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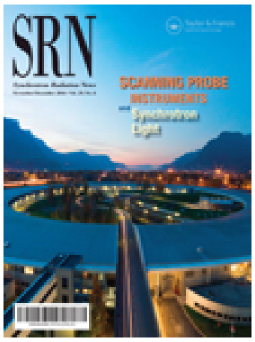

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MAX IV is Ready to Make the Invisible Visible

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In a ceremony held on June 21, the brightest day of the year in the northern hemisphere, Swedish Prime Minister Stefan Löfven and H.M. King Carl XVI Gustaf, together with Director Christoph Quitmann, inaugurated MAX IV Laboratory in the presence of about 500 staff, funders, stakeholders, and guests from all over the world.

By closing door no. 7 to the storage ring, the King, Prime Minister Löfven, and Director Quitmann marked the facility ready for operation. Photo: Kennet Rouna.

The inauguration of MAX IV lasted four days. It began on a weekend with Open Days, when the facility was opened to the general public. More than 900 visitors, curious about this new shiny building in the northeast of Lund, arrived to explore the facility.

One of many young scientists-to-be trying his skill aligning a magnet block during the Open Days of the MAX IV inauguration. Photo: Kennet Rouna.

On Monday, almost 200 staff, industry representatives, and users from all over the world took part in the MAX IV Science Day, with seminars and talks on the accelerators and beamlines. A guided tour of the facility by machine and beamline staff at MAX IV was offered.

On Tuesday, June 21, it was finally time for the long-awaited formal inauguration. During the lunch buffet, speeches were given by all initial funders: Torbjörn von Schantz, Vice-Chancellor of Lund University; Henrik Fritzon, Chairman of the Executive Committee Region

Skåne; Charlotte Brogren, Director General of Vinnova; Peter Wallenberg, Jr., Chairman of the Board of the Knut and Alice Wallenberg Foundation; and Sven Stafström, Director General of the Swedish Research Council.

Guests enjoying the inauguration lunch buffet. Photo: Kennet Rouna.

Next, the guests were seated in the special "dark-room" built in the experimental hall for the more formal part of the inauguration. Director Christoph Quitmann bid all guests welcome and then the show started, including a short documentary with all former directors as well as a dance number and a song written especially for this occasion. Following this, speeches were given by the Swedish prime minister, Stefan Lövfen, as well as Professor Maria Selmer of Uppsala University and H.M. King Carl XVI Gustaf. The ceremony ended when the king, prime minister, and director closed door no. 7 to the 3 GeV storage ring, thus marking the facility ready for operation. After the formal inauguration, the prime minister and king were given a guided tour of the facility by former Machine Director Mikael Eriksson and Professor Marianne Sommarin of Umeå University.

The full version of the inauguration ceremony can be found at www.maxiv.se/about-us/public-media/inauguration-live-streaming/

Mahan Moin performing Elysium, the MAX IV inauguration theme song. Photo: Kennet Rouna.

Former Machine Director Mikael Eriksson explaining the finer details to Swedish Prime Minister Stefan Löfven and H.M. King Carl XVI Gustaf. Photo: Kennet Rouna.

"In terms of Swedish and international research, this is truly a major event and a good example of how a small country like Sweden can pursue trendsetting projects that create an international impact. Looking ahead, MAX IV, together with European Spallation Source ERIC, will provide a unique and first-class research environment which will benefit research and innovation," noted Helene Hellmark Knutsson, Swedish Minister for Higher Education and Research.

In a few years, more than 2,000 international researchers will use the Swedish-based synchrotron laboratory each year to conduct ground-breaking experiments in materials and life sciences using the most brilliant X-ray light ever generated. So far, the investment in the facility amounts to EUR 470 million—the biggest-ever investment in national research infrastructure in Sweden.

Christoph Quitmann, director of the laboratory, noted that MAX IV is the result of decades of research and innovative ideas. "It is immensely satisfying that we reached the stage where we could inaugurate the facility," he said. "The financiers have shown great trust in us and now we have to live up to that. There are great hopes both in the research community and the business sector that we will deliver results that the world has never seen before. We have an exciting period ahead of us, establishing an operation that attracts the business sector and researchers to collaborate on making new, ground-breaking discoveries to help solve the global challenges."

Work on the MAX IV site, outside Lund in southern Sweden, started in 2010 and construction was completed in 2015. MAX IV will have cost about EUR 640 million by the time it has been fully developed with approximately 28 beamlines. The facility has been built with a strong focus on environmental aspects. Its innovative approach has won prizes and awards, such as the prize for best future project at the MIPIM real estate show in Cannes, France, in 2014.

Industrial cooperation at MAX IV: A first example

The Swedish Government has allocated 10 million SEK (approx. €1 million) to the Royal Institute of Technology (KTH) for a feasibility study on ForMAX, a collaboration between industry and academia that will generate forest-based products that fit into a bio-based economy. The purpose is to achieve both the Swedish government's vision for a carbon-free society by 2050 and maintain Sweden's unique position with a competitive forest-based industry.

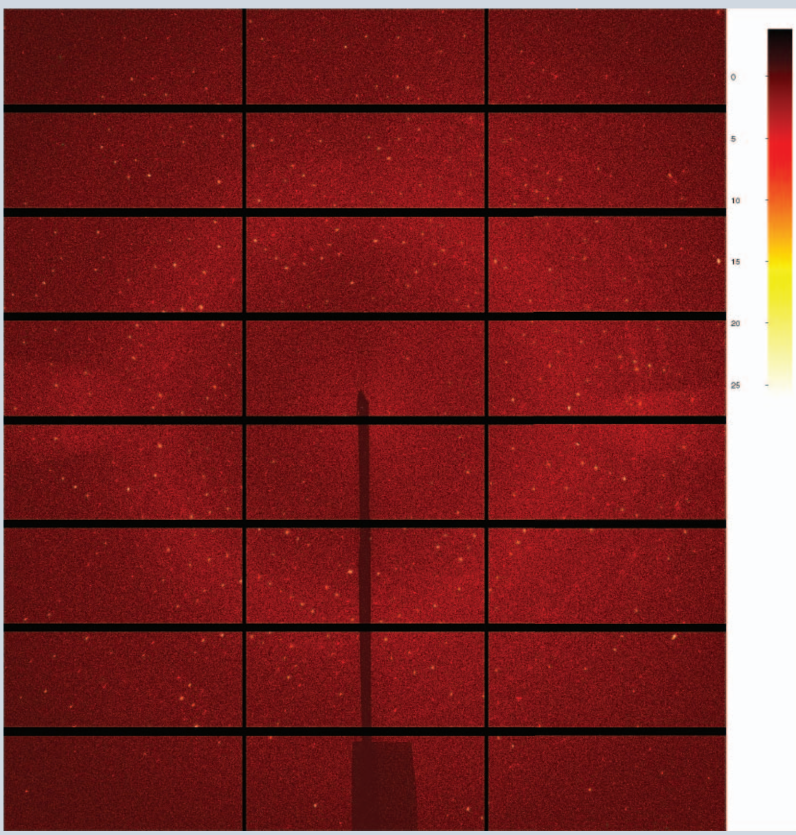
Partnering with MAX IV in this project are the Royal Institute of Technology and Chalmers University, together with forest industry companies BillerudKorsnäs, Holmen, SCA, Stora Enso, Sveaskog and Södra. The project will open unique opportunities to study raw materials, optimize processes, and develop new products.

ForMAX is to become a tool customized to address research issues surrounding bio-composites, nano-cellulose, and dissolving wood pulp process. ForMAX will also serve as a portal to make available other instruments and measurement techniques at MAX IV, all of which can be beneficial for research on bio-based materials. Possible future projects include the large-scale production of green lightweight materials used in, e.g., packaging, houses, and vehicles. More concrete examples of possible future applications include 3D printers, textile, sanitary and electronics, insulation, filters, and self-healing and cleansing medical materials of various kinds.

Commissioning status beamlines

The goal that had to be met on inauguration day was "light on first sample." This was achieved on June 10 when BioMAX carried out the first diffraction experiment with a 40 × 20 μm^2 X-ray beam on a protein crystal and diffraction images were collected.

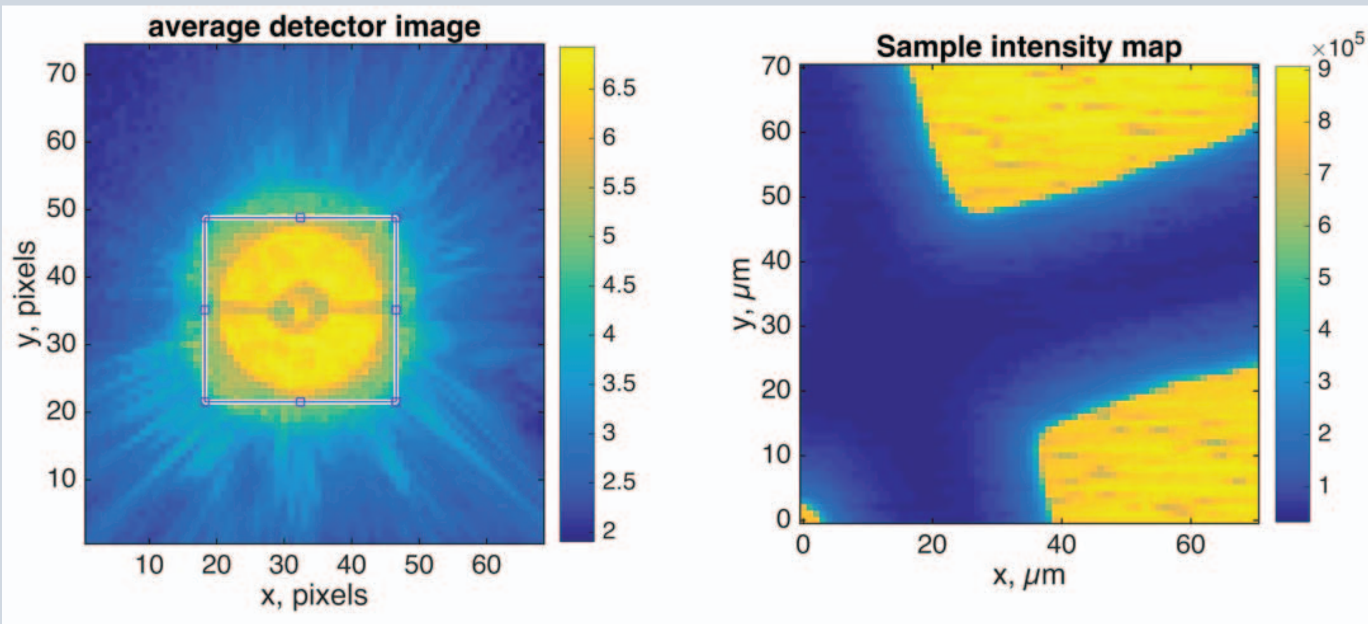
Due to its extensive energy tunability, BioMAX is the ideal source for *de novo* phasing using the anomalous signal of heavy elements. It is equipped with a high-capacity sample changer and an Eiger 16M hybrid pixel detector, which designates the highest available performance hybrid pixel detector technology. Due to its small beam cross-section and optional parallel beam, BioMAX is the ideal experimental set-up for microcrystals and ultra large unit cells.



Diffraction images from a thaumatin crystal at BioMAX. Illustration: Uwe Mueller.

In the very last days and hours of beam before the inauguration, the NanoMAX team managed to align a full Fresnel Zone Plate focusing set-up (including a Fresnel lens, a central stop, and an order-sorting aperture) and reach a sub-micron beam spot. After some stability testing, the team collected the first absorption image from a coarse TEM-grid and the first diffraction data from a Fresnel Zone Plate test sample. These first data show that high mechanical stability can be reached, even when using a temporary—not optimized—set-up, and are an encouraging starting point for further optimization of the beamline.

NanoMAX 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 the production of 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 science, earth science, nanoscience, physics, chemistry, and biology.

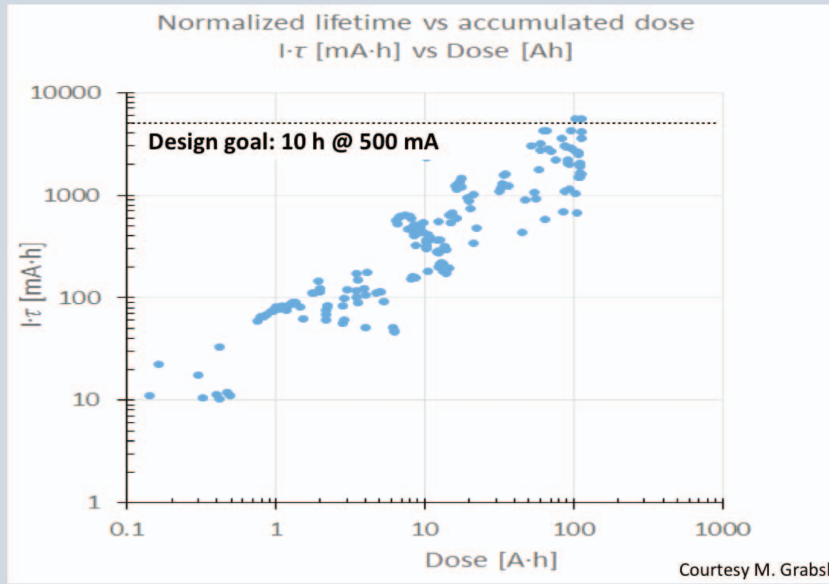


First image from a sample in a focused beam at the NanoMAX experimental position. A coarse TEM grid was scanned in the ~0.5 μm focal spot and absorption was measured with an X-ray pixel detector. The left image shows the illumination of the zone plate projected on the detector. The right image shows the copper as dark; the bright areas are the grid openings. The sample is, of course, too coarse to resemble the potential resolution of the focused beam. Illustration: Ulf Johansson.

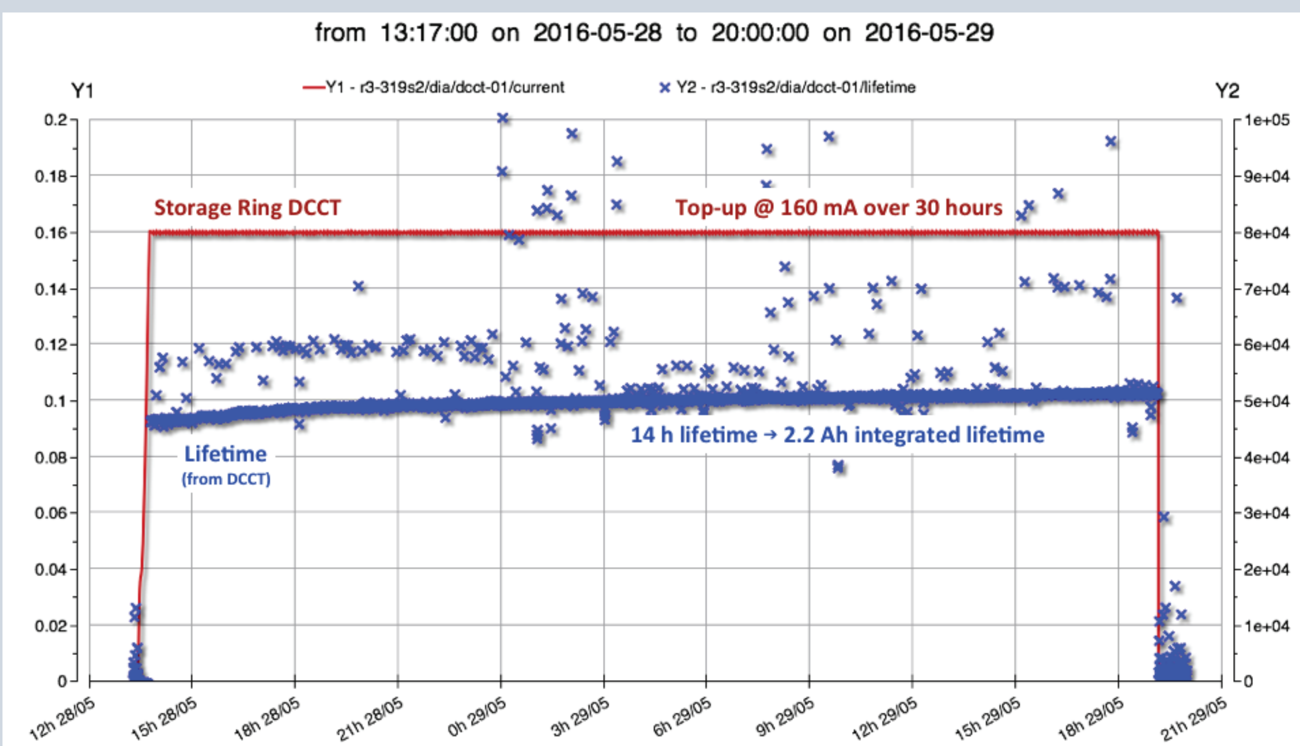
It is the goal that BioMAX and NanoMAX will have first regular users in spring 2017. During the final months of 2016, the first commissioning phase of two more beamlines—Balder and Hippie—will take place. They are the next beamlines to have regular user operation, scheduled for the summer of 2017.

Commissioning status accelerators

The inauguration goals for the 3 GeV storage ring were to achieve stable beam with at least 50 mA stored current and a lifetime in excess of 10 hours. This goal was met and, in fact, surpassed. At the time of writing, the maximum stored current reached in the 3 GeV storage ring was 198 mA, limited only by a precautionary setting of the machine protection system. Top-up injections (albeit still with closed shutters) are being used to maintain high levels of constant stored current. Despite ongoing vacuum conditioning (100 A h dose was achieved at the end of June), integrated lifetimes around 3 A h are now routinely achieved. This is enabled, in part, by the bunch lengthening from three passive harmonic cavities that have been tuned in and become effective for stored currents above 120 mA. So far, results confirm that the technological solutions employed in the MAX IV 3 GeV storage ring are sound and effective. During the summer shutdown, three additional insertion devices were installed which will allow commissioning of three new beamlines during later in the year.



Integrated lifetime in the MAX IV 3 GeV storage ring increases as dose is accumulated and the vacuum improves. Illustration: Marek Grabski.



Stored current and lifetime in the MAX IV 3 GeV storage ring during a weekend of laundry shifts in May 2016. Top-up injections maintain a constant 160 mA. The overall lifetime is about 14 hours. Illustration: Simon Leemann.

During the summer shutdown, the transfer line from the linac to the 1.5 GeV storage ring was installed and subsystem tests were performed. Beam commissioning in the 1.5 GeV storage ring began on September 5 and is ongoing. Beam was threaded through the transfer line and first turn was achieved on September 14. After a short interruption of the beam commissioning, stored beam was achieved on September 30. At press time, 1.6 mA stored beam has been achieved. Beam commissioning is now well underway and is expected to last well into 2017. At the next shutdown, the first two narrow-gap chambers and EPUs will be installed, thus enabling commissioning of the first 1.5 GeV storage ring beamlines during 2017. ■

Achromats in the 1.5 GeV ring with the front end of the beamline SPECIES in the foreground. Photo: Madeleine Schoug.

Experiment hall of the 1.5 GeV ring with the optics hutch of the SPECIES beamline in the center of the image. Photo: Madeleine Schoug.