*SoftiMAX**

External collaborations	SOLEIL, KTH
Original budget and funders	Investment budget 94.4 MSEK, SRC
Official start	March 2014
Expected date of completion	January 2019 (commissioning users from autumn 2018)

The SoftiMAX beamline exploits the best of the brilliance of MAX IV: coherent soft X-ray microscopy using either a nano or micro beam to push the boundaries of resolution. The Scanning Transmission X-ray Microscopy (STXM)/ptychography branch will provide spectroscopy and phase maps (≤10 nm resolution) for many different scientific fields, ranging from e.g. environmental science to magnetism, catalytic chemistry, and the life sciences. The Coherent X-ray Imaging (CXI) branch will aim at studying materials and magnetic samples using Fourier transform holography and (magnetic) X-ray resonant scattering. This branch can also be used for time-dependent measurements to study dynamics in materials and life science samples. SoftiMAX will moreover provide an excellent platform for developing novel techniques using highly coherent beams on the nanometer (point probe) or micrometer (full field) scale.

Technical description

Energy range 275 – 2500 eV, full polarisation control, focus diameter: 10-100 nm (STXM/ptycho) / 20 µ (CXI).
Flux: up to 10^{11} in a diffraction limited spot (25 nm ZP, STXM/ptycho), up to $5x10^{13}$ in a 20 μm^2 spot (CXI).
Sample environment (STXM/ptycho): vacuum chamber with fast fly scan stage & point detector (MHz, STXM), fast 2D detector for ptychography (>100 frames/s), LN2 cooling & cryo transfer, possibility for different sample environments (e.g. hydrated, electrochemistry, magnetic field), fluorescence detector.
Sample environment (CXI): UHV chamber with in-plane goniometer, small pixel-high dynamic range 2D detector, thermostat (<20K), and magnetic sample environment (1-2T)

Technical implementation:
EPU (48mm period, collimated plane grating monochromator (330 l/mm, 1200 l/mm), zone plate refocusing (STXM/ptycho), Rh-Au coated mirrors (STXM), KB refocusing (CXI),
CCD with fast read-out speed (STXM/ptycho), large CCD with low read-out noise, small pixel size (CXI), direct data pipeline to parallel computing cluster.

Present status

Optics: in production (Kirkpatrick-Baez mirrors (KB) system in procurement phase).
Infrastructure: under construction. Undulator: designed. Front end: Final Design Review (FDR) stage
STXM/ptycho end station: is in design phase (combining fast scanning, tomography & LN2)
CXI end station: updated science case, requirements and capabilities.
Data analysis: (with NanoMAX & IT-group) towards 2D ptychography tests.

Expected status end 2018

The STXM/ptycho branch: fully commissioned. End station is in its final stages of commissioning and the first wave of regular users is planned, some more advanced options (3D tomography, LN2 sample transfer) are still on the horizon. The CXI branch: end station factory acceptance test (FAT) reached and KB commissioning ongoing.

Major partners and additional funding

The MAX IV-SOLEIL project has funded a magnetic sample environment for the CXI side as well as coherence diagnostics for both branches. Zone plate development is done in collaboration with U. Vogt (Biox, KTH). Data analysis/handling will hopefully benefit from a grant proposal to the Swedish Foundation for Strategic Research, involving MAX IV, Uppsala (F. Maia: Advisory Board SoftiMAX) and others.

Changes made since the start

Recruitment of a second scientist (CXI) has taken 1.5 year: the CXI branch is therefore behind the STXM/ptychography side in maturity. CXI has expanded to include both transmission and reflection experiments. Appropriate tools for coherence evaluation had to be developed simultaneously with the detailed

* https://www.maxiv.lu.se/accelerators-beamlines/beamlines/softimax/

optical design (K. Klementiev, MAX IV Laboratory). Intensities at STXM/ptycho imply faster scanning than currently (commercially) available.

Comparison to beamlines world wide

CSX-1 at NSLS II (USA) (https://www.bnl.gov/ps/beamlines/beamline.php?b=CSX-1)
SEXTANTS, HERMES at SOLEIL (France) (http://www.synchrotron-soleil.fr/Recherche/LignesLumiere/HERMES)
ID08 at Diamond Light Source (UK) (http://www.diamond.ac.uk/Beamlines/Spectroscopy/I08)
SM at CLS (Canada) (http://exshare.lightsource.ca/sm/Pages/SM-Home.aspx)
11.02/5.3.2.1/Cosmic at ALS (USA) (https://www-als.lbl.gov/index.php/beamlines/beamlines-directory.html)

Future development

The unprecedented coherent flux will give rise to observing smaller effects (e.g. magnetic, orbital) and push the boundaries of resolution (towards 1 nm in ptychography) and become more turnkey, easily useable even for inexperienced users. Simultaneously, the intense beam will allow new coherent techniques to be developed.

The energy range of the beamline can quite readily be expanded to 3 or 4 keV, and then optimised by purchasing a multilayer grating.

A second end station can be added to either the STXM/ptycho and CXI branches to tailor more specifically to the high or low energy range/new coherence techniques/specific scientific areas, such as strong magnetic fields/bio-imaging/3D-tomography/time-resolved (laser, beam chopper) - it remains to be seen which scientific areas will come to dominate the user community at SoftiMAX.

Crucial to stay at the forefront in all areas are the 2D detectors, which will have to be replaced with newer models after a number of years in service.

Zone plate development and production: with Biox (KTH) especially important for the tender hard X-ray range and 'special' designs for new coherent techniques.

We also support a common surface science and material science facility at MAX IV Laboratory that our users can use to prepare (microtome/ultratome) and characterise (SEM, IR) their samples before, during, and after beamtime.

Data analysis is crucial for indirect imaging methods like ptychography and diffraction-based 3D tomography. Robust algorithms, on-the-fly analysis and fast data transfer are a must. Efforts together with NanoMAX, MedMAX and other relevant (imaging) beamlines are ongoing.