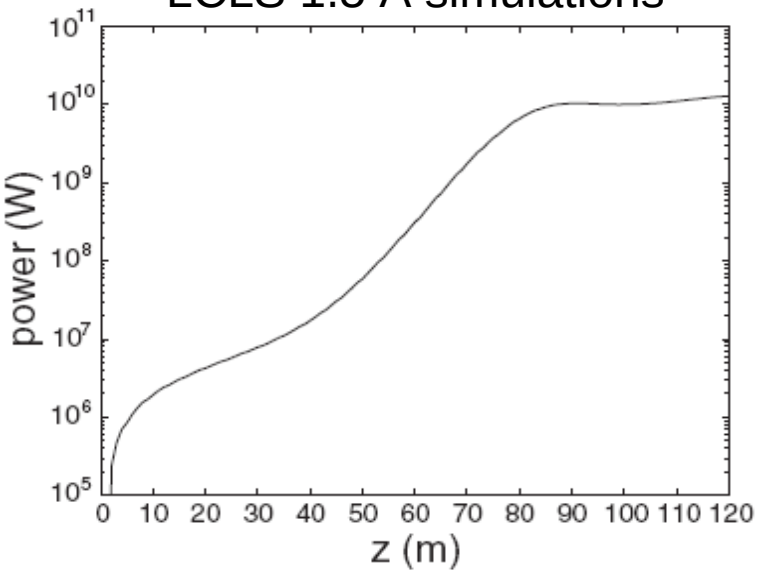
$$\tau_c = \int_{-\infty}^{\infty} |g_1(\tau)|^2 d\tau$$

First order time correlation function:

$$g_1(\tau) = \frac{|\langle E(t)E^*(t-\tau)\rangle|}{[\langle |E(t)|^2\rangle \langle |E(t-\tau)|^2\rangle]^{1/2}}$$

1-D linear regime : $g_1(\tau) = e^{-\frac{\pi\tau^2}{2\tau_c^2}}$ $\tau_c = \frac{\sqrt{\pi}}{\sigma_\omega}$

LCLS 1.5 Å simulations



10 % of X-Ray Pulse Length

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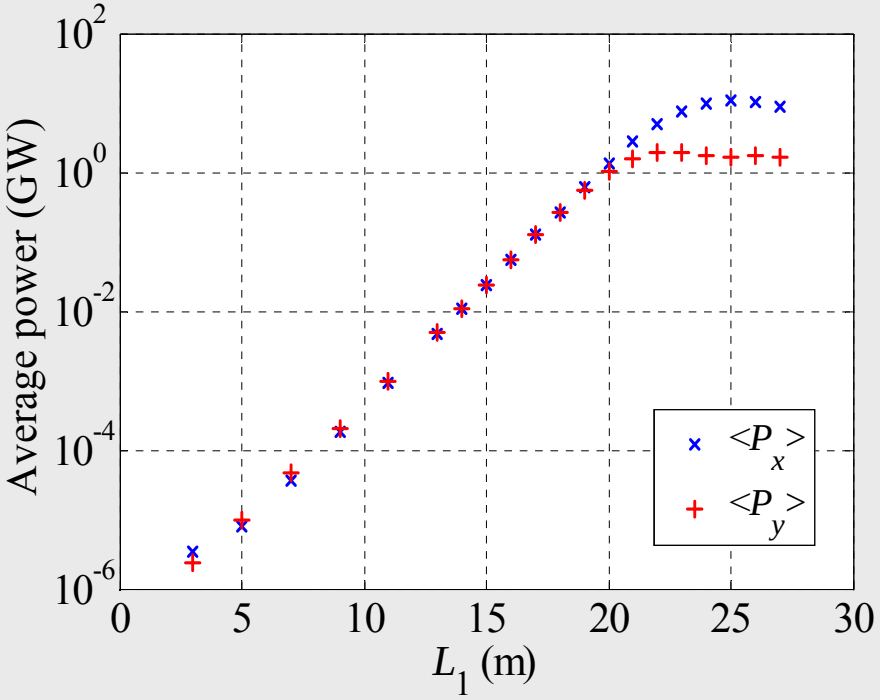
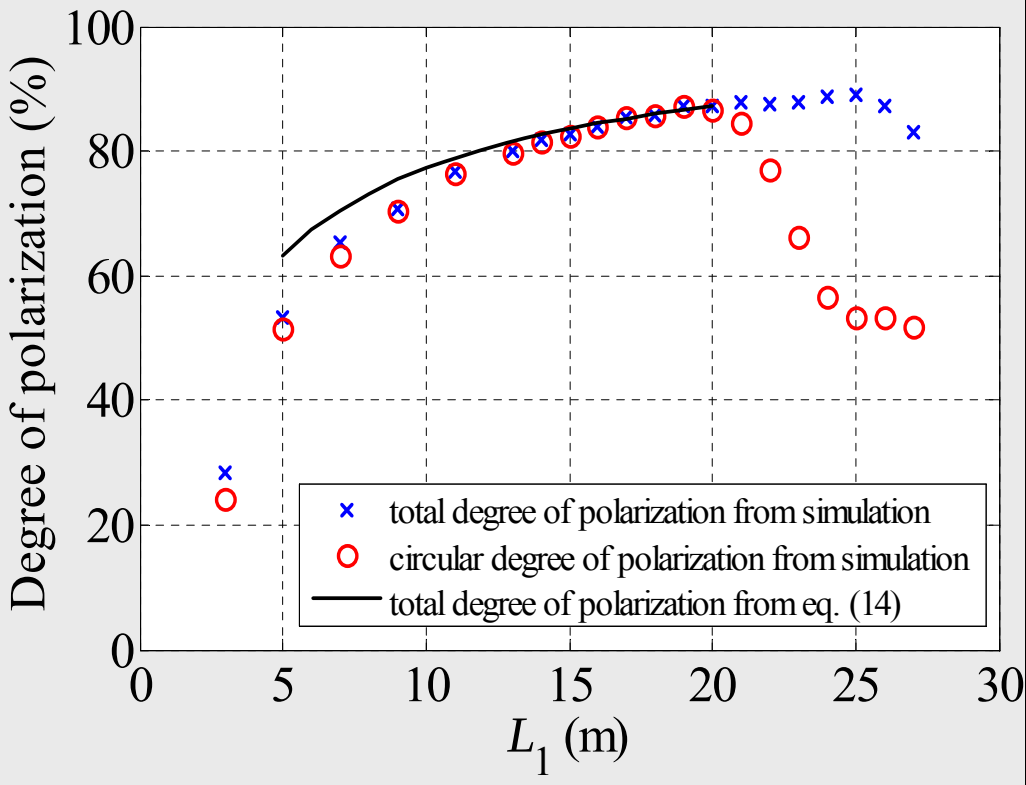
1-D simulation results of 1.5 nm

In exponential regime, to get same power, L2 = 1.3 Lg.





1.5 nm sase FEL; E = 4.3 Gev;

Emit = 1.2 um; I = 2 kA;

L2 = 1.3 Lg , (1.53m), fixed

each points with 200 runs.

(Y. Ding and Z. huang, PRSTAB **11**, 030702 (2008))

Work in saturation regime?

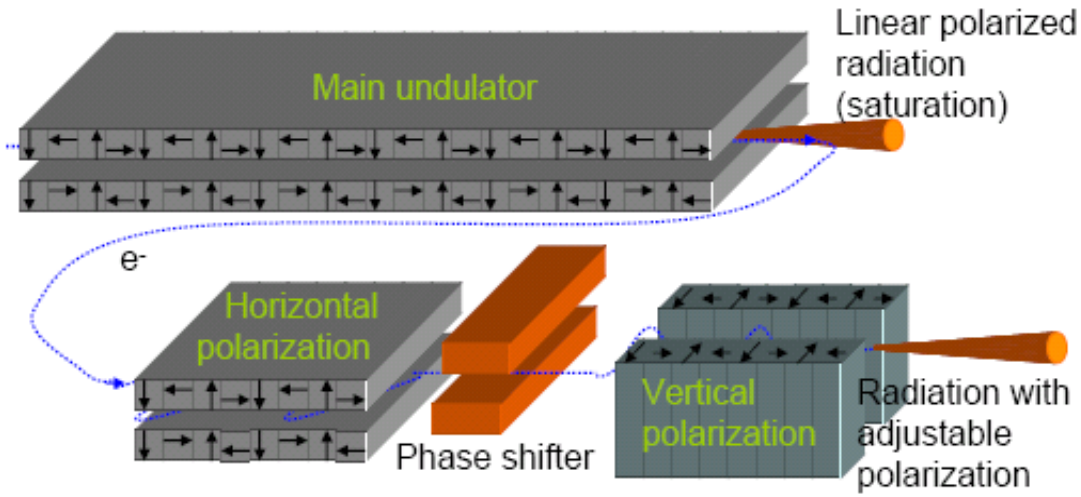
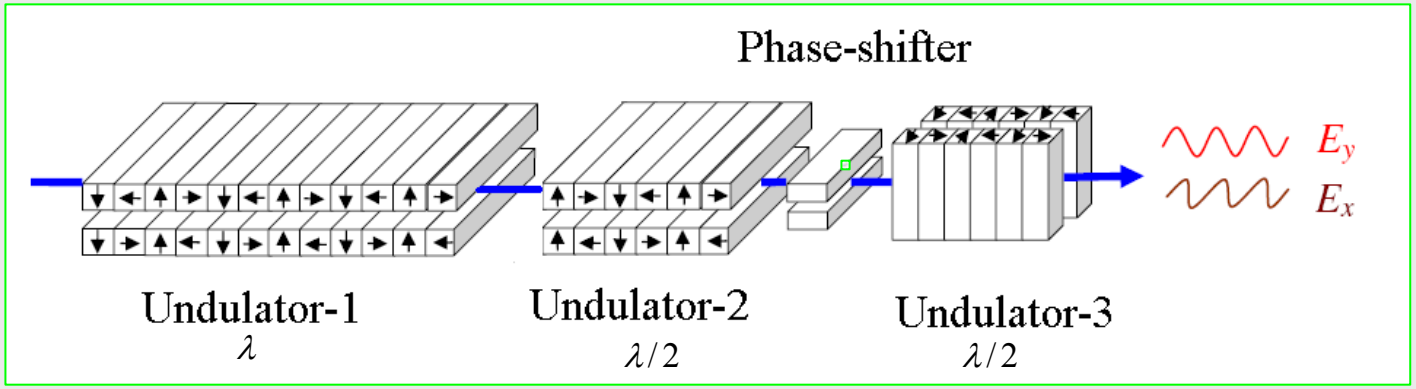


Figure 1: Modified crossed-planar undulator system for high-gain FEL generation.

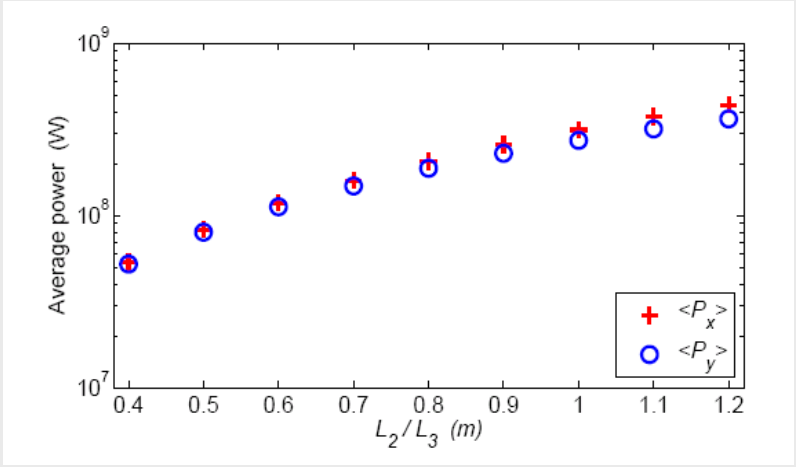
(Y. Li et al, EPAC08.)

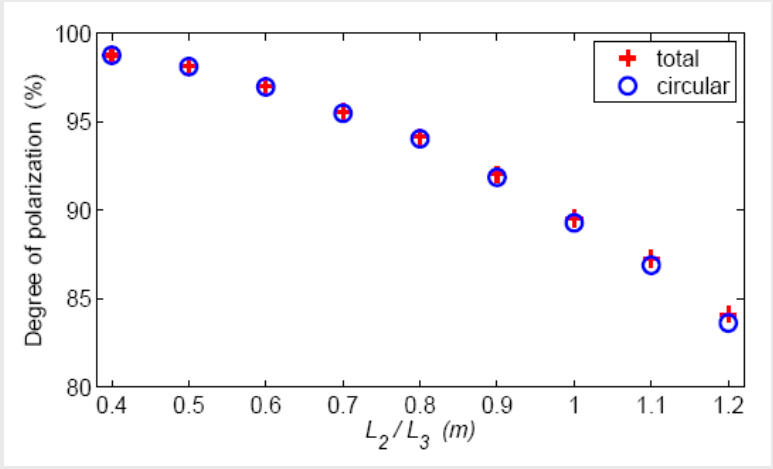
After the main undulator, the electron bunch has to be separated with the radiation Ex using bending magnets but preserve the bunching. This is extremely difficult at the x-ray wavelength.

Work in saturation regime at 2nd harmonics



- Very weak on axis 2nd harmonics from Undulator-1;
- Working in saturation regime , can combine with after-burner.

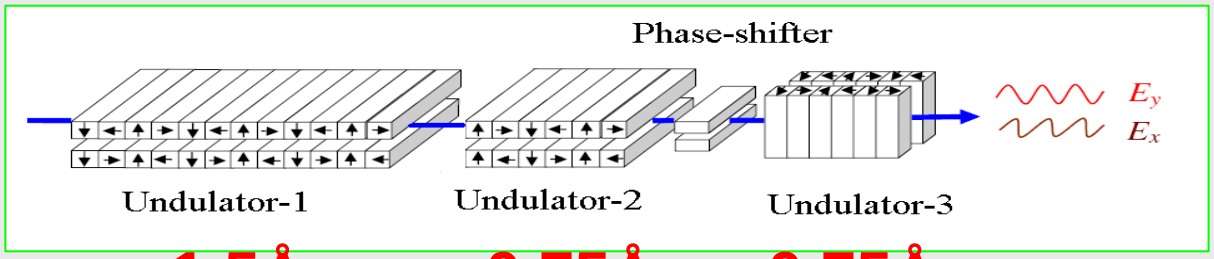




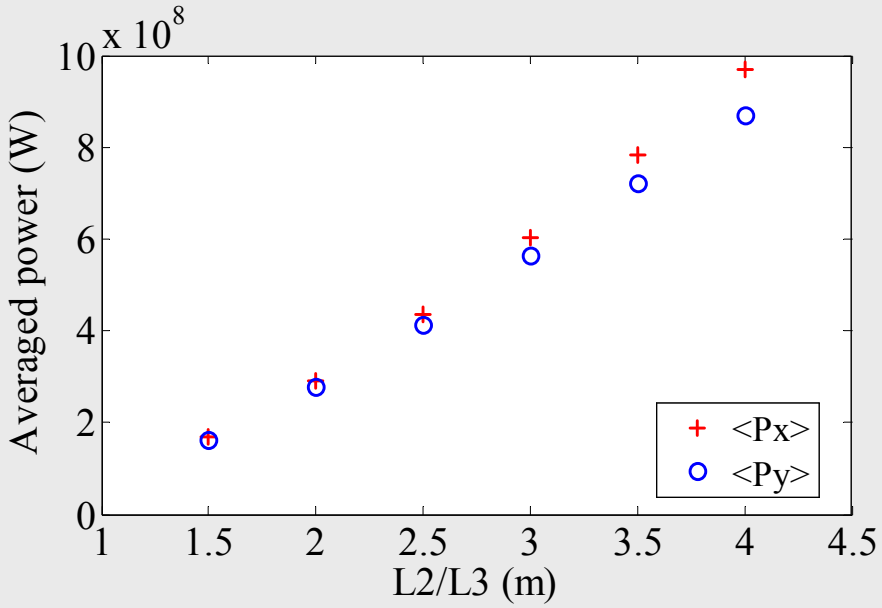
1.5 nm, 4.3 GeV, L1 = 21m (saturated), L2 = L3. 1D simulations.

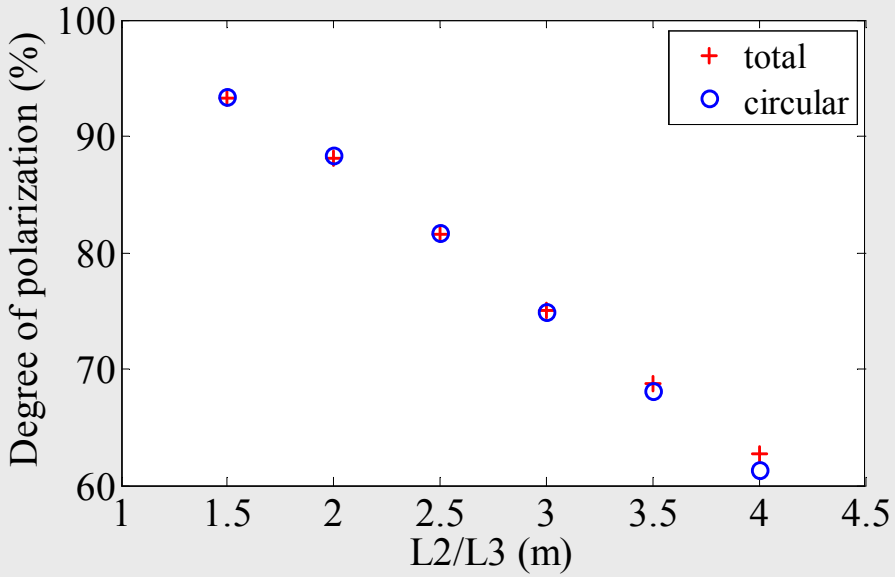
(H, Geng, Y. Ding and Z. huang, PAC09.)

Extend to hard x-ray, for 2nd harmonics



1.5Å **0.75Å** **0.75Å**





1.5 Angstrom, 13.6 GeV, L1 = 52.5m(saturated), L2 = L3. 1D simulations.

3D simulations checked by H. Geng, the degree of polarization is almost same with 1D results, but power reduced due to emittance effects.

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Summary

- Arbitrarily polarized light from SASE FELs fundamental can be generated using crossed planar undulator

  ➔ polarization over 80% near SASE saturation;

- 2nd harmonics setup at saturation regime is more robust, and can be combined with after-burner scheme;

- Pulsed dipole magnets may be used for fast polarization switch, ~100Hz is possible.

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THANKS !

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