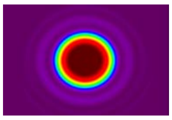

Workshop on Round Beams, 14-15 June 2017 at SOLEIL
Summary of the presentations

Benefit of using round photon beams at the sample

Gwyndaf EVANS (DIAMOND)

Introduction to macromolecular crystallography and round beams

Matching beam divergence to detector properties: divergences of beams at sample should be ~< 100 µrad. Future advances in detector technology may drive this number down.

Current issues: for many MX beamlines the vertical (electron beam) X-ray source size is much smaller than required. Creating larger beams to match sample size is not straightforward (in fact it is still a challenge for many beamlines).

Could round beams help (or more generally, versatility in e-beam parameters)? Trading off vertical beam size against horizontal to create a more isotropic source shape would potentially simplify optical configurations. A reduced overall emittance would hopefully keep horizontally divergence to acceptable levels (< 0.1 mrad), mirror optics would be smaller, required acceptance for in-line optics are smaller, working distance at sample larger.

Can machine optics and X-ray optics work together to create clean (structureless) and variable beam shapes and sizes, low divergence X-ray beams at the sample?

Andrea SOMOGYI (SOLEIL)

Benefit of the round beam for scanning hard X-ray imaging

Biology, medical sciences: with small round beam, statistically significant measurements will be readily available. After upgrade: 3D ptychography becomes available for users with increased data rate and spatial resolution. For scanning hard X-ray multi-technique tomography, a whole 3D image can be obtained with µm resolution in some hours.

Beautiful technical challenges (detectors, sample, positioning, stability, optical quality, data treatment, automatic sample preparation and handling, radiation damage).

Christoph RAU (DIAMOND)

X-ray imaging and coherence: I13 Beamline at Diamond

Imaging in direct and reciprocal space on micro- and nano- length scale: in-situ studies with dedicated sample environment, broad field of scientific applications.

Reduction of ß$_y$ vertical beta function: high brilliance. Slope ß$_x$: beam focus. Important increase of coherence. With the upgrade, important increased of brilliance. New opportunities for holography, speckle and grating. Decrease insertion device gap to use lower harmonics.

Timm WEITKAMP (SOLEIL)

Perspectives for X-ray phase-contrast imaging at SOLEIL with an upgraded storage ring

Effects of smaller horizontal photon source size for X-ray phase contrast imaging: better phase contrast. For relatively short beamlines phase contrast at medium spatial resolution (pixel sizes 10 µm and more) becomes accessible (needs long propagation distances). For long BLs (e.g. ANATOMIX) improved detection limit for weak refraction angles. Very weak density variations in matter. BLs will become more sensitive to imperfections of beamline optics and need e^- beam stability (position, direction) matched to the new, smaller beam size. BLs can obtain much higher flux density in small spot by long-distance focusing (mirror or refractive lenses). Potential for faster tomography in high resolution. Potential of using refractive lenses as monochromator.

Effects of monochromaticity: undulator harmonics become narrower with higher peaks. More monochromatic flux: good for monochromatic imaging in general, increased flux density, but we will need very good undulator phase errors as we work on higher harmonics.

Andreas MENZEL (SLS)

Ptychographic nanotomography at SLS

Reduction of longitudinal coherence may be problematic: while it can be controlled and accounted for, it limits probe size and thus affects already stringent scanning requirements.

While developments are still ongoing, X-ray ptychography has already matured to a reliable technique, sought after scientists who want to learn about their samples (and have no particular interest in the technique itself). To satisfy the increasing demand, ptychography needs to become faster and more efficient. This requires new sources and state-of-the-art optics, detectors, positioning and metrology, and computer power.

With upcoming/planned sources, the future looks bright indeed in regard to sample-limited resolution, high throughput, large sample ensembles, representative volume, increased time-resolution. However, oftentimes and already now, neither data nor image reconstruction prove "rate-limiting" in most imaging projects but the subsequent analysis, such as segmentation, parametrization and quantitative evolution. User training needs to be organized accordingly.

Ian ROBINSON (BNL)

Introduction to Coherent Diffraction Imaging

Complex density can image strain associated with nano-shape: dislocations imaged. Diffusion of Cu in Au nano-particle: porous structure generated. Bragg Projection Ptychography: 3D imaging from 2D data.

Horia POPESCU (SOLEIL)

Coherent imaging of magnetic domains on SEXTANTS beamline

Sextants beamline is adapted for coherent diffraction imaging. Coherent scattering instruments on Sextants: COMET for transmission and IRMA2 for reflectivity. Imaging techniques: holography (state of the art 15 nm resolution) and ptychography (under development). Geometries: OK in transmission but in reflectivity: we really need the round beam !

Horizontal emittance manipulations to produce round electron beams

Olivier MARCOUILLE (SOLEIL)

Undulator radiation and effect of electron beam characteristics

Undulator radiation is composed of series of lines (harmonics). The amplitude and the bandwidth of the harmonics strongly depend on the beam optics: emittance, energy spread, betatron and dispersion functions. Changes in the particle trajectory are due to magnetic defaults: intensity reduction and bandwidth increase. Adding a longitudinal field has no significant impact on the spectral performances if electron beam divergence is small.

Hitoshi TANAKA (Spring8)

Emittance control in a normal orthogonal coordinate

A lower coupling condition is advantageous for achieving higher brilliance, as long as we adopt the normal orthogonal system for the emittance range from several to 0.1 nm.rad currently available. As the emittance decreases, the sensitivity to the coupling ratio goes down, but the sensitivity to beta functions is enhanced.

Pantaleo RAIMONDI (ESRF)

Horizontal-vertical emittance exchange schemes in a ring

The emittance exchanger has the potential to lower the horizontal emittance in the Insertion devices. The optics requirements for the transport line are easy to meet with the present technology. The requirements for the undulator and solenoid are very challenging. Jx/Jy trade off could be an intermediate (and tunable) step toward round beams. Potentially almost the same gain in the horizontal emittance is obtained by coupling the ring ex => ex/2, while keeping a very small vertical emittance. The requirements for the Robinson wigglers are very challenging but similar to the state of the art of present in-vacuum undulators.

Joël CHAVANNE (ESRF)

Photon beam from an undulator in the case of an emittance adapter

Brilliance of photon beam from undulator in a emittance adapter is limited due to large beta function value of round electron beam. A better beta function matching requires a priori very high solenoid field or very long undulator.

Undulator technology: staggered undulator concept seems interesting with an emittance adapter (the undulator field is generated by the solenoid field). Other types of undulator (conventional permanent magnet undulators, superconducting undulators) probably need more studies.

Pascale BRUNELLE (SOLEIL)
Application of the emittance adapter to SOLEIL and MAX IV
A comprehensive study has been performed to evaluate the benefit of the emittance adapter for SOLEIL and MAX IV electron beam configurations. Dedicated tools were developed to calculate the emitted radiation and its propagation to the diaphragm. For the two SOLEIL beamlines tested as example, it has been demonstrated that the gain in flux density at the sample is mainly due to the reduction of the horizontal electron beam size at source. A reduction by a factor ~3 is obtained on the present SOLEIL and MAX-IV storage rings with a 10 T solenoid field (perfect adaptation is obtained with a solenoid field of ~140 T for an undulator length of 2 m). The present design of the two beamlines should be optimized to benefit from a small horizontal photon beam size. During this Round Beam project, photon users, optics and radiation experts, accelerator physicists worked together in a very pleasant and efficient way.

Peter KUSKE (BESSY)
Review of methods to produce round beams
Four techniques for the production of round beams have been proposed: radial wiggler fields, the Möbius accelerator, artificial excitation of the coupling resonance with special magnet and sitting on the coupling resonance and tune shift with amplitude. These techniques require careful tune stabilization or adjustment of excitation frequency and strength of coupling fields (skew gradients or solenoid field).

Technical Approach	Injection	Emittance Control	Complexity
Radial Damping Wigglers	off-axis	Yes	large
Möbius Accelerator	on-axis	no	challenging
Coupling Resonance Excitation	off-axis	(no)	moderate
On Coupling Resonance	on-axis off-axis, tune shift with amplitude	(no) (no)	challenging trivial

Discussion
What is the ideal beta function at source point (organize a workshop)?
Possibility of local adjustment of the beta function?
Operation of the ring should be flexible.
What is asked by the temporal structure community?

Optimized beamline for coherent round photon beams

Oleg CHUBAR (BNL)

Simulation of propagation of coherent and partially-coherent photon beams across beamlines

High accuracy partially-coherent synchrotron radiation emission and propagation calculations for light sources are possible and (more-or-less) feasible with SRW code. Many applications are possible, including simulation of performances of insertion devices, X-ray optics in beamlines, and in some cases entire user experiments.

Creating "round" electron beams in new low-emittance storage rings looks attractive for cases when round radiation spots at sample are required. This can result in gain in brightness and coherent flux and facilitates manipulations with / conditioning of X-ray beam. However, "matching" of single-electron undulator radiation angular divergences and source sizes with those of electron beam is important. Any particular case can be studied using partially-coherent simulations.

Konstantin KLEMENTIEV (MAX IV)

Rigorous simulation of partially coherent waves from undulator to sample

xrt calculates undulator sources reliably and quickly. Undulator source in xrt can have custom magnetic field. xrt offers wave propagation that can be freely intermixed with ray tracing. xrt can work with fields with very complex wave fronts such as vortex (singular) waves. The coherence properties can be analyzed by Eigen mode decomposition (or PCA) of mutual intensity. This method gives a reliable evaluation of coherent fraction which is invariant of the screen position.

Thierry MORENO (SOLEIL)

Synchrotron beamline design

Optical simulations are essential in the design and the construction of synchrotron beamlines. Through the description of a bio-crystallography beamline, the simulation tools employed in the design of Soleil hard X-ray beamlines are reviewed and analyzed. Important metrology characterization such as slope errors and roughness or thermal deformations of optics are taken into account in ray-tracing calculations. Using experimental results, it is possible to identify and correct for them at the beamline. The use of a new generation of round beam sources with emittances of 100 pm.rad should allow Soleil hard X-ray beamlines such as PX1, to increase by two orders of magnitude the photon beam densities focused on the sample. In order to fit to this new type of synchrotron sources, the beamline will have to be completely re-designed, the stability and the quality of the beamline optics being the major constraints.

Raymond BARRETT (ESRF)

Beamline Optics for Small Round Beams

Flat versus Round beams: often mirrors are used in horizontal deflecting geometry to mitigate the effects of 'moderate' mirror quality. This benefit would be lost with round beams (but relaxed for vertical deflection). Highest flux nano-probe beams tend to be formed using KB mirror pairs which partially compensate the beam asymmetry. Use Montel mirrors as alternative? Increase of vertical source size would penalize beamlines aiming for highest energy resolutions and those aiming to maximise transverse coherence.

X-ray optics are constantly improving but do not yet preserve the source emittance. An increase in the vertical emittance in a round beam scheme might relax some of the optical constraints but would not be desirable for certain applications.