326
doi:10.1017/S1431927618013958
Microsc. Microanal. 24 (Suppl 2), 2018

Optics and Coherence at the Soft*i*MAX Beamline

Karina Thånell[1*], Walan Grizolli[2], Konstantin Klementiev[1], and Rami Sankari[1,3]

[1.] MAX IV Laboratory, Lund University, Lund, Sweden
[2.] Advanced Photon Source, Argonne National Laboratory, Lemont IL, USA
[3.] OptoFidelity, Tampere, Finland
* *karina.thanell@maxiv.lu.se*

The MAX IV 3 GeV ring is a diffraction-limited storage ring, producing photon beams with a very high brilliance ***B*** and extremely low emittance **ε**; which scale inversely with each other: $\mathbf{B} \propto 1/\varepsilon_h\varepsilon_v$ where *h* and *v* are the horizontal and vertical components, respectively. The emittance is a measure of the size **σ** and angular spread **σ**' of the electron beam. Because the bending (dispersion) plane of a storage ring is horizontal, the corresponding beam size σ_h, and divergence σ_h', are significantly larger than the vertical components σ_v and σ_v'. For the 3 GeV ring σ_h/σ_h' is 48/5.3 versus $\sigma_v/\sigma_{v'}$ = 3/1.5 in µm/µrad [1]. The coherent photon flux, F_{coh}, available at the beamlines scales also inversely with emittance as $F_{coh} \propto \lambda^2/4\varepsilon_h\varepsilon_v$ with λ the wavelength of the photons. Soft x-rays are therefore particularly well-suited for coherent x-ray experiments. The 3 GeV ring produces soft x-rays beams that can be considered completely coherent in the vertical direction, but horizontally they are only partially coherent. Important questions to explore are then how can we preserve the coherence along the beamline and how do we maximize the horizontal coherence at the sample position?

We addressed this during the Soft*i*MAX beamline (275 – 2500 eV) design, which will have two branch-lines for imaging applications: one is for Scanning Transmission X-ray Microscopy (STXM) and Ptychography, and the second branch is dedicated to Coherent X-ray Imaging (CXI) techniques, including Coherent Diffraction Imaging and Fourier Transform Holography, amongst others.

Optics	**M1**	**M2**	**PG x2**	**M3$_{CXI}$**	**M3$_{STXM}$**	**M4**	**M5**
Shape	Cylinder	Plane	Plane	Toroid	Toroid	Elliptical	Elliptical
Deflection	Hor	Vert	Vert	Hor	Hor	Vert	Hor
Distance (mm)	24000	Variable	26000	28800	30500	46100	46500
Inc. Angle	1°	0°-9°	0°-7°/ 9°	1°	1°	1°	1°
Coating (40 nm)	Au & Rh	Au, Rh AlF3	Au & Rh	Au	Au & Rh	Au	Au
Roughness max (Å)	3	3	3	3	3	3	3
Slope error (arcsec)	0.1/0.25	0.035/ 0.07	0.02/0.04	0.1/0.25	0.1/0.25	0.01/0.05	0.01/0.05
Entrance arm (mm)	-/24000	-	-	28800/∞	30500/∞	5300	5700
Exit arm (mm)	-/∞	-	-	12000	8000	2600	2200
Parameters (mm)	ρ = 837.7 ± 0.25%		l/mm / blaze	R= 970707.2	R= 726279.5	y_0=60.883 z_0=1350.2	y_0=55.404 z_0=750.21
			300 / 0.6° 1200 /1.0°	ρ = 418.9	ρ = 279.2	a =3950.0 b = 64.79	a =3950.0 b = 61.80

Table 1: Soft*i*MAX beamline design parameters, distances are relative to the center of the undulator.

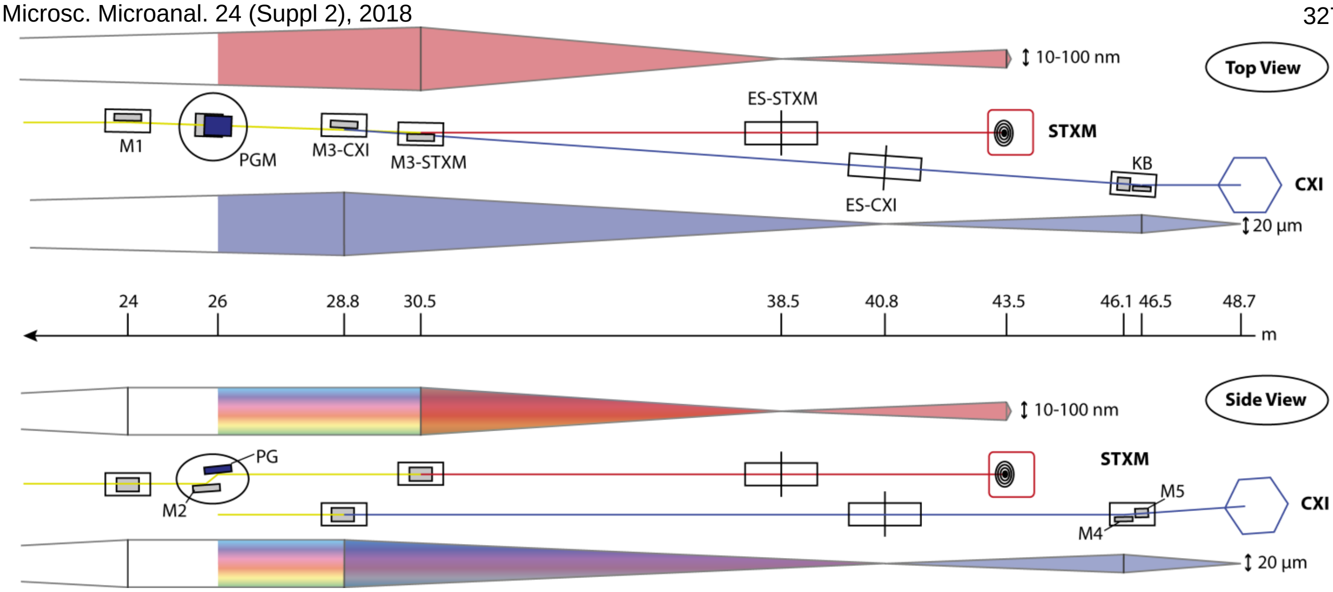

Figure 1: Schematic layout of the Soft*i*MAX beamline, see Table 1 for label explanation.

For the preservation of (spatial) coherence competing views exist: either create an intense secondary source, or do not disturb the light with optics, just propagate the beam. Some optics is always needed for meaningful experiments (*e.g*. a monochromator) but it is generally agreed that non-ideal mirror surfaces can have a devastating effect on coherence. We have studied the effects of mirror roughness and slope errors in full wave propagation methods as provided by XRT [2]. We found that 'perfect' optics is critical for coherence only after the exit slit. Preceding optics, on the other hand, affects only the coherent flux. The two Kirkpatrick-Baez (KB) mirrors on the CXI branch can therefore crucially affect the beam coherence, with especially mirror roughness dramatically reducing the coherence at higher energies (>2keV) when larger than 2-3 Å.

The energy dispersive plane of the Soft*i*MAX beamline is vertical, which leaves us free to monitor the horizontal degree of coherence by studying the effects of horizontal focusing to create either a secondary source or allow free horizontal propagation. This can be done with the choice of M3-CXI mirror, placed upstream of the exit slit: a toroid produces stigmatic focus at the exit slit plane, which then works as a secondary source, whereas a sagittal cylinder leaves horizontal focusing and acceptance angle selection to the KB mirrors (especially M5-CXI). Intensity and degree of coherence (DOC) are then linked through the percentage of illumination of the KB focusing mirrors. In simulations, this was realized by a combination of pre-KB baffles and the adjustable exit slit. Results show that both alternatives can deliver equal flux/coherence curves, but the stigmatic focus moreover offers the possibility to decouple the spot size, defined by the exit slit, from the flux/coherence control, provided by the baffles, and was therefore chosen as the preferred design for Soft*i*MAX, as depicted in Figure 1 and with parameters summarized in Table 1.

References:

[1] https://www.maxiv.lu.se/accelerators-beamlines/accelerators/accelerator-documentation/3-gev-storage-ring/
[2] K. Klementiev and R. Chernikov, https://pypi.python.org/pypi/xrt

Acknowledgements: Although not directly involved in this coherence study, the Soft*i*MAX team includes Jörg Schwenke and Igor Beinik for everything else. The Soft*i*MAX beamline is funded through a grant from *Vetenskapsrådet*; the Swedish Research Council.