Breakout Session 2: Beamlines

Chairs: Lahsen Assoufid (APS) and Christian Schroer (DESY)

Program:

Christian Schroer (DESY)	Source parameters for optimal brilliance
Jean Susini (ESRF)	The ESRF Upgrade Programme Phase II: The Scientific Instrumentation Roadmap
Ian McNulty (APS)	Optics and Other Beamline Considerations for Coherent X-rays
Dina Carbone (Max-IV)	NanoMAX, the Hard X-ray Nanoprobe Beamline at MAX IV
Shunji Goto (SPring-8)	X-ray Optics for the Upgraded Ring SPring-8-II
Daniele Cocco (SLAC)	The Optics Challenges for the LCLS and LCLS II
Xianbo Shi (APS)	X-ray Optics Simulation and Beamline Design using a Hybrid Method
Ye Tao (IHEP)	The R&D of Beamline and End-Station Technologies in HEPS
All	Discussion

Source Parameter Optimization (C. Schroer)

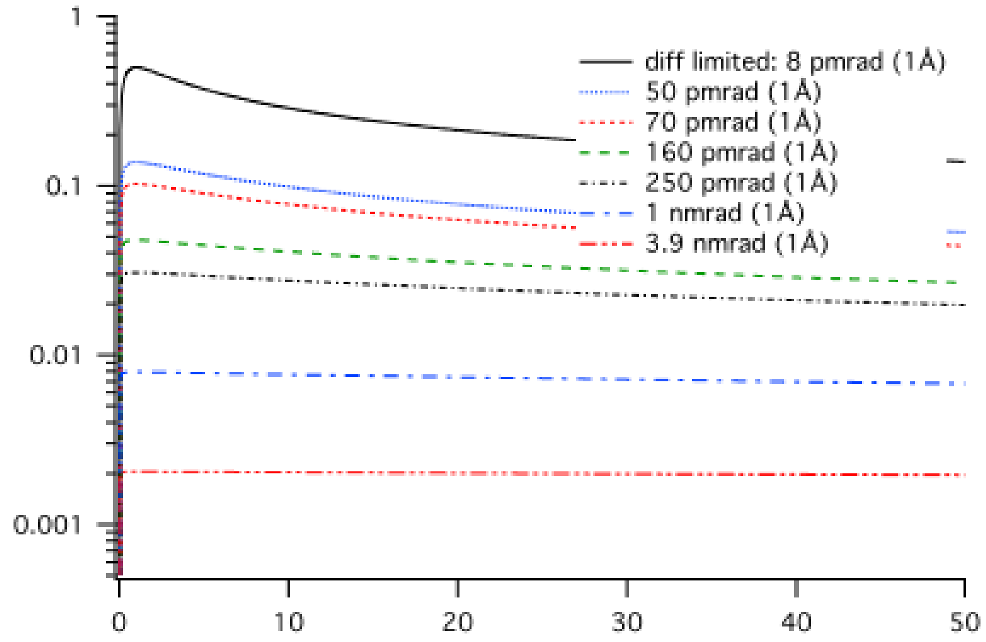
Optimal coherent fraction or brilliance:

$$F_c = F_0 \cdot \frac{l_{c_h}}{2\Sigma_h} \cdot \frac{l_{c_v}}{2\Sigma_v} \cdot = F_0 \cdot \frac{\lambda^2}{(4\pi)^2 \sigma_{T_h} \sigma'_{T_h} \sigma_{T_v} \sigma'_{T_v}} = Br \cdot \left(\frac{\lambda}{2}\right)^2$$

> Minimize emittance

> adjust β-function

When approaching the diffraction limit, optimal brilliance becomes more and more dependent on β-function in the straight section



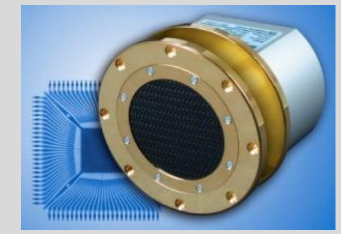
coherent fraction (1D):

$$\frac{\lambda}{(4\pi)\sigma_{T_{h,v}}\sigma'_{T_{h,v}}} = \frac{1}{\sqrt{1 + \frac{\epsilon_{h,v}}{\epsilon_0}\frac{4\pi\beta_{h,v}}{L_u}}\sqrt{1 + \frac{\epsilon_{h,v}}{\epsilon_0}\frac{L_u}{4\pi\beta_{h,v}}}}$$

THE FOUR PILLARS OF THE ESRF UPGRADE PHASE II

Ultra low Emittance SR

New X-ray detectors



4 new beamlines

Data Analysis and IT

Phase II

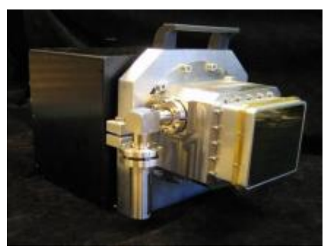
2015 - 2022

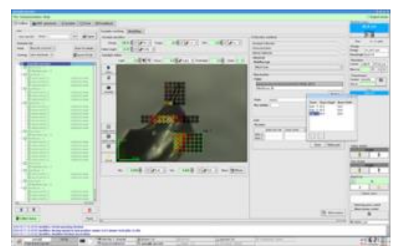
Orange book
Technical Design Study

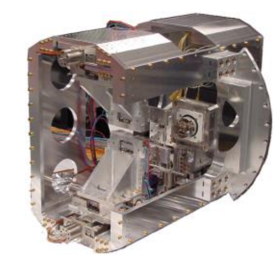
- a comprehensive overview of ESRF's strategy for the development of this instrumentation, driven by the new storage ring's performances
- a vision for the future ESRF beamline instrumentation across entire beamline portfolio

SCIENTIFIC INSTRUMENTATION ROADMAP: DRIVERS & 4 MAJOR PROGRAMS

- Transfer of the brightness/flux to the sample
- Preservation of the photon beam properties (e.g. coherence)
- Optimum conversion of brightness/flux into high-quality data
- Scientific discoveries from the recorded data







priority

1. A new detector programme with consolidation of ongoing projects on enabling technologies and development of two new 2D detector systems
2. IT and computing infrastructure: control system modernisation and data analysis platforms
3. Development of new expertise in mechatronics and on-line metrology
4. Development of advanced metrology tools and methods for X-ray optics

Optics and Other Beamline Considerations for Coherent X-rays (Ian McNulty)

Preserving Coherence

- First Law: "Do no harm"
  - Minimum use of apertures: every edge makes fringes
  - Best quality optics: maintain wavefront quality
  - Stable optics!

- Second Law: "Provide tunable coherence properties"
  - Enable trade-off between coherence for flux
  - Adjustable coherence-selecting slits, ideally focusing too

- Third Law: "Use every drop!"
  - Coherence experiments are coherent-flux hungry
  - Experiments needing temporal as well as spatial coherence even more so (E^{-3} scaling)

Issues with "small" and brilliant beams at DLSR and beamlines

Dina Carbone, Max IV

Reviewed beamline design considerations and critical issues for NanoMax (first BL at MBA source)

General considerations:

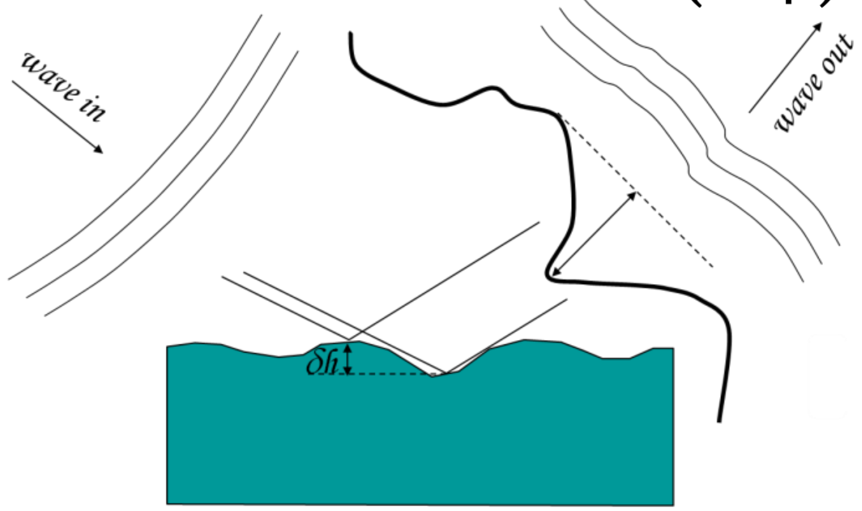
Stability	*At all levels: environment, equipment modules, sample, …* *All dimensions: real space (vibration or drift amplitudes) reciprocal space (frequencies), temperature, …*
Control	*Measurement of instabilities and Active feed-back*
Access	*Still be able to perform experiments*
Science	*Research and thirst for knowledge are the driving forces of all effort put in techniques, methods and solution*
Data / Results	*Facility: develop technical approaches and efficient data analysis tools.* *Users: contribute to the research and development of tools (detectors, sample environment …) and methods.*

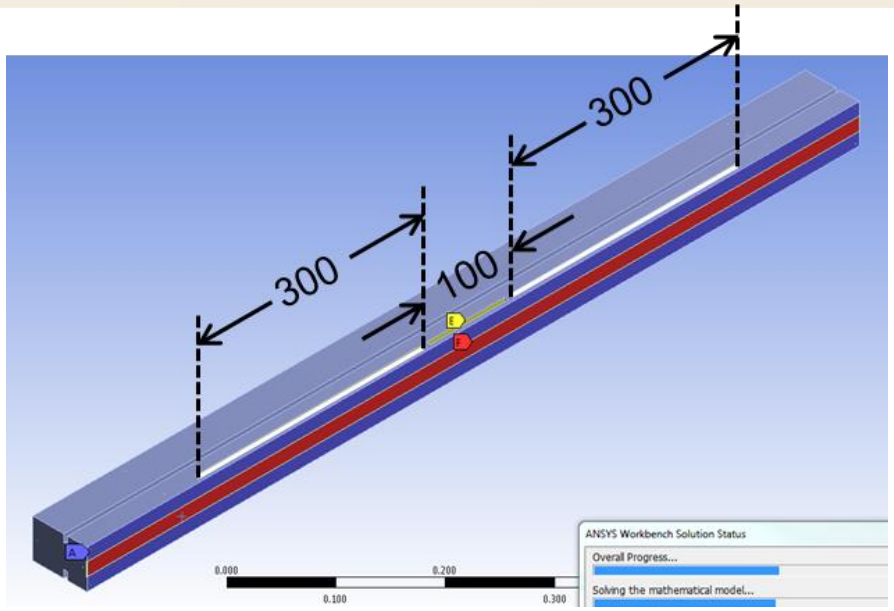
X-Ray Optics for the Upgraded Spring-8-II (Shunji Goto)

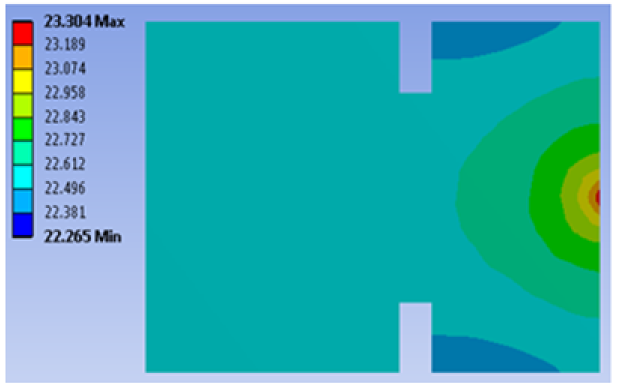
- Standard x-ray undulator beamline at SPring-8-II
  Brilliance (Coherent flux) x20,
  Photon flux x1.5 (<15 keV, 300 W @DCM)
- Coherent beam treatment under high heat load
  R&D on the speckle-free optics is still ongoing
- Bright 100-nm beam w/ direct focusing is feasible
  (~10^{13} ph/s)
- Vibration suppression of pre-optics is one of key issues
  <0.1 μrad is challenging
- *Beam diagnostics (white beam):*
  several issues @high heat load

From FEL sources (Daniele Cocco, LCLS)

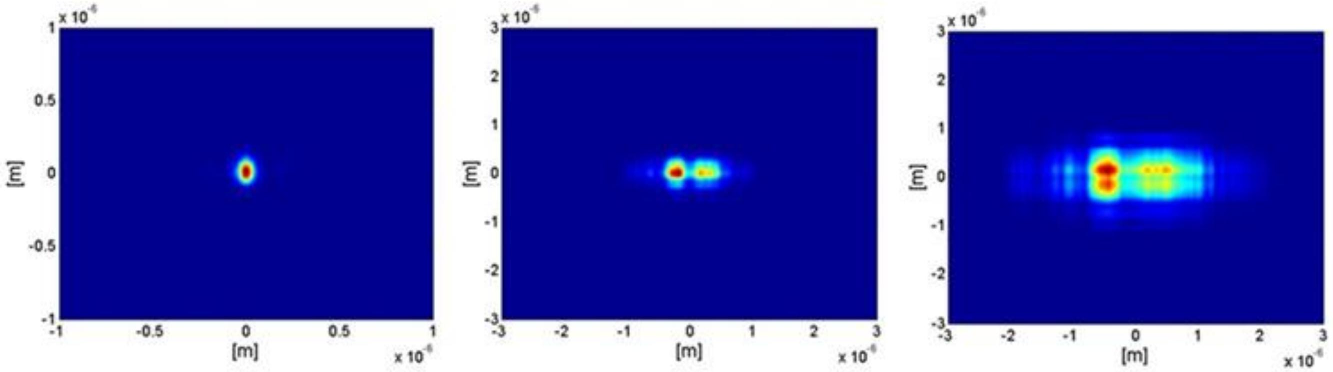
$$\text{Strehl Ratio} \approx e^{-(2\pi\varphi)^2} \approx 1-(2\pi\varphi)^2$$







200 eV, 200 W incident
T_{max} ~ 23.3°C, ΔT ~ 1°C



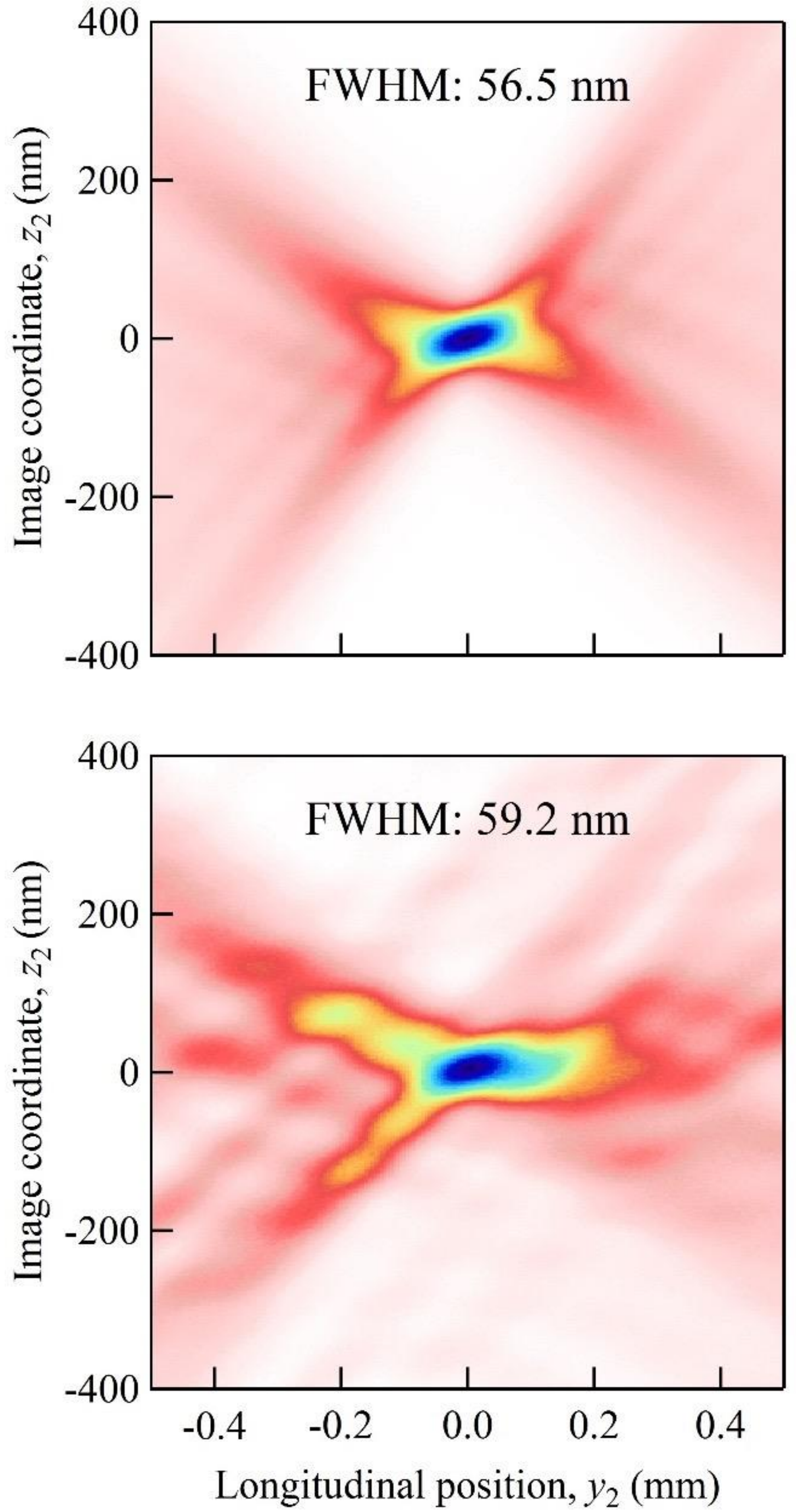
- Some problems DLSR we will face were already taken into consideration by FEL sources. DLSRs will benefit from experience gained at XFEL.
- There should be a closer discussion with the machine group.
- Cryo cooling is not an option if it produces a strong contamination of the optics. If this is not an issue it is the viable solution. It's important to have a clear feedback on the mirror contamination before pursuit on this road.
- Non-invasive diagnostics are essential for active feedback. FELs are working on this problem for years. In the HXR some good results were obtained, less in the SXR
- Mirror optimization is mandatory, including validation of the FEA models and prototyping of holders and cooling systems

X-ray Optics Simulation and Beamline Design – Xianbo Shi

- Diffraction-limited light sources: develop theories and optics simulation methods.
- A hybrid method combining ray-tracing and wavefront propagation is developed at APS for X-ray optics simulation and beamline design.
- The code is implemented into XOP-SHADOWVUI for easy user access. It is a success of inter-laboratory collaboration (APS and ESRF)
- The hybrid code is optimized for simulating apertures and reflective optics with figure errors. It efficiently accounts for partially coherent sources and is capable of calculating beam profiles along the beamline. The beam coherence can be determined through reconstructing Wigner distribution function.

Open questions (to dos):

- Needs of accurate and efficient start-to-end tool link for simulating SR sources, optics and experiments.
- Incorporate heat-load calculations with finite element analysis into ray tracing and wavefront propagation.
- Build the database of real mirror metrology data.
- Enhance collaboration among facilities to develop, standardize, and integrate simulation codes.



R&D of Beamlines and End-stations for BAPS (HEPS) (Cont'd)
by Ye Tao

Beijing Advanced Photon Source (BAPS)
5-6 GeV, 1300m ring; 6GeV, 7BA, 48pm.rad

R&D for beamlines

- High energy-Resolution monochromator: 2-3 meV
- High energy X-ray monochromator : 80-120 keV
- High Precision Bending and Metrology: 0.3/0.1μrad
- Nanofocusing: 10-30nm
- Nanopositioning, 1 nm
- Cryogenically cooled DCM: 800W, 10W/mm^2
- **R&D for end-stations**
- Ultrafast X-ray probe, sub-ps to 100ps
- dynamics extreme conditions (P-T)
- X-ray detector, APD and XPAD
- Imaging: CDI and DCT
- Experimental apparatus for engineering materials

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Beijing Advanced Photon Source (BAPS)
5-6 GeV, 1300m ring; 6GeV, 7BA, 48pm.rad

Stability:

- diagnostic for electron and photon beam
- feedback
- environment & infrastructure
- beamline optics (Monochromator)

Coherence Preservation

Detector:

- Detector Consortium for specific detectors with common interests in DLSR application
  like ones specific for XPCS, CDI/ptychography…

Discussion

Mirrors:

- State-of-the-art: ~100 nrad for 0.8-m-long mirrors
  Question: Is this sufficient for DLSRs?
- Thermal management is still a concern (especially for XFEL): Cryo-cooling
  may solve the problem.
- Concern: Would the effect of cryopumping result in possible mirror surface contamination? More R&D is needed in this area.
- Stability of bimorph mirrors is still an issue
- Demand for mirrors may be larger than supply.
- Questions:
- How to avoid the bottleneck? Is there a need for a collective effort? Is it necessary to involve the mirror manufacturers in the discussion?

Discussion

Monochromators:

- Standard DCM may not work: Stability of double-crystal monochromators (DCM) is a big concern. Limiting factors: Thermal and mechanical stability, flow-induced vibration from the cooling lines and manifolds, etc.
- Materials: Shortage of high-quality large-size crystals (diamond, sapphire, Lithium niobate, etc.), limited number of suppliers, cost.
- Polishing of channel-cut crystals to the desired quality is a challenge.
- Efforts to improve DCM stability have been initiated at various facilities (SPring-8, ESRF, PETRA III, APS…) to tackle some of these problems.
- GM/CA CAT at APS (Bob Fischetti) reported < 50 nrad stability. Question: Is this sufficient?
- Workshop has been held at ESRF to address fixed-exit monochromators design (cf. report of breakout session 4), but many more issues remain to be resolved. More focused workshops are needed.
- Question: Would an international concerted effort be needed to tackle key issues and resolve them?

Discussion

Transmission windows:

> Assessment done at SPring-8, thin CVD diamond windows used at PETRA III seem to work, more R&D may be needed…

Modeling and simulation of beamline optics is essential:

> New optics and beamline simulation (post-XOP era) tools are needed. Some progress has ben done (See talk by Xianbo Shi)

> More needs to be done, e. g., incorporate optics imperfections and thermal distortions into modeling, simulation tools for Montel mirror optics, simulation integration from source to experiment

Other requirements and issues:

> Scatterless slits, blades, or pinholes are available, thin double-sided polished crystals can be used as attenuators — this is solved

> Beam position monitors (white beam) and feedback and control systems

> Detectors

Discussion

Encourage continuing discussion between machine and beamline scientists, engineers, and users.

Acknowledgements

> Speakers of the workshop

Jean Susini
Dina Carbone
Ian McNulty
Shunji Goto
Xianbo Shi
Daniele Cocco
Ye Tao

> Contributors to the discussion session:

Edgar Weckert
Dennis Mills
Bob Fischetti
Thomas Rabedeau
Ercan Alp
Michael Sprung
(We apologize if we missed anyone!)