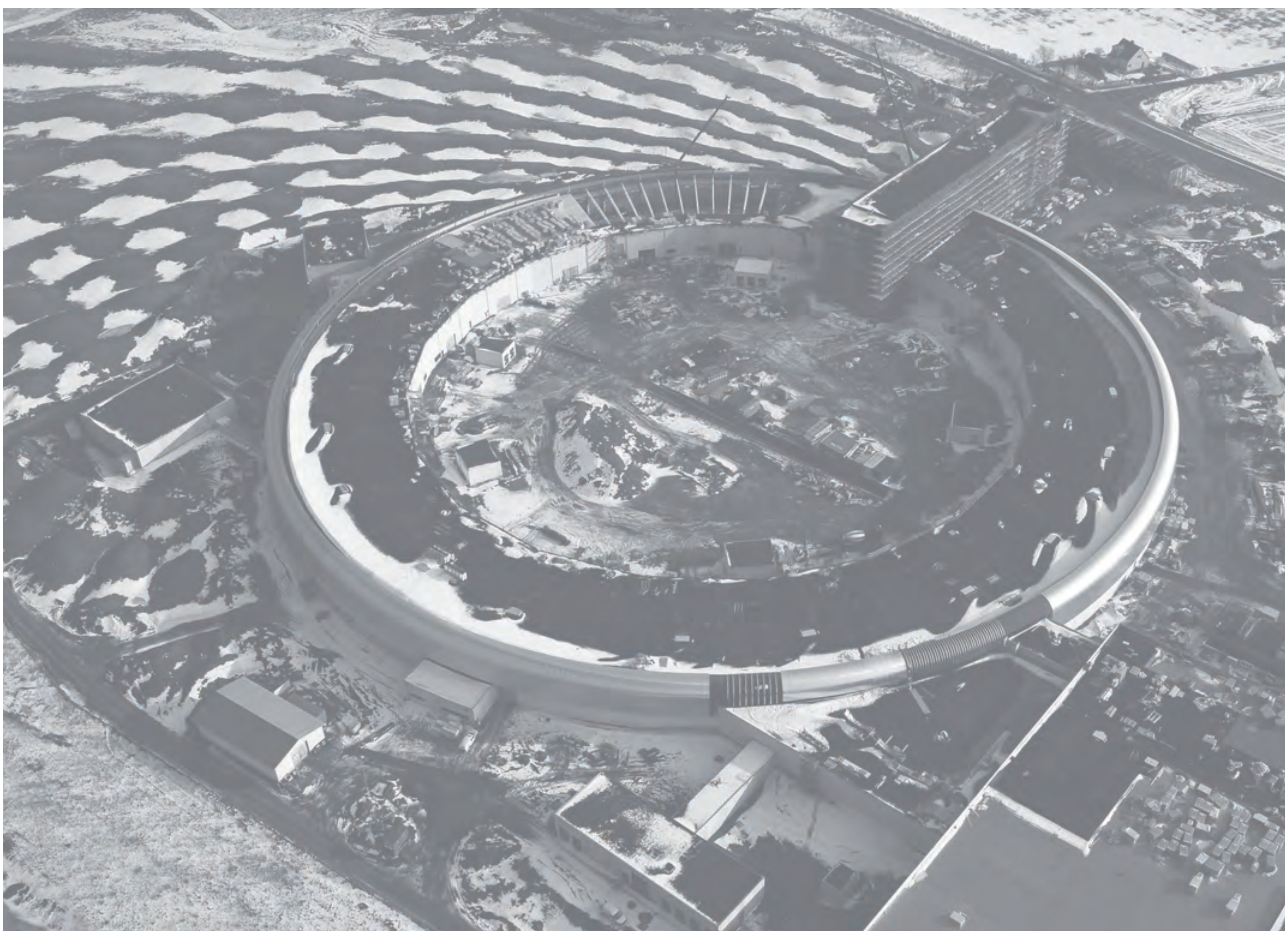
We make the invisible visible


11 BIOMAX


11

Airphotos Januari 2014



Unique facility
on the international scene

→ A new synchrotron light facility - MAX IV - is under construction in southern Sweden. It will be inaugurated in 2016.

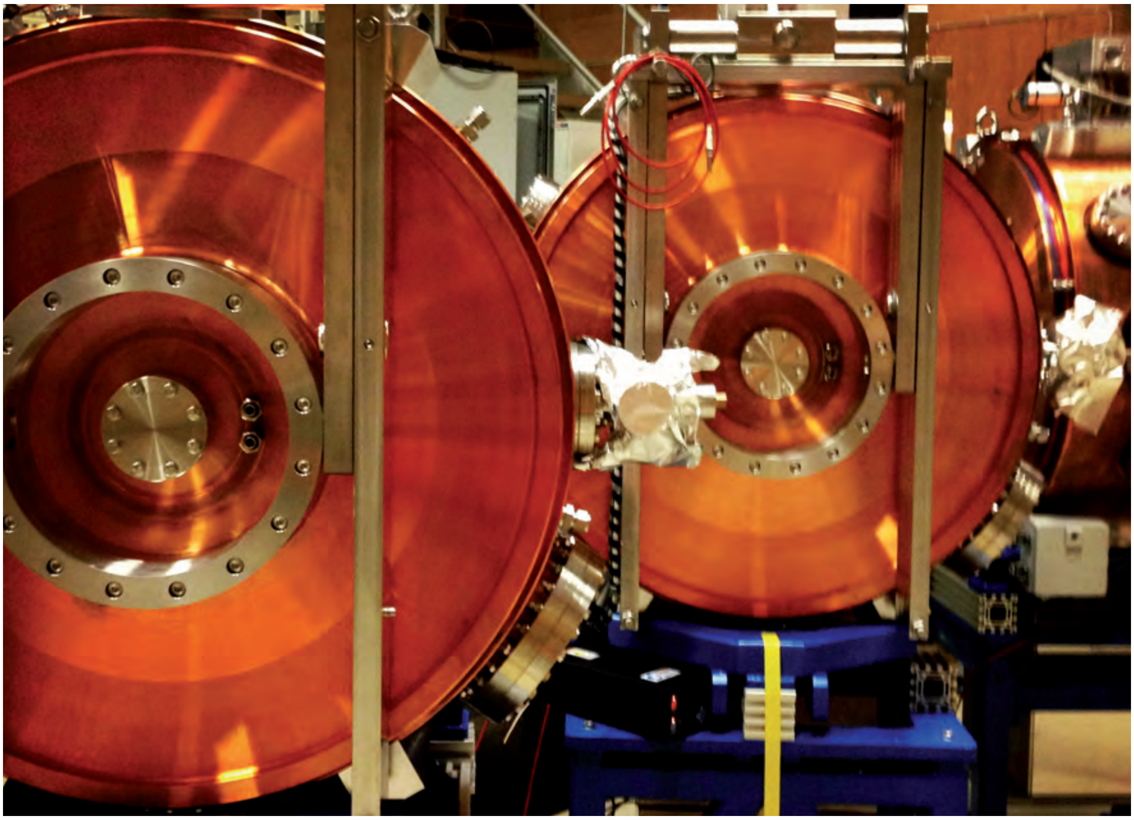
MAX IV is being built in the northeastern part of Lund, the Brunnshög area. MAX IV will be one of the most advanced synchrotron X-ray light facilities in the world for materials and life sciences. It is hosted by Lund University.

MAX IV Laboratory offers scientists from the whole world unique possibilities for research on different materials' properties as well as within life science. The Swedish Research Council, Lund University, VINNOVA, Region Skåne, the Knut and Alice Wallenberg Foundation and eleven other Swedish universities finance the construction of MAX IV.

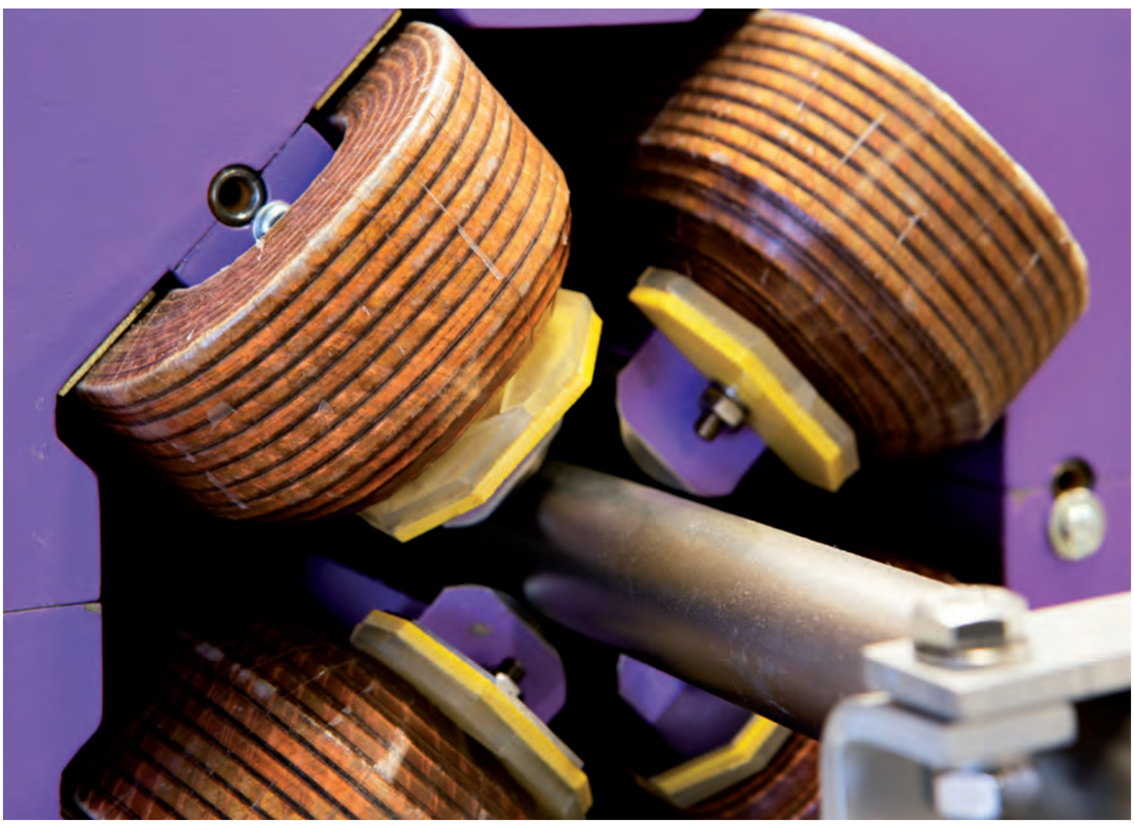
The European Spallation Source, ESS, will be a close neighbour, opening for research around 2020. A science village will be developed in the area between MAX IV and ESS. Lund has a very unique concentration of science and innovative companies along the so-called Science Road that stretches through the city, from the medieval town centre via Lund University, Skåne University Hospital, Lund Institute of Technology as well as the science park Ideon. Brunnshög creates new innovative environments closely connected to the existing ones.

The Background
MAX IV Laboratory in Lund, Sweden, has more than 25 years of experience of operating a synchrotron facility. The laboratory became a national laboratory in 1994 with Lund University as host university. The successful operation has established it as a unique synchrotron facility at the international scene that continues to attract scientists from all over the world.

The Future
MAX IV will provide the Swedish, Scandinavian and international scientific and technological communities with opportunities for experiments that make use of the unique properties of the MAX IV light sources. MAX IV will have two storage rings: one larger 3 GeV ring and one smaller 1.5 GeV ring. It will be possible to construct 26 beamlines around these rings and at present thirteen beamlines are funded and under construction. The beamlines at MAX IV will benefit from the unique performance of the accelerators offering possibilities to focus down to extremely small beam sizes in combination with low divergence, extreme resolving power and a very high degree of coherence. These properties is of key importance in areas as diverse as the life or materials sciences and applications ranging from identifying contaminants in soils to studying the structure of new packaging materials. The high brilliance and the very tiny size of the X-ray beam of the 3 GeV ring opens new dimensions in X-ray imaging of all types of materials.



RF cavities for MAX IV



Quadropol magnet for linac at MAX IV

Allows performances a factor 10-20 higher

→ Three integrated parts make up the MAX IV Accelerator System: two storage rings for the production of synchrotron light as well as an injector linear accelerator (linac).

The 3 GeV storage ring is optimized for high performance production of hard X-ray radiation. The introduction of a radically new design concept allows performances a factor 10-20 higher compared to existing similar facilities. This new concept is based on tight system integration, in which several new technical solutions previously developed and tested in the existing MAX-lab accelerators, make up a coherent system.

Examples of such new technical solutions are: integrated complex magnets machined out of a single iron block, special accelerating subsystems (RF cavities) which generate long electron bunches as well as vacuum chambers with distributed linear pumping capability. All of those subsystems are strongly miniaturized so as to make the whole project economically feasible.

The injector linac is used to provide the storage rings with electrons, which are injected into each ring at their respective operating energies. By compensating the inevitable electron losses from the rings, a nearly constant stored current can be achieved which contributes to stable measurement conditions. Apart from its role as injector, the linac will also be used to generate short X-ray pulses for studies of fast processes in the Short Pulse Facility (SPF). The linac also opens the door for complementing the MAX IV facility with the later construction of a Free Electron Laser, a next generation light source.

Magnets

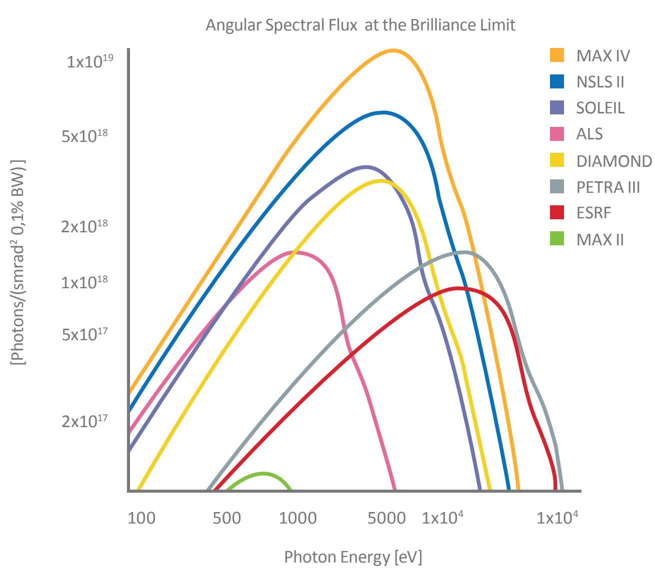
In older rings, such as the existing MAX II ring, the magnets are built as separate units of relatively large dimensions. In MAX IV, multiple magnets of reduced dimensions are machined out of a single iron block. This concept leads to a very compact design, featuring high mechanical position accuracy as well as low energy consumption.

RF Cavities

RF cavities restore the energy lost in the form of synchrotron light. MAX IV uses a new design of these cavities, resulting in less power consumption and longer electron bunches, which contributes to enhanced beam stability.

Vacuum

The electrons circulate inside a metallic tube. For this to work optimally, near absolute vacuum must be achieved in the tube. In the 3 GeV storage ring the tube will therefore be internally coated with a very thin film (known as NEG coating), which will suck out residual gas molecules. These would otherwise be in the way of the electrons and reduce their lifetime. MAX IV will have very small vacuum chambers and the 3 GeV ring will be the first fully NEG coated synchrotron light source. Compared to other conventional pumping schemes, NEG pumping can be seen as a totally passive mechanism, which does not require energy while in operation. This reduces the power consumption.



A radically new design concept makes the performance of MAX IV world-leading. Here a comparison of brilliance.

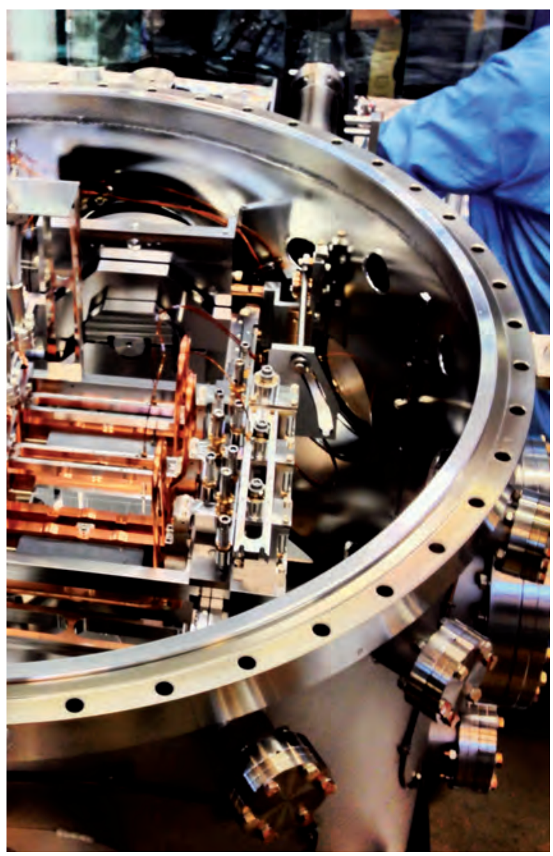
13 cutting edge beamlines for a wide range of disciplines

→ The Knut and Alice Wallenberg Foundation, twelve Swedish Universities, Academy of Finland, Estonia and Vetenskapsrådet are the funders of the first thirteen beamlines at MAX IV.

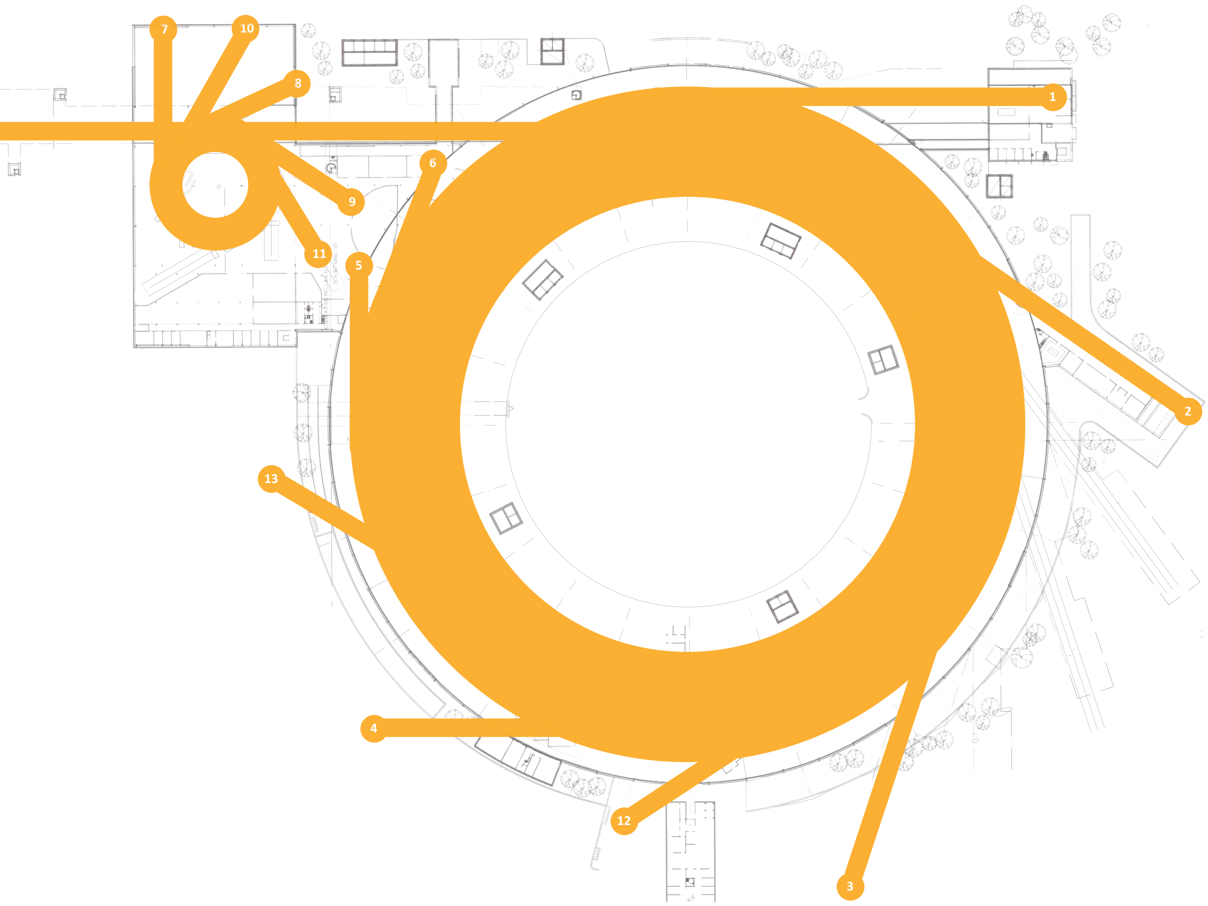
These cutting-edge beamlines will go into operation in 2015-17 but will soon be followed by others. The MAX IV facility has a capacity for 26 different beamlines, situated either on any of the two storage rings or on the extension of the linac at the Short Pulse Facility. The aim is to have two more beamlines operational every year until full capacity is reached by 2026.

The beamline program has emerged from a process involving the user community. It will provide Swedish and international natural sciences with cutting edge research infrastructures at the international forefront. The open access policy, with peer review of proposals and free-of-charge use, ensures that the resources are available to the entire community at all universities and for the best experiments. Sweden has invited the neighbouring countries to financially contribute to the operation and investment costs of the MAX IV Laboratory so this open access policy can be continued.

Each and every beamline will provide a performance that is not available anywhere in the world today or is very rarely available and therefore highly needed. These beamlines will serve a wide range of disciplines including materials sciences, energy research, biogeochemistry, atmospheric chemistry, corrosion chemistry, nanotechnology, catalysis research, environmental sciences, cultural heritage, basic physics and chemistry as well as energy research, pharmacy, molecular biology and medical imaging.



Plane grate monochromator for SPECIES



NAME	NO	METHODS	MAIN AREA(S) SERVED
FemtoMAX	1	Femto-second X-ray scattering, EXAFS and Spectroscopy	Physics, Chemistry, Accelerator development
NANOMAX	2	Scanning X-ray, Microscopy X-ray, Fluorescence Microscopy and scattering techniques as XRD, SAXS/WAXS, Coherent XRD	Nano-science, Materials Science
BALDER	3	(in-situ) XAS, combined with additional methods e.g. FTIR and RAMAN	Materials & Environmental Science, Energy research, Cultural heritage
BioMAX	4	Diffraction	Life Science
VERITAS	5	RIXS (Resonant Inelastic X-ray Scattering)	Physics, Chemistry, Materials Science
HIPPIE	6	High Pressure XPS (X-ray Photoelectron Spectroscopy)	Chemistry, Catalysis, Corrosion, Materials Science, Physics
ARPES	7	Angle resolved Photoelectron Spectroscopy	Physics, Nano-Science, Materials Science
FinEstBEams	8	Gas Phase Photoelectron Spectroscopy	Materials Science
SPECIES	9	Ambient pressure XPS & RIXS	Physics, Chemistry, Catalysis, Corrosion, Materials Science
FlexPES	10	XPS, XAS	Physics, Nano Science
MAXPEEM	11	XPEEM, LEEM, XPS	Physics, Nano Science
CoSAXS	12	SAXS/WAXS, XPCS & CDI	Soft matter, Life Science
SoftiMAX	13	CXI & STXM	Physics, Nano Science

Meet one of our staff – Kurt Hansen

→ Associated professor in Nuclear Science and research engineer at MAX IV Laboratory. Group manager User Support. Started at the lab, then called LUSY, in 1978.

You are a nuclear physicist?
– Yes, that's what I am trained to do and I've done research in it but what I work with mostly is the more technical equipment. But there is a clear advantage to have a formal education. Then you'll learn about computers and electronics and a bit of everything. For example, how to glue the small cells storing liquid gases under high pressures and low temperatures that can be used as beam target. I have been responsible for this when we run experiments in nuclear physics. Nearly all experiments in physics require a lot of equipment and therefore large groups of people with different skills where someone is in charge of data collection, some of the electronics, some of the detectors and someone is in charge of the target. It is impossible for one person to know everything.

If you were to describe the MAX IV Laboratory for a young person who wants to pursue a career as a physicist - what would you say is so special here?
– What are really special is that here are so many people who have so many good ideas and therefore it becomes a very stimulating place to work. You meet people from all over the world who find out all kinds of things, some that actually seems impossible from the start. It's great fun. Also, this means that you can connect with others and get to travel the world. If you want to be at the forefront in your field as a research engineer, you need to learn from others in other places. So even if you do not work directly research oriented but with instrumentation you'll get in contact with people who also work in the small narrow area you try to become an expert in. There is also a lot of freedom here, to solve tasks by yourself. People get a lot of confidence to fix what needs fixing. In research, there's not the same requirement to bill every hour as it might be in the industry. If the results are good it does not matter if it takes another month, especially if you do something that you cannot buy and that perhaps no one else even thought that one could do. So there is a great freedom to develop your own ideas and take advantage of your own talents. There is an opportunity to experiment, even if you are a craftsman, not a scientist, which might not be the reality in so many other work places.

Kurt in the Parallel Plate Avalanche Counter

New diabetes drugs and graphene-based transistors

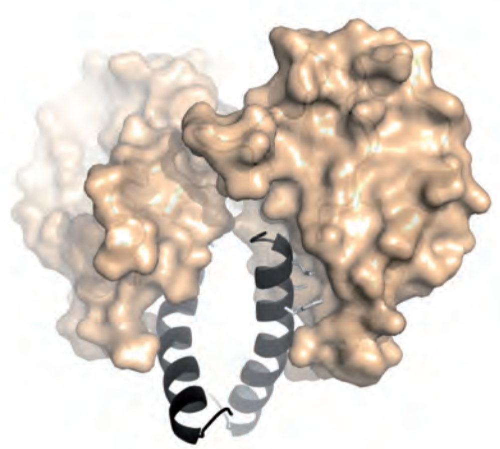
→ Synchrotron radiation is a versatile research tool and the needs of highly diverse scientific disciplines can be met with a wide range of experimental techniques at the MAX IV facility. Below are a couple of highlights from the existing facility where 25 years of operation has resulted in more than 3 100 published articles in peer reviewed journals.

Protein structure – the key to new drugs

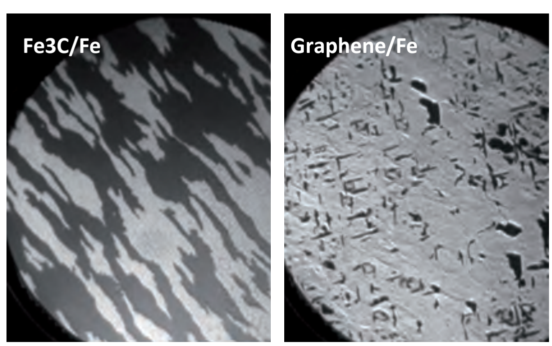
The Danish multinational pharmaceutical company Novo Nordisk is one of the largest diabetes care providers in the world. Researchers from Novo Nordisk's two main R&D sections, the Biopharm Research Unit and the Diabetes Research Unit, are regular visitors at the MAX IV Laboratory and measurements at the facility have provided important puzzle pieces in the development of the company's products. One such example is the investigation of a hormone involved in the production of insulin in the human body. Glucagon-like peptide-1 (GLP-1) is secreted in the gut and in addition to stimulating insulin secretion it has been shown to reduce and control blood sugar and body weight. The hormone has therefore attracted a lot of attention as a potential treatment of type-2 diabetes patients. In their effort to further understand the bodily functions of GLP-1 and to develop other, more efficient analogs, i.e. similar molecules more suitable for medicinal purposes, researchers from Novo Nordisk used the Molecular Crystallography facilities at the I911-3 beamline at the MAX IV Laboratory to determine the molecule's 3D structure when bonded to its receptor in the body. These results have provided vital clues for the development of the next generation of type-2 diabetes drugs.

Graphene - a Material for the Future

Graphene is a carbon material with exciting properties and promising applications in nanotechnology. Experiments on graphene are examples of the many research projects performed at beamline I311 at the MAX IV Laboratory. Controlling the thickness and homogeneity of the thin sheets of carbon atoms in graphene is a prerequisite for creating electronics such as p-n junctions and graphene-based transistors from the material. Low energy electron microscopy (LEEM) is an ideal tool for graphene studies. LEEM images immediately tell how many graphene layers are present on a surface, and the low energy photoelectrons created in the process carry information about electronic structure, chemical bonding and doping levels. The many different ways of achieving microscopic imaging give complementary information about the surface and the interface.



The structure of GLP-1 (black ribbon) bound to its receptor GLP-1R



Low Energy Electron Microscope (LEEM) images of iron carbide (left) and graphene (right) grown on Fe(110) surface. FoV=15mm. The iron carbide phase on Fe shows two different domains (black and white). In contrast to carbide, graphene on iron forms only one domain showing a uniform coverage (dark elongated features in the right image are due to the cracks developed in the Fe film upon annealing). From N.A.Vinogradov et al. Phys.Rev.Lett. 109, 026101 (2012).

Revisiting animals 190 million years old

→ Now we have revealed the colour scheme of three extinct marine reptiles. The oldest one 190 million years old. They were actually dark-coloured way back when.

Discovery of an original 54 million years old pigment

The survival and preservation of hundred-of-millions years old original biomolecules in animals and plants and the detection and characterization of those is the fundamental problem in molecular paleontology. Today, based on research made at MAX-lab and SP in Borås we know that pigment bearing organelles, melanosomes, can survive in a fish-eye for at least 54 million years. Moreover based on these findings we have revealed the colour scheme of three extinct marine reptiles, the oldest being 190 million years, and that they were dark-coloured in life. Our discovery enables us to make a journey through time and to revisit these ancient animals using their own biomolecules. Now, we can finally use our sophisticated molecular and imaging techniques to learn what these animals looked like and how they lived.

J. Lindgren, P. Uvdal et. al. Nature Communications DOI 10.1038/ncomms1819, 2012
J. Lindgren, P. Sjövall, R.M. Carney, P. Uvdal et. al. Nature 506, 484-488 (2014)

The discovery of pigment particles in a fish eye let us reveal the color of extinct marine reptiles.

Meet one of our users – Mehrdad Mahdjoubi

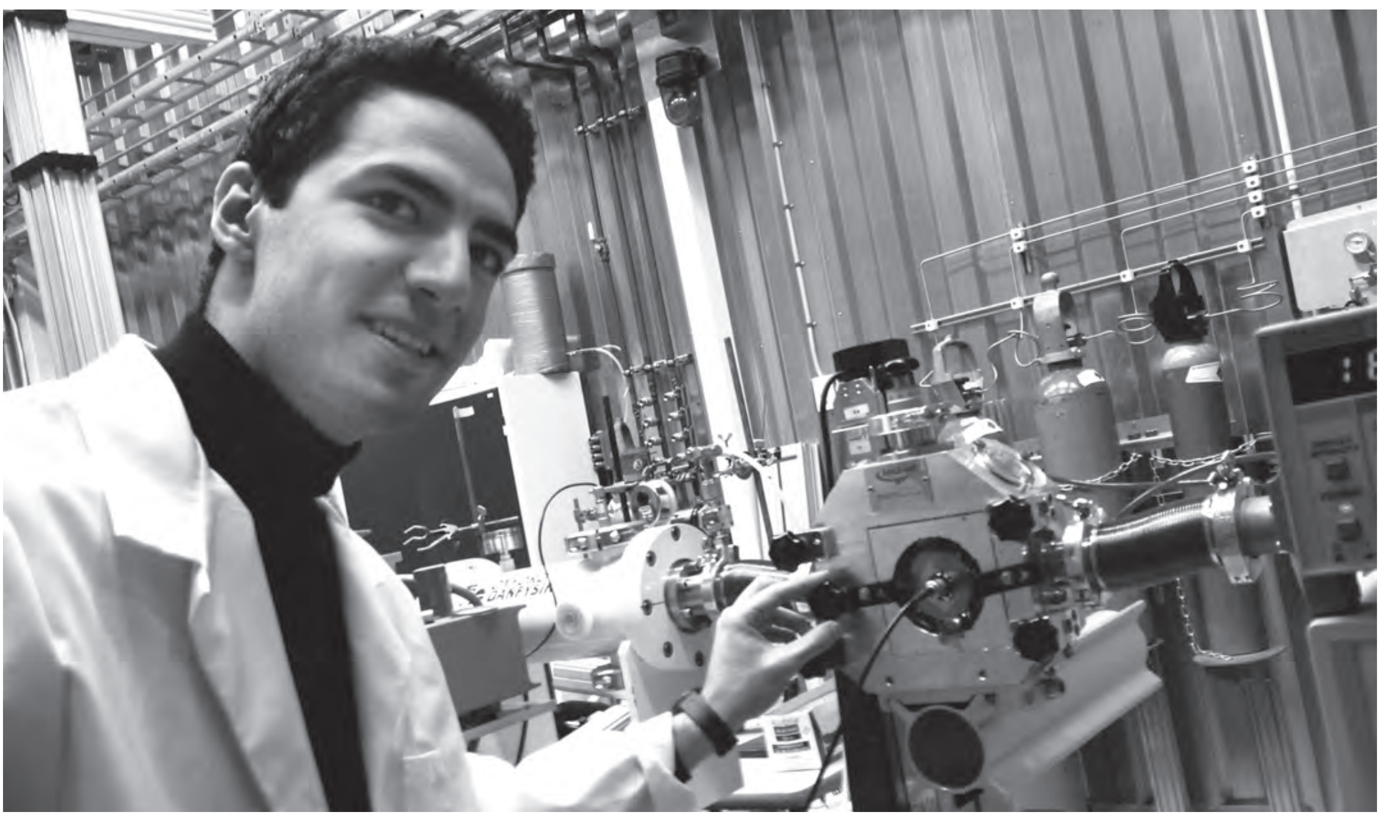
→ Founder & CEO Orbital-Systems. In 2012 he won the prestigious Niklas Zennström Green Mentorship Award.

Mehrdad and his company Orbital Systems have developed a revolutionary water recycling technology that can be applied to various household products. When applied to showers, it makes it possible to save over 90 percent of water consumption and over 80 percent of the energy needed to heat the water. Ordinary tap water contains both bacteria (albeit very low in Sweden compared to most countries in the world) and precipitation of metals from the pipes. This recycling system should take away such impurities.

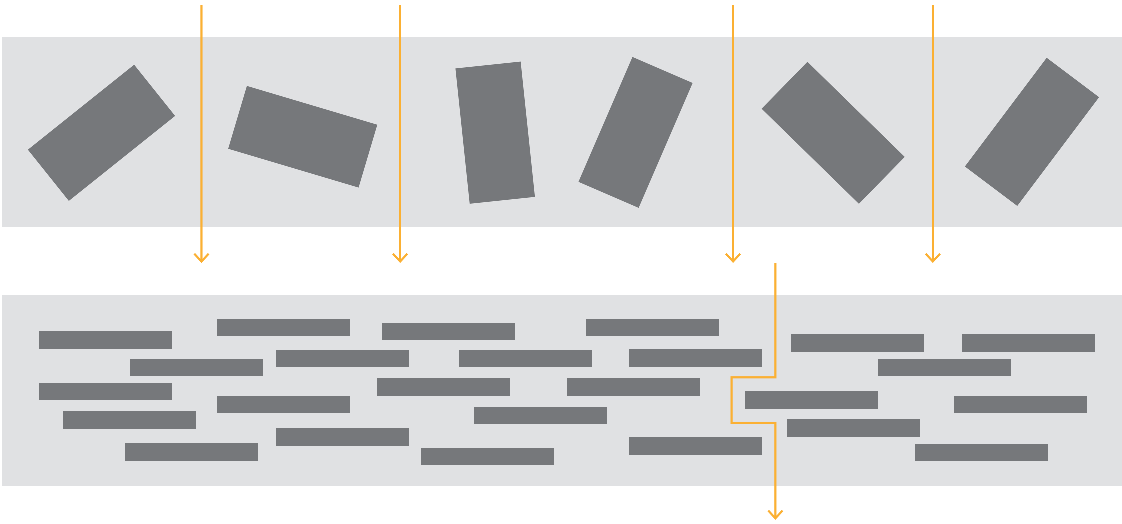
How did you come up with the idea?
It started as a graduate job in Industrial Design at LTH, Lund University. I simply questioned how we use water today. One thing that I think is quite bizarre is that we flush toilets with drinking water in Sweden. And no one questions it. Nothing happens in any case. And then I checked if we could have a more intelligent management of this resource, water, which actually is limited.

What is the purpose of your visit at MAX IV Laboratory?
The time here will be used to investigate our purification system and look into how it can be even more improved. The method used is called X-ray absorption spectroscopy*, and it's done at beamline I811 at MAX-lab.

** X-ray absorption spectroscopy allows the scientists to determine, for example, at what temperatures or pressures a particular chemical process occurs or how different chemicals react with each other. This can be done in real-time meaning that during ongoing analysis one can alter various parameters of the process and thus find the processes that produce the results the users desire.*



Improving package material and visualizing cancer

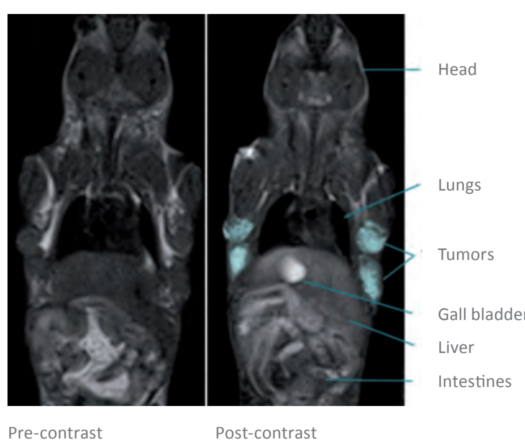


The more "tortuous" diffusion path of gases through the membrane makes this type of composites suitable for applications such as gas barriers. Used in milk cartons it will keep the milk fresh preventing the milk from taking flavour of that delicious but smelly Danish cheese you also keep in the fridge.

→ Researchers at Tetra Pak are continuously developing new materials for use in their various packages. One such material is a polymer based composite. In their effort to understand the properties of the composite material, Tetra Pak researchers visited the beamline I911-SAXS at MAX IV Laboratory to perform small-angle X-ray scattering. The technique is sensitive to the size, distribution, orientation and aggregation of the particles in the polymer matrix, which are factors known to influence the gas barrier properties of the material. The figure above illustrates the advantage of using the material with the "tortuous" diffusion path instead of conventional composites in gas barrier plastic films. The experiments helped the Tetra Pak researchers understand how the particles were distributed in the polymer matrix and how they influence the final properties of the composite. Their visit to MAX IV Laboratory thus provided them with an important puzzle piece in their development of improved materials for packages for food distribution.

Nanoparticles to visualize breast cancer

SPAGO Pix, a novel and proprietary nanomaterial, is being developed for use as cancer selective MRI contrast agent. It has the potential to significantly improve visualization of soft tissue tumours. Early and accurate diagnosis is vital to ensure treatment efficiency and increase long-term patient survival. SPAGO has verified size, composition, and manganese coordination geometry for the SPAGO Pix MRI contrast agent. The results were generated in collaboration with the scientists at the MAX IV Laboratory in Lund, Sweden. The techniques used were XAFS and SAXS, both utilizing the high intensity, monochromatic X-rays generated by the accelerator. The results obtained at MAX IV Laboratory are important as they support previously on size and composition generated data by other methods and also ab initio calculations of binding geometry.



SPAGO Pix is a gadolinium-free nanoparticle based contrast agent with exceptionally high relaxivity (signal strength) that selectively accumulates in tumour tissue via passive tumour targeting (EPR effect). The images show a MRI scan of a rat with breast tumours before and after injection of the contrast agent. The tumours have been colour coded in blue as an aid for the eye.

Sustainable and energy-saving facility

→ MAX IV is not only world leading when it comes to the scientific properties. It is also a very energy efficient facility due to the technical design of the accelerator and the buildings. The different new techniques developed for MAX IV will reduce the energy consumption compared to traditional synchrotron facilities. The smaller magnets, the lower frequency used in the RF cavities and the NEG coating in the storage rings makes MAX IV less energy consuming than any other synchrotron. The total power consumption of magnets in the 3 GeV ring at MAX IV is about half of that in the MAX II ring even though MAX IV is five times bigger. And yet the quantity and quality (brilliance) of the synchrotron light produced by MAX IV will be vastly superior to that in MAX II.

Still, research facilities as big as MAX IV use a lot of energy. The ambition is to use only electricity coming from renewable sources, mainly water and wind. A small amount of electricity will be generated by solar panels on the roof of the office building. Great efforts have been made to recycle and reuse the excess heat generated from the linac and accelerators. All accelerator equipment is connected to a cooling system with heat exchangers and heat pumps which makes it possible to reuse the excess heat via the district heating system in Lund and getting cooling water for the accelerator equipment in return. This is not only a way to make really good use of all the excess heat generated in the facility but also a way to receive cooling water, reduce the operation cost for the facility and reduce the carbon footprint.

A Green Design and Construction

The design and construction of MAX IV are based on the latest technique and knowledge and aims to be classified according to, amongst other, Green Building and BREEAM Excellent according to the new Swedish manual. The commissioner of the building project, Fastighets AB ML4, has helped to develop the BREEAM-SE manual with MAX IV as one of five testing pilots. The very first application, number 001, belongs to MAX IV, and we hope to be the first to receive approval according to BREEAM-SE. This classification and the one of Green Building relates to the office building but the same high-level environmental standards have been used for the entire facility. To reach the goals, an extensive program for sustainable construction has been implemented. This has for example resulted in LED-lights in all of the buildings, demand controlled ventilation and green roofs that improves insulation, helps stabilizing the temperature in the experiment halls while storing and delaying rain water drainage, reducing the impact on sewage systems and improving wildlife environment. The construction process in itself includes goals for sustainability, for example "greener" logistics, low energy consumption, a minimum of waste, waste sorting etc.

A Green Site

The landscape around MAX IV follows the high sustainability agenda for the area. For example, all the cut and fill from the excavations are kept on site and are reshaped into a hilly landscape, constructed to reduce vibrations and to maximize the land surface area, giving room for more grass, flowers, recreational areas, birds and frogs. To further enhance the ecological diversity, a mix of seeds from the nearby nature reserve Kungsmarken and from commercially available seeds will be sown on the slopes. And instead of using your ordinary, motorized lawn mower the slopes are planned to be grazed by sheep. Water is an important feature for wildlife and also enhances the biological diversity, and there will be arranged rainwater delay ponds for the surface water where wetland vegetation will be introduced.

Highlights on the road to the bright light

21 JUNE 2016
Inauguration of the functioning MAX IV facility is planned to take place on the brightest day of the year.

1 SEPTEMBER 2015
The finalised building, installation and landscaping project will be handed over to Lund University and MAX IV Laboratory.

1 NOVEMBER 2013
The linac and klystron tunnels, the start and SPF (Short Pulse Facility) buildings were completed on time and has been handed over to the MAX IV Laboratory.

1 NOVEMBER 2014
The large experimental building with the tunnel for the 3 GeV synchrotron ring is to be handed over for early access.

1 JANUARY 2015
The office building will be accessible for furnishing and the staff will start moving in.

1 MAY 2015
The small experiment building and tunnel for the 1.5 GeV synchrotron ring is to be handed over for assembly.

Come join
the bright future!

→ MAX IV Laboratory is an international environment with scientist visiting from all over the world. We are around 150 employees with more than 25 different nationalaties represented and our working language is English. We cover a broad range of professions: scientists, engineers, administrative staff and more. Up until the inaguration of the new facility in June 2016 we will need to recruite some 40 to 50 more people. We need all kinds of skills but what we need most is engaged people who has the ability to work in teams to solve problems together. The atmosphere is friendly and familiar. Do you want to be part of our bright future? Then come and join us!

As an employee at MAX IV Laboratory you are also an employee at Lund University with around 7200 employees. The University has a long history and the traditions goes all the way back to 1666 when it was founded.

Follow us on

twitter.com/MAXIVlab

facebook.com/MAXIVLAB

instagram.com/maxivlaboratory

linkedin.com/company/max-lab

vimeo.com/MAXIVLaboratory

Partners

University of Gothenburg
Uppsala Universitet
Region Skåne
Lund University
Stockholm University
Umeå Universitet
Linköpings Universitet
SLU
Vinnova
Karlstads Universitet
Luleå University of Technology
KTH Vetenskap och Konst
Karolinska Institutet
Knut och Alice Wallenbergs Stiftelse
Academy of Finland
Vetenskapsrådet
Chalmers

CREDITS

Editor: Andreas Lassesson & Tutti Johansson Falk
Design: Borstahusen Kommunikation AB
Print: Media-Tryck, Lund University
Paper: Cover Arctic Volume White 300 g,
insert Arctic Volume White 130 g
Photos: Perry Nordeng och Johan Persson
Illustrations: FOJAB arkitekter, Borstahusen

MAX IV Laboratory
Lund University
PO Box 118
SE-221 00 Lund
Sweden

Tel: +46 (0)46 222 98 72
maxiv.se