Highlights from the 5th Diffraction Limited Storage Ring workshop
DESY, Hamburg, Germany

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Advanced Photon Source
Argonne National Laboratory

APS-U Forum
March 24, 2016
5th DLSR - Workshop Program

Brought together:

- Facility operations
- Accelerator physics
- Beamline technologies
- DLSR scientific drivers

2011 - Cornell
2012 - Spring-8
2013 – Stanford/SLAC
2014 – Argonne/APS
2016 – DESY/Hamburg

~100 participants
~35 Talks over 2.5 days
DLSR - Workshop Program

Day 1

Keynotes:
- Harald Reichert (ESRF) – Science Opportunities at DLSRs
- Mikael Eriksson (MAX-IV) – DLSR Machine Physics

Facility Updates

Day 2

Science opportunities
Challenges in DLSR machine physics

Day 3

Beamline technologies and instrumentation challenges
$M = \frac{\varepsilon C^3}{E^2}$


Courtesy P. Willmott (SLS)
### DLSR - Facility Updates

<table>
<thead>
<tr>
<th>Facility</th>
<th>Talk</th>
<th>E (GeV)</th>
<th>E (pm-rad)</th>
<th>Year</th>
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<tr>
<td>MAX-IV</td>
<td>P. Tavares</td>
<td>3</td>
<td>328</td>
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<td>SIRUS</td>
<td>H. Westfahl</td>
<td>3</td>
<td>236</td>
<td>2019</td>
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<td>ESRF-II</td>
<td>P. Riamondi</td>
<td>6</td>
<td>140</td>
<td>2020</td>
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<td>APS</td>
<td>G. Decker</td>
<td>6</td>
<td>47-68</td>
<td>2021</td>
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<tr>
<td>SLS-2</td>
<td>P. Wilmott</td>
<td>2.4</td>
<td>~150</td>
<td>2024</td>
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<tr>
<td>Spring-8-II</td>
<td>T. Ishikawa</td>
<td>6</td>
<td>190</td>
<td>2020s</td>
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<td>Petra-IV</td>
<td>C. Shroer</td>
<td>5</td>
<td>20</td>
<td>2026+</td>
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<tr>
<td>Diamond-II</td>
<td>R. Bartolini</td>
<td>3</td>
<td>100-270</td>
<td>??</td>
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<tr>
<td>Elettra-II</td>
<td>E. Karantzoulis</td>
<td>2</td>
<td>~250</td>
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<td>Soleil-II</td>
<td>A. Nadji</td>
<td>2.75</td>
<td>~200</td>
<td>??</td>
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<td>ALS-U</td>
<td>R. Falcone</td>
<td>2</td>
<td>50</td>
<td>??</td>
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HEPS – China (5 GeV) ; SLiT-J – Japan (~3 GeV); ......
DLSR Facility Updates - Max IV

3 GeV Ring Commissioning Timeline

- Beam in TR3: Aug 11, 2015
- First Turn: Aug 25, 2015
- Stored Beam: 0.1 mA, Sep 15, 2015
- Stacking: 4 mA, Oct 08, 2015
- First Light: Nov 2, 2015
- 120 mA: Jan/31, 2016

March 2016 DLSR Workshop 2016

Courtesy of Pedro Tavares
320 pm-rad

Sigma polarized SR, 632.8 nm, SRW calculation (left) and measured image (right). The simulation is done for $\varepsilon_x = 320$ pm rad, $\beta_y = 1.5$ m.
Both figures show a 2 x 2 mm$^2$ area of the image plane.
The fringe pattern is too weak to be visible.

Optical magnification of $m = -2.28$ is taken into account in the SRW model
Horizontal opening angle: 6 mrad
Vertical opening angle: 8 mrad
Exposure time: 2.9 ms

March 2016
DLSR Workshop 2016

Courtesy of Pedro Tavares
Building construction (~20% concluded – 03/2016)

Slide courtesy of Harry Westfahl
Expected first light/experiments early 2019
DLSR Facility Updates - ESRF

Design finalized; Currently procuring magnets

PROCUREMENT: MAGNETS

All contracts in place
More than 1000 Magnets to be procured by the end of 2018

Slide courtesy of P. Riamondi
Looking at designs with reverse bends (585° & 488°)

Slide courtesy of Andreas Streun

- 12×TBA ⇒ 12×7BA lattice: ½ + 5 + ½ cells of LGB/AB type
- Circumference 288.00 m ⇒ 287.25 m
  - in order to keep undulator positions (source points)
- Periodicity 3: 12 arcs and 3 different straight types:
  - 6 × 4 m ⇒ 6 × 2.9 m 3 × 7 m ⇒ 3 × 5.1 m
  - split long straights: 3 × 11.5 m ⇒ 6 × 5.1 m
- Beam pipe: 64 mm x 32 mm ⇒ ⌀ 20 mm
  ⇒ magnet aperture ⌀ 26 mm
Use 4BA (or 6 BA) to convert BM to ID ~3m

One DDBA cell in the existing lattice

One DDBA cell is going to be installed in the existing lattice in order to have one more beamline (no significant gain in emittance)

Dipole  Quadrupole  Sextupole

Slide courtesy of R. Bartolini
DLSR - Facility updates - Petra-IV

Circumference 2300m $\rightarrow$ ~20 pm-rad

PETRA IV at DESY in Hamburg

Transform PETRA into ultra-low emittance ring  
Starting: 2026

Slide courtesy of Christian Schroer
What about bending magnets?

ESRF CONTEXT

ESRF today has DBA 6 GeV lattice

BM beamlines use X-ray from

- 0.856 T dipole $E_0=20.5$ keV, 6 mrad max
- 0.4 T soft end $E_0=9.5$ keV, 6 mrad max
- Very productive Beamlines

ESRF II will be 7BA 6 GeV lattice

Available BM field for Beamlines:

- 0.39 T dipoles $E_0=9.3$ keV, 2 mrad max
- 0.57 T soft end $E_0=13.6$ keV, 2 mrad max

Slide courtesy of Joel Chavanne (ESRF)
DLSR - Facility Updates - Bending Magnets

ESRF considering super-bend, 2,3,4,5 pole wigglers (similar to most facilities)

Some designs need to cant quads

GEOMETRICAL CONSIDERATIONS (CONT’D)

Limited available space for insertions

Slide courtesy of Joel Chavanne (ESRF)
DLSR - Beamline/Instrumentation Challenges

Nano – Positioning
- Accuracy, speed, and stability
- Experimental and optics (monochromators)
- Vibration reduction

Optics/Cohereence
- Measure and preserve wave fronts

Detectors
- Faster detectors for higher energy

Velociprobe
C. Priessner et al. (APS)
DLSR - Beamline/Instrumentation Challenges

Stability of monochromators -> Coffee break discussions

**Reduction of vibration in LN-cooled DCM**

1) Improvement of conventional DCM: reduction of vibration with cooling; stabilization of mechanics

![Beam stabilization using improved LN2 flexible tube](image)

- Conventional
- Improved (Clear Flow Flex™)


5 µrad to 0.5 µrad

Need much larger (x10) improvements

2) New optical scheme

Courtesy of M. Yabashi (Spring-8)
DLSR - Beamline/Instrumentation Challenges

ESRF working on high-Z sensors (CdTe, GaAs, ...) for pixel array detectors

**FIRST 5X1 CdTe DETECTOR**

- **1280 x 256 pixels**
- **75 mm x 15 mm field of view**
- Slim edge sensors (100 um)
- **30 um gap in between modules**
- Alignment precision < 1 pixel over the whole width

Slide courtesy of Marie Ruat (ESRF)
DLSR - Beamline/Instrumentation Challenges

- Spring-8 working on wide band-pass optics to take advantage of suppressed off harmonic intensity (SLS)
- Not all techniques need energy resolution of Si/C mono

Classification of applications for SPring-8 II

SP-IVU to produce high energy x-rays in lower-order, well-separated harmonics

Achromatic mirror optics

ML mirror/CRL

Ultra-stabilized DCCM

 Courtesy of P. Willmott (SLS)

 Courtesy of M. Yabashi (Spring-8)
DLSR - Science Opportunities

Nano-focusing
- “The ultimate 3D microscope”
- “Taking flux starved techniques into the nano-world”
  - ✓ High-pressure
  - ✓ RIXS
- Serial MX (SLS, ESRF, DESY, …)
- Looking at materials processes in-situ at ultra-fast time-scales (additive manufacturing)

Coherence
- “Atomic scale dynamics down to nano-seconds”
- $10^{4-6}$ speed-up in dynamics for XPCS
- XPCS in complex environments
- CDI on nano-particles undergoing chemical reactions
DLSR - Science opportunities

X-ray ptychographic tomography

Pilatus 2M

Energy: 6.2 keV

Mouse bone specimen

Voxel size: 65 nm
Resolution: 120 nm
Dose: 2MGy

M. Dierolf et al., 467 Nature (2010) 436

Slide courtesy of Ana Diaz (SLS)
Hierarchical imaging using ptychography

The EIGER “selfie” M. Guizar-Sicairos et al., Opt. Express 22 (2014) 14859

- 500 μm x 290 μm image
- 41 nm resolution
- 25,000 resolution elements / second
- Effective dwell time of 40 μs / resolution element

Slide courtesy of Ana Diaz (SLS)
DLSR - Safety

Altoona Hospital Room 1015A

Safety doesn’t end at the lab gate

Watch out for ice even on travel

Hamburg in March (rain + cold)