NanoMAX[*]

External collaborations	KTH, LU
Original budget and funders	103.4 MSEK, KAW and 12 Swedish Universities
Official start	September 2011
Expected date of completion	Regular users on ES2 starting in Mar 2017 (with limited performance, i.e. 2D scanning fluorescence microscopy at 8-10 KeV incident X-ray beam), in parallel with commissioning activities. User dedicated beamtime will steadily increase along with the increased tested abilities of the beamline. ES1 Commissioning starting late 2017.

NanoMAX, the hard X-ray nanoprobe of MAX IV is designed to take full advantage of MAX IV's exceptionally low emittance and the resulting coherence properties of the X-ray beam. The use of diffraction-limited optics will allow producing tightly focused coherent beams enabling imaging applications using diffraction, scattering, fluorescence and other methods, at unprecedented resolution. NanoMAX will offer exciting applications for a wide variety of research fields, such as materials science, life and earth science, physics, chemistry and biology.

Technical description

The beamline will have two experimental stations (ES). ES 1 is based on Fresnel Zone Plate (FZP) optics for obtaining extremely tight beams. ES2 is based on KB mirrors providing a working distance of 100 mm and allows for a more flexible sample and detector geometry at the expense of a larger focal spot.

Design goals:

E-range: 5-30 keV; Focus: ES1 30 nm (10 nm ultimate goal), ES2 50-200 nm with KB mirrors.

ES1: 2D and 3D imaging with the highest possible direct resolution using fluorescence and scattering; in vacuum operation; cryocooling; microheaters/fluidics as used in Transmission Electron Microscopes.

ES2: 2D and 3D diffraction in local probe and microscopy mode. Direct and inverse imaging methods with fluorescence and scattering. 2-axis goniometer and robot for detectors. Sample environment up to 5 kg.

Environments supplied by beamline: cryogenic temperatures (cryostat & cryojet), controlled atmosphere (vacuum, inert gas), heating. More specialised sample environments will be developed with external users.

Technical implementation:

In-vacuum ID (18 mm period, 4.2 mm minimum gap); horizontal DCM Si(111); horizontal focusing mirrors: KB mirrors & in-house mirror mechanics, FZP optics (at KTH), nanometer precision sample manipulation (piezo-based scanners, interferometers)

Present status

The beamline hardware up to the experimental hutch is installed and is being commissioned. First monochromatic undulator light in experimental hutch was observed 12 May 2016. A test set-up providing basic performance was built and has been used for first measurements on 17 June 2016.

ES1 prototyping is ongoing since 2012 within a SOLEIL-MAX IV collaboration between NanoMAX and 'Nanoscopium'. The gained experience is used for an in-house development to realise the instrument. The design of this experimental station will continue during late 2016 and early 2017. First commissioning is anticipated to take place during the second half of 2017.

ES2 is realised almost completely as an internal MAX IV development. All components of the focusing optics and the sample goniometer will be assembled during September-December 2016. Procurement of detectors is ongoing, their installation and test is foreseen to start early 2017. Purchase of a sample manipulator is foreseen in October-December 2016. From November 2016 first commissioning experiments are expected to take place and conditions for a first user call will be specified.

Expected status end 2018

We expect to have achieved complete commissioning of the beamline for the planned performances of ES1 and ES2, and to have regular user operation for both stations.

[*] https://www.maxiv.lu.se/accelerators-beamlines/beamlines/nanomax/

Major partners and additional funding

Within the MAX IV – SOLEIL collaboration (Domain2 SP1) the following was secured: 2 M€ for two prototypes, of which one will be shipped to NanoMAX at the end of 2016; the salary for one postdoc spending 50% of time at SOLEIL and 50% at MAX IV.

Changes made since the start

Some design changes have been introduced to accommodate scientific and technical developments in the field; (i) The instrumentation for the ES1 will be developed in-house. A thorough investigation of commercial alternatives undertaken 2012-2014 brought to the conclusion that that no competitive alternatives exist. (ii) Fixed curvature KB mirrors are used to produce a fixed beam size in ES2 instead of a tuneable one, to favour stability and small focal spot versus flexibility. (iii) Imaging methods based on inversion of coherent diffraction data also in Bragg conditions have taken a larger role in the beamline portfolio, with a consequent investment in resources for the development of data analysis.

Comparison to beamlines world wide

- HXN at NSLS II (USA) (https://www.bnl.gov/ps/beamlines/beamline.php?b=HXN)
- P06 at PETRA III (Germany) (http://photon-science.desy.de/facilities/petra_iii/beamlines/p06_hard_x_ray_micro_probe/index_eng.html)
- 26-ID-C at APS (USA)(http://www.aps.anl.gov/Beamlines/Directory/showbeamline.php?beamline_id=112)
- ID16A, ID16B, ID01, ID13 at ESRF (France) (http://www.esrf.eu/UsersAndScience/Experiments/XNP)
- ID14 at Diamond Light Source (UK) (http://www.diamond.ac.uk/Beamlines/Spectroscopy/I14)
- Nanoscopium at SOLEIL (France) (http://www.synchrotronsoleil.fr/Soleil/ToutesActualites/2011/ligneNanoscopium)

Future development

After the initial commissioning phase NanoMAX will work towards establishing a steady and broad user community that will use NanoMAX as a high end tool for answering questions relevant to their scientific domain (be it materials science, biology or other). This work will need to be supported by a continuous technical and methodological development for NanoMAX to keep being a flagship beamline. A clear goal will be to keep pushing the beamline performance beyond state-of-the-art for technical parameters such as spatial resolution, acquisition times and chemical/electronic sensitivity. To improve on these issues a continuous investment in upgrading the 2D and 3D scanning systems, optics (zone plates etc.), supporting the development of sample environments in collaboration with users as well as responding to any new detector development will be relevant. An equal investment in human resources and in scientific partnerships within and outside MAX IV will also be required.

The complexity of the imaging beamlines, the continuous development demanded to keep the beamline state of the art, along with the large variety of the methods and scientific areas included in the portfolio requires a contious development and adaption of user friendly software.

From an equipment point of view, the beamline would gain from the implementation of the following capabilities:

- Improving capabilities for bio-imaging. This will include competences as well as the implementation of a cryogenic system, a cryo transfer and sample changer for ES1 (FZP) and an off-line cryogenic light microscope.
- The possibility of controlling the incident radiation polarisation using a phase plate. This will counteract the decrease of diffracted intensity due to the polarisation factor and will allow scanning diffraction microscopy methods in the more stable horizontal geometry. Furthermore, this will allow the exploitation of other contrasts, like absorption in birefringent materials, anomalous scattering on chiral molecules and anisotropic media, resonant and non-resonant scattering on magnetic materials.
- The implementation of new types of focusing optics, like CRL or MLL, WG