



MAX IV Roadmap – Executive Summary

1. The Vision and Mission of MAX IV

A leading synchrotron enabling world-class science for a better future.

The mission of MAX IV is to develop and operate world-class accelerator-based light sources, synchrotron beamlines, and related tools for the Swedish and international communities for science at the highest level of excellence. We serve academic and industrial communities by conducting research and developing methods and techniques in collaboration with these communities.

2. Introduction

This document is the summary of the Roadmap for MAX IV and outlines the most important processes contributing to it. Following these, the roadmap will be periodically updated and aligned with the MAX IV strategy. In parallel, a detailed Roadmap document is developed. It lists planned activities across the different divisions from a short, medium, and long-term perspective. The latter version is primarily for internal use, while this document targets external stakeholders.

3. Plans for existing beamlines

Central to operating as a user facility, all beamlines have multiple activities to improve user-friendliness, and efficiency while maintaining safety at the highest level. The yet-to-be-funded proposals for expanding the capabilities of our beamlines will be listed in a “cost book” for each respective beamline or science area for cross-beamline activities. The near-time planning for MAX IV includes setting up this process and ensuring that the scope and budget of proposals with the highest priority are clearly communicated, e.g., in the framework of discussions regarding in-kind contributions from Swedish Universities. In parallel, a plan for the operational phase of each beamline, including finances as well as personnel, will be developed.

Moreover, MAX IV must maintain a competitive portfolio of beamlines that can cater to the current and future research needs of our user community, while ensuring that the beamline components, including optical elements, sample environment, and detectors, remain technologically advanced and do not become outdated or obsolete. As the scientific landscape constantly evolves and new methodologies and instruments emerge, an upgrade program must be established to keep the beamlines relevant and competitive thus ensuring they can address scientific and societal issues of interest. From a long-term perspective, a review of our beamline portfolio will be conducted when many of the existing beamlines require upgrades to ensure that the overall development of MAX IV supports its mission to the fullest. The first cross-beamline review will be organized within the next five years, by which time, the first MAX IV beamlines will have been operational for ten years.



4. Plans for new beamlines

There is space for about 10-15 new beamlines to be located at either storage rings or the Short Pulse Facility. MAX IV aims to begin the construction of five new beamlines during the coming five year period. New beamlines can be proposed through so-called Expressions of Interest (Eols). MAX IV regularly initiates this process¹, which is open to internal and external stakeholders.

In 2021, the first call for Expressions of Interest was initiated. In total, 13 proposals were submitted. Seven were related to new beamlines. The six others were related to activities on existing beamlines and are addressed in a cost-book process. In spring 2022, all Eols were evaluated by an external committee and ranked into three categories: A – Clear pass, B- Question remains, and C – No pass this time. The following beamline proposals were ranked A (in no priority order):

- SXL – A Soft X-Ray free-electron laser beamline driven by the MAX IV 3 GeV linac
- GTiMAX: Tomographic imaging beamline at MAX IV
- MedMAX: Bio/medical imaging beamline for tomography of soft materials
- MIRARI; IR for everyone
- Tender-to-Hard X-ray beamline for X-ray Spectroscopies

Amongst these, the Soft X-ray Free Electron Laser – SXL stands out in scope, ambition, and cost. It was, therefore, decided that it would be treated separately.

The following beamline proposal received a B – questions remain:

- OPERA: A hard X-ray operando diffraction beamline

Over the coming two years and in parallel with exploring funding opportunities, we will continue engaging with Eols proposers and the User Community to develop these proposals further into a Conceptual Design Report, which includes a budget and a preliminary project plan.

MedMAX

MAX IV has prioritised obtaining funding for the biomedical imaging beamline MedMAX which would visualise complex structures and processes in life sciences and soft matter down to the sub-micrometre spatial resolution using hard X-ray tomographic microscopy. This allows researchers to use MAX IV for scientific questions to obtain information from the atomic to the micrometre length scale. Pre-clinical studies at MedMAX will contribute to building profound knowledge on the origins of various poorly understood physiological and pathogenic processes by enabling micrometre resolution functional anatomy and pathoanatomy of small animals and tissues. The beamline will serve the user community in three modes of operation: micrometre resolution in vivo and ex vivo tomography, medium (10-30µm) resolution fast in vivo tomography and nano holo-tomography (with basic spectroscopic capabilities). A funding request for a pre-study aiming to deliver a full Conceptual Design Report, including a budget, possible funding schemes, and project time plan has been submitted to the Craaford foundation.

Broadening of our beamline portfolio for materials research

¹ Target every second year from 2024



MAX IV has prioritized exploring funding opportunities for beamlines fulfilling the current and future research needs of materials research that can benefit from the unique properties of our X-ray sources. This, for example, resonates with the WISE initiative, the Wallenberg Initiative – Material Science for Sustainability (<https://wise-materials.org/>), providing an unprecedented investment in driving Swedish research in this area over the next decade. We envision exploring funding opportunities together with WISE; opportunities that support the growth of our beamline portfolio with advanced and dedicated instrumentation platforms that provide modern, world-leading, spectroscopic, imaging, and diffraction/scattering capabilities.

In the recent Expression of Interest call, three beamline proposals were pushed forward that could fulfill these ambitions. Our 3 GeV storage ring (R3) provides unique opportunities with coherent hard X-rays to develop a state-of-the-art tomographic imaging beamline, such as GtiMAX, providing 3-dimensional imaging capabilities with impressive time and spatial resolution relevant to materials science in action. In addition, a tender to hard X-ray photoemission beamline that will benefit from the world-leading flux available on R3 would dramatically expand our breadth of X-ray Photoemission spectroscopic capabilities, with photon energies spanning from 4eV until 10s of keV. MAX IV would be a unique place to investigate systems in real conditions, much closer to ambient pressures than currently available. These two beamlines would benefit from being complemented by a dedicated hard X-ray diffraction beamline with a focus on operando and in-situ studies, such as Opera.

The strategy process of MAX IV will guide the laboratory through the next decade. As part of this process and as an important milestone, we have now published a Strategic Plan for the years 2023-2032.

[Link to download the strategy](#)

What happens next?

With the Strategic Plan as a foundation, we intend to deepen the discussion with the research community, and foremost national stakeholders to ensure that MAX IV stays at the forefront as a Swedish national user facility through the next decade. Outreach activities will be organised and we will continuously develop and seek funding opportunities for the most prioritized instruments. In addition, we are working internally with a MAX IV RoadMap identifying activities throughout the organisation needed to achieve the vision and mission as described in the strategic plan. A short version of the RoadMap is already completed. This document, containing for instance the outcome of the Expression of Interest call 2021/2022, can also, at least partly, be seen as an executive summary of Strategic Plan.

[Link to download the short version of the RoadMap.](#)

The mentioned Expression of Interest process is our main tool to identify and prioritize proposals for new major infrastructure investments. The next call will open 2024 and will only be open for beamline proposals.

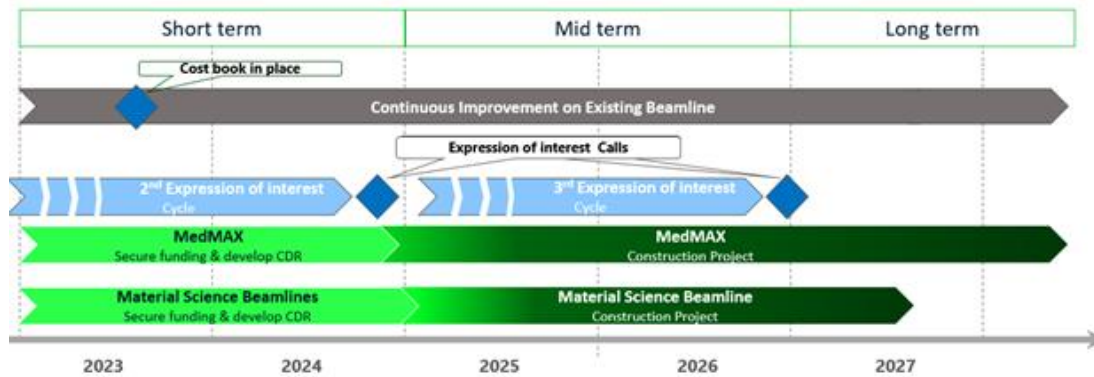


Figure 1: Summarized beamline roadmap (Short-term planning corresponds to 1-2 years, Mid- to 2-4 years, while the Long Term planning stretches beyond 4 years)

In addition to the abovementioned beamlines for which MAX IV has started to identify possible funding opportunities, the facility has taken initiatives on the following beamline proposals.

MIRARI

When most medium-energy storage rings across the world complete their upgrade with variants of Multi-Bend Achromat lattices, the extraction of IR light from such machines becomes difficult. However, MAX IV is in a unique position to host such a beamline thanks to its 1.5GeV storage ring that is a premier source of X-rays for softer radiation. Therefore, MAX IV is investigating funding opportunities to move forward with a detailed analysis of how to best generate an optimized source of Infrared radiation on our 1.5GeV storage ring. We also intend to discuss beamline design with our collaborators at Synchrotron SOLEIL that have a long-standing experience in this area.

A flagship beamline using diffraction-limited soft X-rays

In addition, MAX IV will explore opportunities with diffraction-limited soft X-rays, such as the one readily available on our R3 storage ring. This could be concretized in identifying, together with the community, partners, and collaborations, scientific areas that could benefit from significant advancements in experimental capabilities that are until now rare. This includes developing resonant coherent scattering to a level such that it can be used to complement structural information by probing the dynamics of materials with dynamic speckle-related techniques. It is envisioned that it could provide access to unique dynamic information in correlated and quantum systems but also in chemical processes. MAX IV is also interested in exploring opportunities to use Orbital Angular Momentum and other structured lights, and to assess their coupling with complex systems of materials and chemical interests involving vortices and chirality. We aim to develop a CDR for such a beamline that could be submitted at the next EoI call sometime in 2024.

5. Plans for accelerator systems

Providing reliable, continuously improved, and internationally competitive accelerators with world-leading X-ray brightness and access to ultrafast X-ray pulses constitutes the central strategic goal of the accelerator



programme at MAX IV. To achieve that goal of addressing the present and future needs of the user community, a roadmap of developments for the MAX IV accelerators (**Figure 2**) has been developed. The roadmap includes shorter-term incremental improvements and longer-term, radical, game-changing proposals. The shorter-term initiatives aim to meet the user community's immediate needs while establishing critical enabling technologies that set the stage for longer-term upgrades.

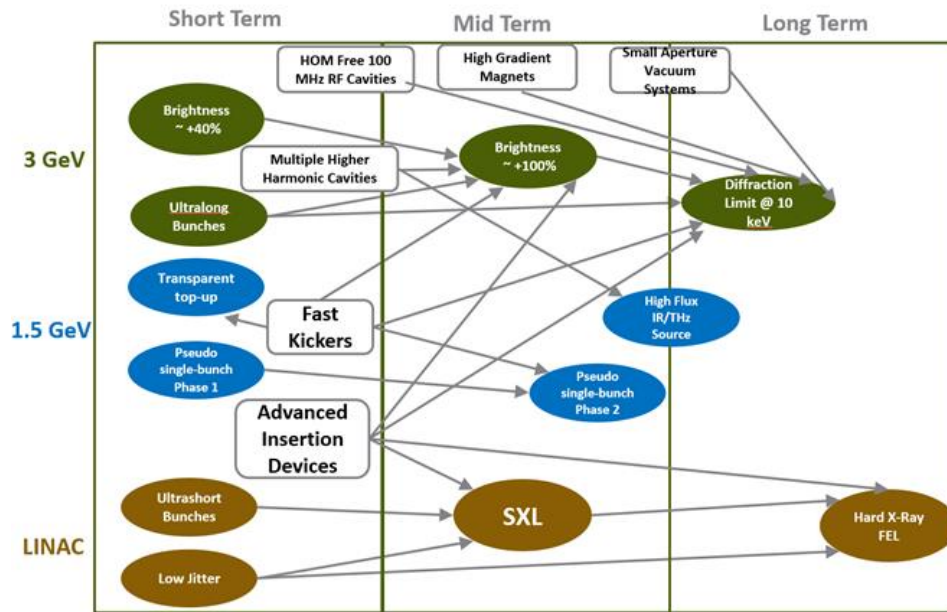


Figure 2: The MAX IV accelerator roadmap (Short-term planning corresponds to 1-5 years, Mid- to 5-10 years, while the Long Term planning stretches beyond 10 years)

6. Enabling technology, systems and solutions.

Near term, we need to work in parallel with two development paths for technologies, systems and solutions. One is to enable world-leading technologies for science, and another is to consolidate operational excellence. An enabling organization is of utmost importance, and we strive to be an attractive workplace and to establish more structured practices with a proactive approach and cross-functional way of working. We will also continue to develop strong user interactions. Some challenging developments are exemplified below:

- New technologies such as NEG coating, smart materials, and new sealing techniques,
- Control and data acquisition systems need to provide a stable but flexible user-friendly interface for the higher complexity of the integrated experimental set-ups,
- Detectors will deliver two orders of magnitude more data, which necessitates investment in DAQ infrastructure and application-specific data reduction and processing pipelines,
- Artificial Intelligence/ Machine Learning (AI/ML) technology offers the possibility to handle complex systems, time-consuming operations, and data analysis,
- Data management will play an increasingly important role in the experimental workflow due to ever-increasing amounts of data and metadata,



- Strive for standard solutions that are also user- and service-friendly, enabling good technical operations support (on-call),
- Set and implement a policy for “make or buy”, or collaborate with external partners,

7. Financial strategies

Long-term financial planning faces increased challenges due to the present situation with increased costs for electricity and rent. MAX IV faces the pedagogical challenge of arguing for secured funding for the operation and further development of the existing beamlines and accelerators; while, at the same time, exploring funding opportunities for building new beamlines. Given the scale of the necessary investment, the only realistic scenario is for the government to be the majority funder. Our ambition is to proactively work toward a dedicated funding stream for MAX IV operation, that will not require periodic negotiations with all major funders. MAX IV will also seek to partner with user groups to get new beamlines funded and realised. This work will rely on existing and new strategic partnerships, primarily in the Nordic and Baltic regions. A list of up to seven prioritised beamlines will be maintained and updated via calls/evaluation of Expressions of Interest.

In addition, several initiatives have recently been taken to further strengthen the financial governance in projects as well as operation.