Lightsource R&D Activities at SLAC

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5-way Meeting, Oct. 2016

U.S. DEPARTMENT OF ENERGY
Office of Science

SLAC NATIONAL ACCELERATOR LABORATORY

Source Development

- Superconducting undulator
- FEL gun and injector R&D
- Self and external Seeding
- Delta-II undulator
- attosecond pulse generation

Optics & Diagnostics

- Wavefront preserving mirrors
- Diffractive Optics
- High repetition rate beam diagnostics

Detector

- ePix family detectors
- Transition edge sensor (TES)
- vfCCD
- FLORA: hybrid CMOS imager
- Tixel: MHz 2D TOF
- PixFEL MHz

Optical laser system

- high power laser amplifier
- Wavelength extension, short pulse
- Femtosecond timing & synchronization
- manipulation of charged particles.

Sample environment & delivery

- High throughput sample delivery
- low consumption injectors
- sample environment for FEL experiments.

DAQ, control, and analysis

- Application of machine learning in machine tuning and beamline optimization
- Large scale computing for LCLS-II

Outline

Optics

- Wavefront preserving mirrors (D. Cocco)

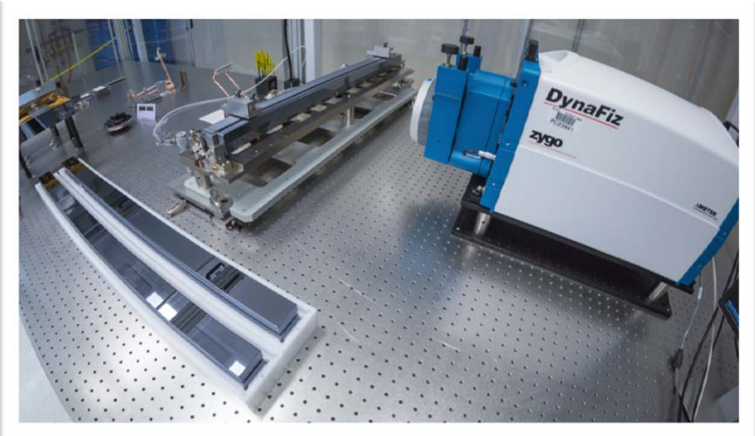
Detectors

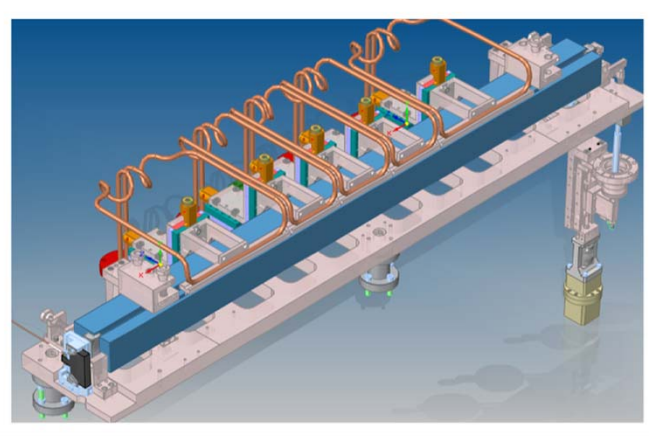
- ePix family detectors, ePix-HR (G. Carini)
- TES (K. Erwin)
- vfCCD (w LBNL)
- FLORA (w Fermi)

Source Development

- Delta-II undulator for soft x-ray polarization control (HD. Nuhn)
- Superconducting undulator R&D (P. Emma, w ANL)

Wavefront Preserving Mirrors





Mirrors requires cooling system, in-situ, at wavelength wavefront sensing, to preserve the beam quality at both X-ray FELs and Diffraction Limited Storage Rings.

At SLAC, we are setting up both metrology and simulation capabilities to support new mirror installations and their characterization/optimization.

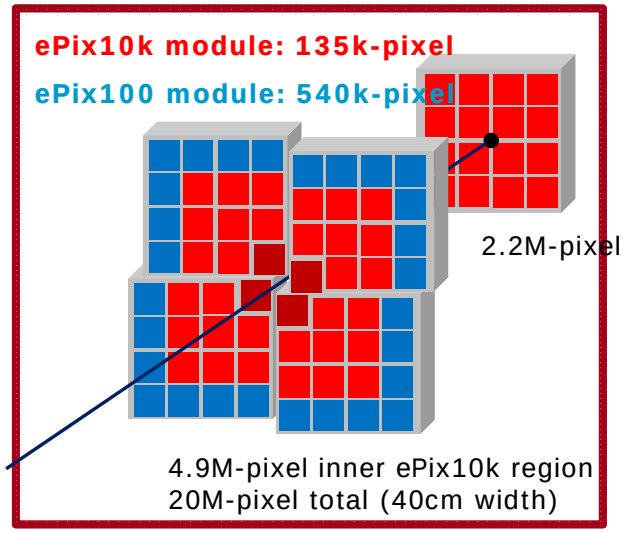
Collaborative Proposal led by D. Cocco

1. **SLAC**: Development and demonstration of the new cooling scheme.
2. **BNL**: Implementation of an 'invasive' wavefront sensor to test the cooling performance under 50-100W.
3. **LBNL/ANL**: Study of 'non-invasive' beam diagnostics (soft/hard x-ray ray).

ePix detector family (ePix100, ePix10k, etc)

Requirements

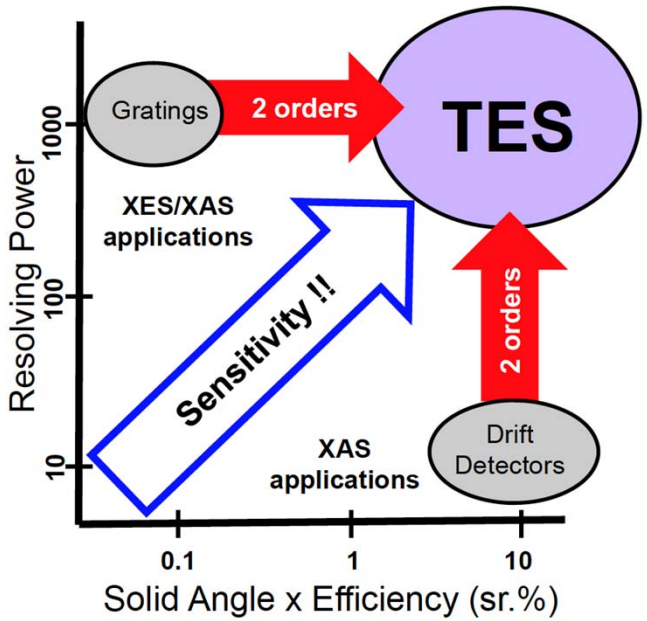
- Lower noise, higher dynamic range through gain switching.
- Scalability up to large cameras
- Easy to operate, repair, and maintain.
- Trigger and Veto capabilities at high rate.



	ePixHR100	ePixHR10k	
		High Gain	Low Gain
Pixel per ASIC	384 x 352	192 x176	
Pixel size	50 µm x 50 µm	100 µm x 100 µm	
Noise r.m.s. (eV)	270	450	7k
Maximum Signal (Ph.)	100 (8keV)	100 (8keV)	10,000 (8keV)
Frame Rate	1 kHz	2 kHz	
Pixels per camera	0.5M	Various sizes up to a Megapixel	

Gabriella Carini

TES spectrometer



Installation at SSRL BL 10-1, Robust and easy to operate!!!

Status: 1eV resolution, 240 pixels, prototype at SSRL.

Goals/Requirements

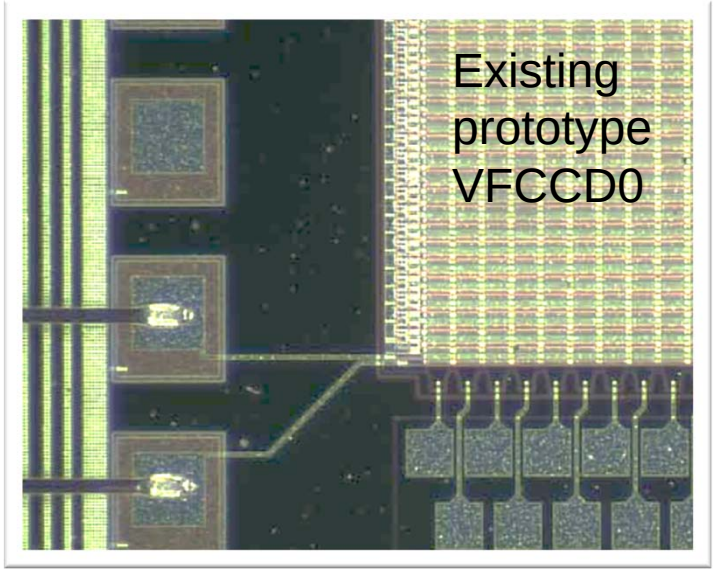
0.5 eV resolution below 1 keV, 10 – 100 kHz, 10,000 pixels.

R&D needed

1. Faster TES pixels, larger arrays.
2. High-efficiency filters for background photon rejection

Kent Irwin

VeryFastCCD – collaboration with LBNL



Spec	Value	Unit
X-ray energy	250-1200	eV
QE (at 524 eV)	≥80	%
Pixel size	~~30~~-50	µm
Substrate thickness	200	µm
Pixels	1M	
Full well	≥250	keV
Noise	≤30	e^-
Frame Rate	≥5	kHz
Form Factor	Guillotine	
Vacuum	HV (UHV option)	
Rad. Hardness (normal operation)	5	years
Operating Temp.	-70	C

An improved version of the fCCD, 1M pixel, based on thick, fully depleted LBNL CCD process.

Provide a robust path towards the delivery of a low noise, high speed and QE soft x-ray detector for the early LCLS-II science experiments.

LBNL: front end, **SLAC**: integration, DAQ, mechanics

Peter Denes

FLORA – Fermilab-LCLS CMOS 3D-integRated detector with Autogain

Motivation

Go beyond the performance achievable with conventional detector technology

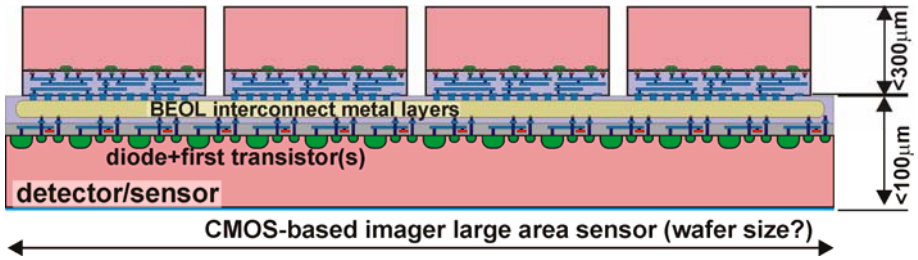
Design goals:

- ***Fast frame readout***: > 10 kHz
- ***Very low noise***: ~ 10 e-
  - ***Suitable for the soft x-ray range***

Approach

Hybrid CMOS imager (i.e. state-of-the-art imagers in cell phones)

- ***Simple CMOS sensor:***
  - Large area and high yield
- ***Complex electronics:***
  - Standard IC technology
- **Advanced interconnects**:
  - 3D or integrated electronics
    - Low noise
    - low power
    - high speed

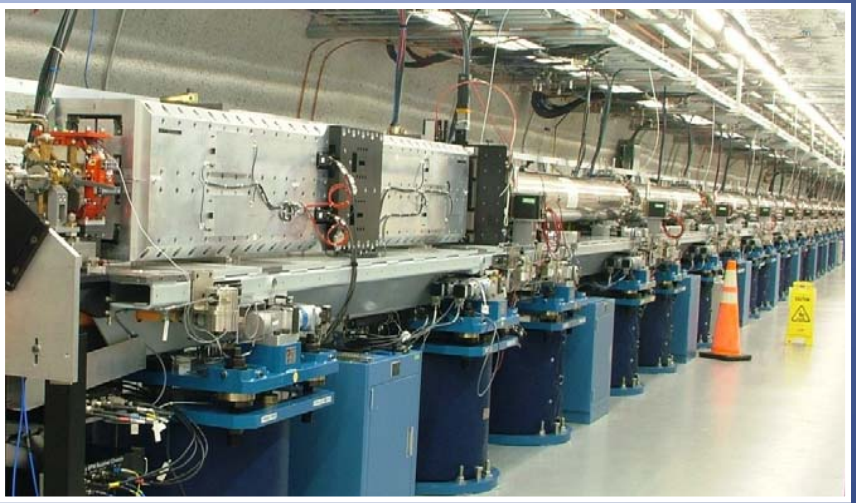


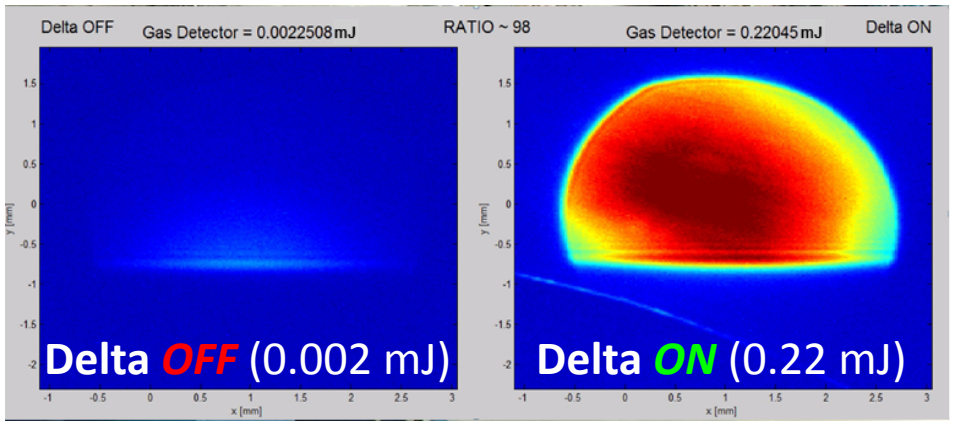
CMOS-based 3D integrated imager; known-good readout ASICs will be bonded to the large area CMOS imager

G. Deptuch

Polarization Control at *LCLS-II* (future)

- Delta-I was tested (needs adj. gap)
- Add three 3.3-m long Delta-II's at end of SXR und. (not in *LCLS-II* baseline)
- *K*-value is resonant with SXR
- Simulations: 5-7 GW (w/3 Delta-II's)
- 100% polarization (<1% stability?)
- All orientations possible (planar: x or y; circular: *L* or *R*) – change in ~1 min.





nature photonics — ARTICLES

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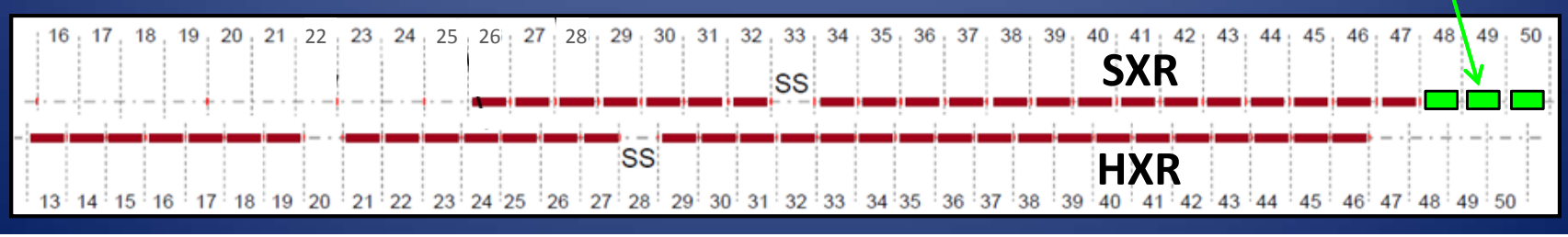
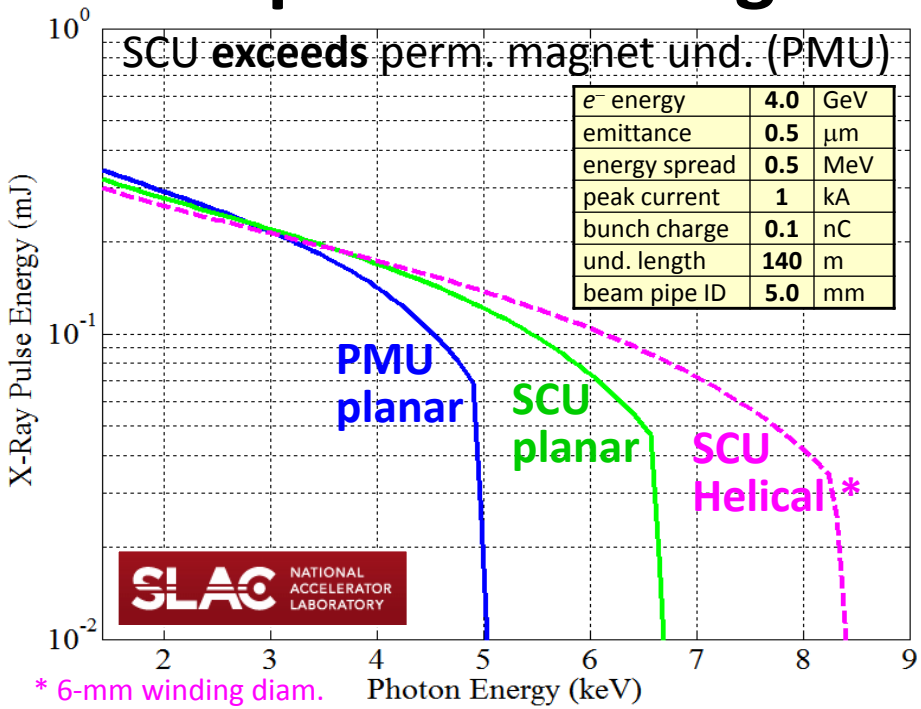
Polarization control in an X-ray free-electron laser

A. Lutman, H.-D. Nuhn, F. Peters, *et al.*

3 new Delta-II's

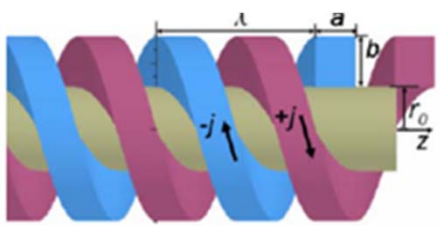


Superconducting Undulator R&D – Phase-II



e^- energy	**4.0**	GeV
emittance	**0.5**	μm
energy spread	**0.5**	MeV
peak current	**1**	kA
bunch charge	**0.1**	nC
und. length	**140**	m
beam pipe ID	**5.0**	mm

* 6-mm winding diam.

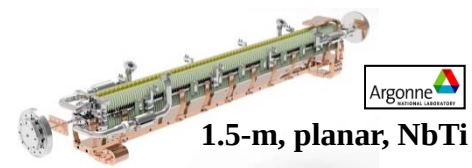


Helical SCU

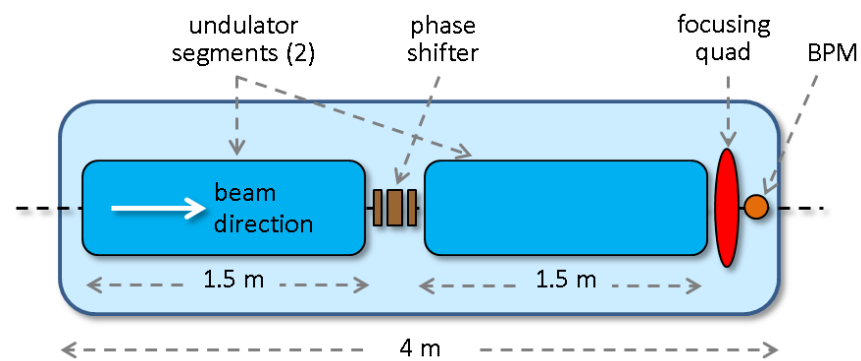
Argonne NATIONAL LABORATORY

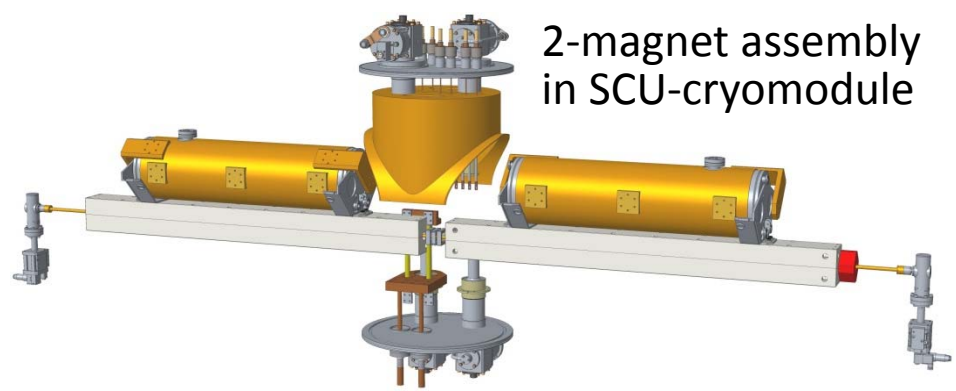
- Winding tests underway
- Proposal submitted to ***DOE/BES***
- Build SCU-module proto. in 3 yrs (5 M$)

- Finished SCU Magnet R&D in March, 2016
- 1.5-m NbTi magnet meets <u>all</u> requirements



- Next phase – design, build, and test SCU cryo-module (2 *helical* magnets, 1 cold-quad, cold phase-shifter, & cold BPM)
- Develop **alignment**, cryo, phasing, etc.





2-magnet assembly in SCU-cryomodule