DNR STYR 2016/367

Annual Report of MAX IV Laboratory to the Swedish Research Council

2015

MAX IV LABORATORY

Contents

1 Introduction

2015 was the last year MAX IV Laboratory operated its two main facilities, MAX-lab and the MAX IV Phase I project, simultaneously. The main buildings of the new MAX IV facility was handed over to Lund University and MAX IV Laboratory in June 2015 and at the end of the year the move of personnel was under way. The storage rings at MAX-lab were shut down for good in December 2015. Almost a thousand researchers had then visited MAX-lab during the year, a remarkable number considering that the availability of the MAX-lab accelerators was lower than previous years due to aging equipment. At the MAX IV facility, commissioning of the large, 3 GeV, storage ring started according to plan in August. Already a month later the injected electron beam was stored in the ring and in November synchrotron light was for the first time extracted on a diagnostic beamline.

The operation of MAX IV Laboratory was during 2015 supported by the Swedish Research Council (VR) grant 827-2013-2235. As a condition for the grant MAX IV Laboratory has been asked to submit an annual report with emphasis on the activities at the facility. This report covers the year 2015 and includes items requested by VR:

- Organisational matters
- Operation and user statistics
- Scientific output
- International contacts/collaborations
- Commercial activities
- Communications and outreach
- Finances

2 Organisational matters

The MAX IV Laboratory organisation continued to grow during 2015 to a total of 200 employees at the end of the year, see Figure 1. The bulk of new recruitments were of staff members for MAX IV beamline projects. No major organisational changes have been made during the year.

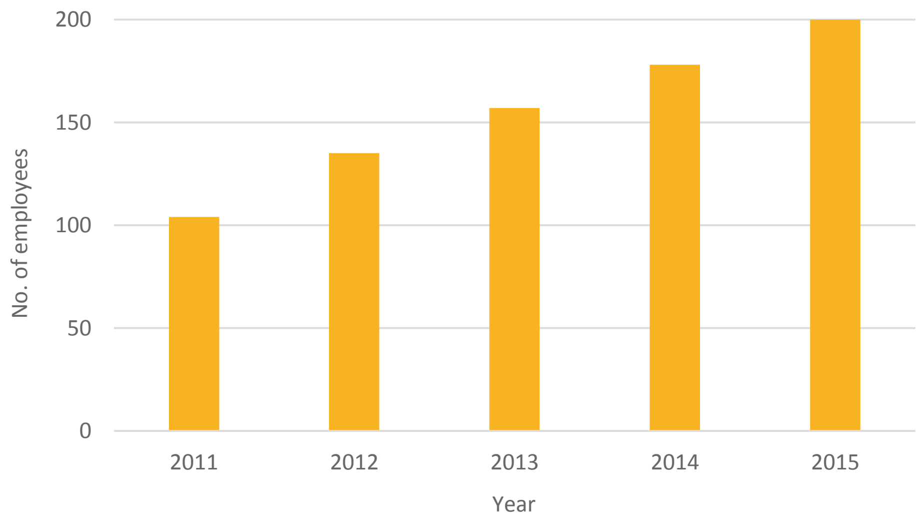

Figure 1 End of year numbers of MAX IV Laboratory employees for the years 2011 – 2015.

3 Accelerators at MAX-lab

The synchrotron radiation sources of the old MAX-lab facility are the result of long lasting developments in accelerator design and development. Maintaining the performance of the accelerators in terms of stability, brilliance, emittance and long term delivery was among the primary goals of the laboratory for this last year of user operation.

The low-energy ring MAX III has been supplying one infrared and two vacuum ultra-violet beam lines with synchrotron radiation, while the medium-energy MAX II ring has served twelve soft and hard X-ray beam lines, during all planned user weeks of 2015. As can be seen from Figure 2, the MAX III ring has offered an availability (beam access for users during six days per week around the clock) in the 93 per cent range, similar to the performance of the latest five years. It also offered the highest mean intensity ever during this last year, namely an average stored beam current of 249 mA. The MAX II ring, being roughly ten years older, could not fully keep up to former years availability during its last year of operation, and dropped down to only 86 per cent. It is worth to mention that the availability mainly dropped during the last half year of operation when immediate manpower was lacking for repairing crucial equipment, since the commissioning of the new 3 GeV ring at MAX IV was prioritised and ran in parallel.

On 13 December 2015 the accelerators at MAX-lab were shut down for good.

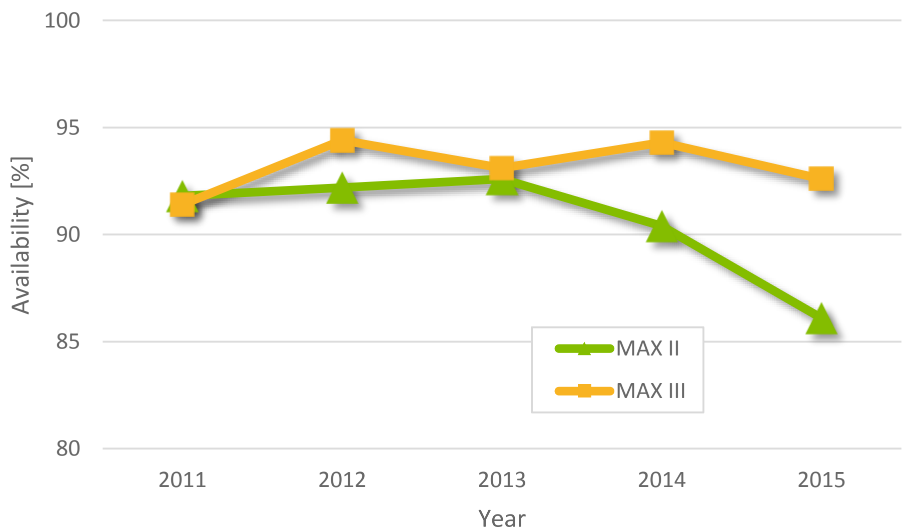

Figure 2 Availability of beam for users at MAX II and MAX III 2011 – 2015

4 User operations

Despite having a lean organisation when compared to many other synchrotron facilities, MAX IV Laboratory prides itself on a friendly and efficient user service. The laboratory also values the input from and collaboration with the user community. An important event to bring users and laboratory staff together is the Annual User Meeting. The 2015 meeting, arranged 21–23 September in Lund, was entitled 'Looking back … & Forward' with a combination of talks and discussions concerning the history of MAX-lab and the future of MAX IV Laboratory, together with featured talks on both current synchrotron research and discussions of future beamlines at MAX IV. The meeting attracted about 300 users and other stakeholders from Sweden and abroad.

The Association for Synchrotron Light Users at MAX-lab ("Föreningen för Användare av Synkrotronljuset vid MAX-laboratoriet", FASM) speaks for all users at MAX IV Laboratory and maintains communication between the user community and the laboratory board and management. FASM also communicates current and future needs within the user community and disseminates information to the users about the plans and prospects for MAX IV. FASM's annual meeting coincides with the Annual User Meeting.

4.1 User statistics

The beamlines at MAX-lab have always been visited by researchers from a wide range of scientific fields and countries. In 2015 MAX-lab had 990 users, Figure 3. The user gender distribution was 28 per cent women and 72 per cent men across international as well as national users. The numbers of submitted and approved proposals for beamtime are shown in Figure 4 and are the same as for 2014. The 2014 proposal call was the last for application of beamtime at MAX-lab and this allocation was extended to its closing in December 2015. There were thus no proposal calls issued in 2015.

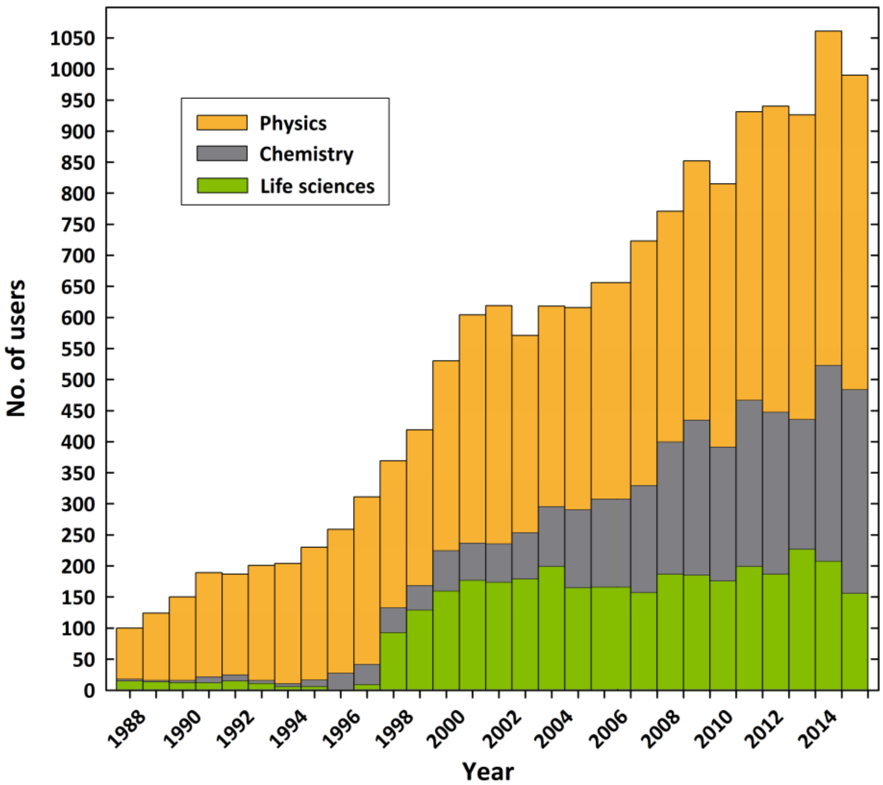

Figure 3 Numbers of annual users at MAX-lab 1987 – 2015.

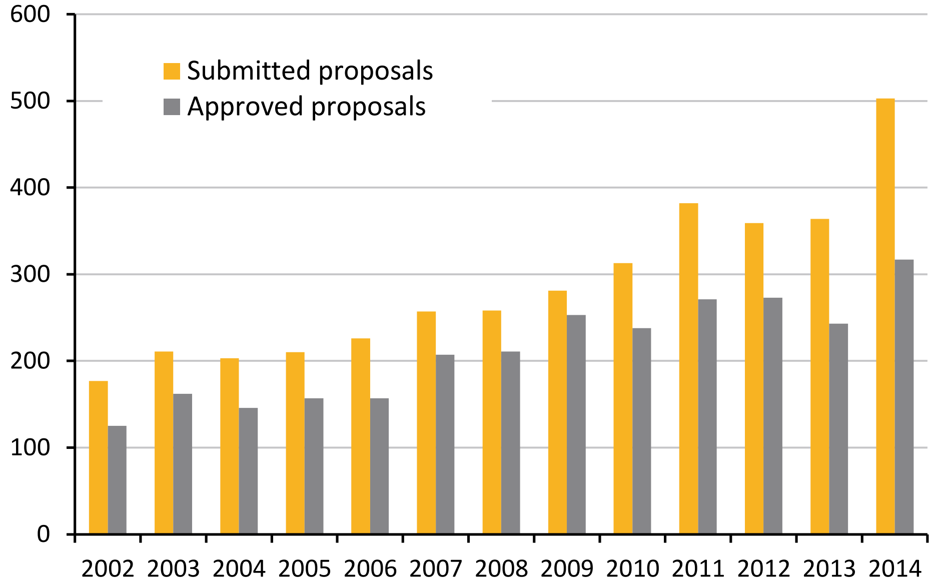

Figure 4   Numbers of submitted and approved proposals for beamtime per year since 2002. The numbers of approved proposals in 2014 also includes those for 2015.

Almost 45 per cent of all users in 2015 came from Sweden. Lund University is the Swedish university with most users with 44 per cent of Swedish users. This is a result of strong local user groups as well as the geographical proximity. Other well-represented national institutes were Uppsala University (17 %), Chalmers and the Royal Institute of Technology (KTH) (both 6.5 %). Stockholm University, University of Gothenburg and Linköping University were all represented by 3-4 % of the Swedish users at MAX-lab. In total users from 16 Swedish academic institutes were registered in 2015.

Swedish researchers could until mid-2015 ask to be reimbursed for travels to do experiments at other European light sources via EU-funded programs. No such reimbursement possibilities exists for Swedish researches wanting to use MAX IV Laboratory. Establishing a program that covers their travel expenses would be a good way to increase the number of Swedish users from outside Lund and it would have our strong support.

A quarter of all users in 2015 came from the other Nordic or Baltic countries and another quarter came from other European countries. In total we had users from 32 different countries and 143 different institutions during the year.

The large number of beamtime proposals and users, and the relatively large number of international visitors illustrate both the quality of the user service at the laboratory and how successful it has been over the years in keeping both accelerators and beamlines updated and internationally competitive.

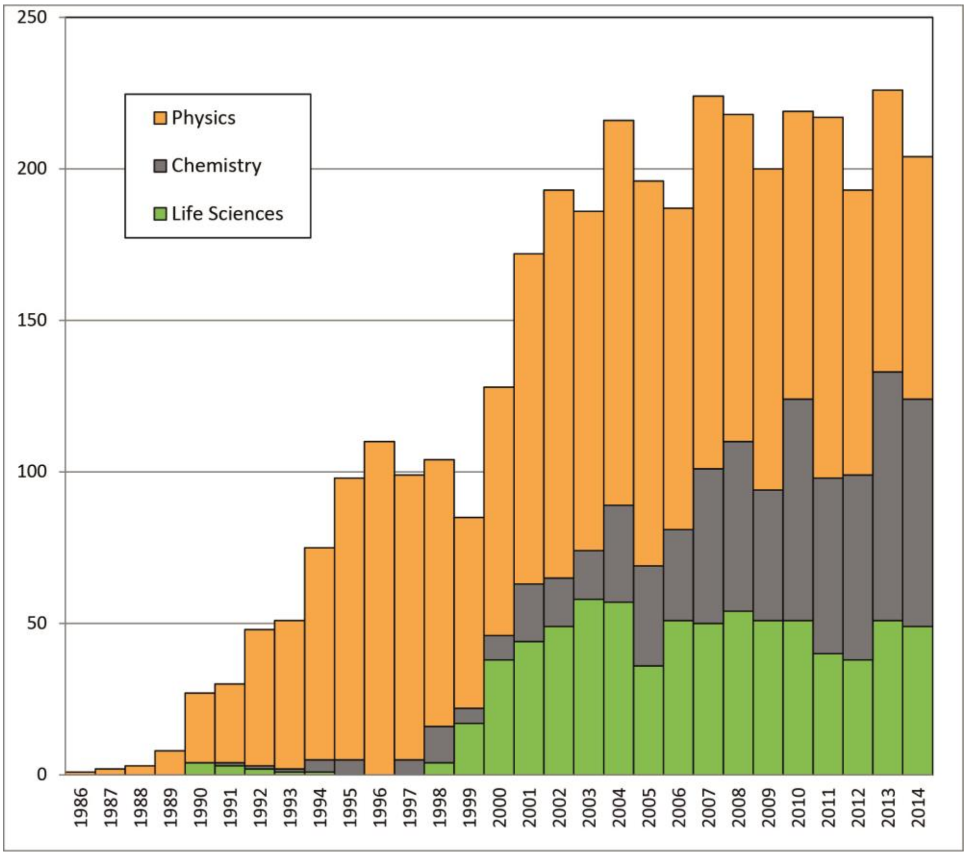

Figure 5 Numbers of reported peer-reviewed publications produced at MAX-lab 1986-2014

4.2 Scientific Output

The yearly numbers of publications published with results produced at MAX-lab is shown in Figure 5. As the figures depend on self-reporting by users, usually done in connection with submissions of applications for beamtime, they are most likely underestimated and also lag behind by one year. In addition, since there was no proposal call last year, there are reasons to believe that there are even more unreported publications this year. In the last 15 years there has on average been one publication per day of operation of the facility, and in the last years they have been divided approximately equally over the fields of physics, chemistry and life sciences.

Below are examples of scientific breakthroughs published in 2015 with results relying on experiments done at MAX-lab.

Semiconductor nanowires represents a technology platform for a wide range of future applications such as Light Emitting Diodes, Solar Cells, telecommunication and high speed/low power electronics. Furthermore they are central components in future quantum computing technologies and can be used for direct probing of living cells. At the MAX IV Laboratory, nanowires of ever higher complexity have been studied with a variety of methods comprising both soft X-ray spectroscopy and hard X-ray diffraction beamlines. This use of multiple beamlines offering different techniques is envisioned to be applied also at the MAX IV facility.

InGaAs is in combination with InP, an important material system for applications such as bipolar transistors, solar cells, and optical communication. In a recent publication[1], growth and characterization of wurtzite InP−InGaAs core−shell nanowire hetero-structures was reported. X-ray diffraction measurements performed at beamline I811 at MAX II revealed important information on morphology, composition and strain of the nanowires. Combined with transmission electron microscopy this gave a complete structural picture of the nanowire – a prerequisite for any understanding of the wire properties. The nanowires showed emission in the infrared regime, making them suitable for applications in optical communication.

Due to their inherent large surface to bulk ratios, the electrical properties of nanowires are extremely sensitive to their surface structure, oxidation state or any adsorbents on the nanowire. A precise chemical characterization of the nanowire surfaces is thus central to explain and control their behaviour. For this purpose, highly sensitive X-ray photoemission spectroscopy (possible at beamline I311 at MAX II), Scanning Tunnelling Microscopy and nanowire device measurements – all under the same conditions has turned out to be extremely useful. Recently it was found that the controlled removal of all native surface oxides from InAs/InSb nanowire heterostructures is possible using atomic hydrogen[2]. The hydrogen treatment resulted in a two orders of magnitude increase in conductance of devices made from the nanowires. This study demonstrated the significant potential of atomic hydrogen cleaning regarding device fabrication when high quality contacts or complete control of the surface structure is required.

At MAX IV research on nanowires will continue at for example the NanoMAX and MAXPEEM beamlines. The proposed DiffMAX beamline would add the possibility to study nanowire growth and their structural connection to the substrate.

In a work published in Nature Communications, the first spectroscopic and full structural characterisation of a protein from the LPMO-family, the AA13-protein, was reported[3]. LPMOs, lytic polysaccharide monooxygenases, is a family of proteins that degrade recalcitrant carbohydrate chains such as cellulose and starch, to molecules accessible for degradation performed by other more abundant enzymes. LPMOs are found in fungi and bacteria and are essential to the global carbon cycle. They have also proven to be key factors in industrial biomass conversion such as bioethanol production. In this publication, the starch-degrading AA13-protein is investigated in order to learn and understand more about its actions. The structure of the enzyme was characterised at beamline I911-3 at MAX II, and it reveals important information about the active site and on how AA13 interacts with starch. This is of importance for the understanding of the activity range of this class of proteins and to explore and exploit the full potential of this particular one.

Protein structure research will continue at the MAX IV BioMAX beamline. The proposed MicroMAX beamline would be a superb supplement since it will allow the study of smaller crystals, opening the field to even more demanding protein molecules.

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[1] Heurlin M. *et al,* Structural Properties of Wurtzite InP-InGaAs Nanowire Core-Shell Heterostructures, Nano Letters (2015) **15**, 2462.
[2] Webb J.L. *et al,* Electrical and Surface Properties of InAs/InSb Nanowires Cleaned by Atomic Hydrogen, Nano Letters (2015) **15**, 4865.
[3] Leggio L. *et al*, Structure and boosting activity of a starch-degrading lytic polysaccharide monooxygenase, Nature Communications (2015) **6,** 5961.

No patents relying on work performed at MAX-lab have been reported, but the laboratory is strongly engaged in activities intended to increase the commercial use of its facilities, as described in the next section.

5 Commercial activities

The closure of the MAX-lab facility in December 2015 ended many years of successful interactions with industry, particularly in the areas of life- and material sciences. Our ambition is to maintain and expand such activities, based on the good relationships of the old facility.

In 2015 we initiated several activities aiming at understanding and increasing the industrial relevance of MAX IV Laboratory. Most notably, in an initiative driven by the Wallenberg Wood Science Centre (WWSC), we engaged with the forestry industry. Through a set of joint workshops, with invited national and international experts, the relevance of techniques present or possible to implement was discussed. The outcome was an agreed view that synchrotron based methods, together with the unique properties of MAX IV, have a lot to offer to the strategic research efforts of the forestry industry. This has now led to a proposal from the forestry industry for investments both at MAX IV to enable new types of in situ studies, and in a large research program that will foster a new generation of scientists to master these methods.

The successful work done together with the forestry industry will serve as a role model for future interactions with other industries. The core of the model is to work with industry, sector by sector, and in close collaboration with the, from a research perspective, leading companies. Furthermore, we should as far as possible use existing structures and networks, such as research centres/groups, institutes and strategic research programs. The later part of the strategy is also driven by necessity as we do not yet have the internal capacity to carry out these types of initiatives by ourselves. Worth mentioning in this context is that Diamond, the national synchrotron in the UK, has an Industrial Liaison Office, ILO, with ten people working to assist industry. At MAX IV the same function now consists of one person. MAX IV Laboratory and its funders need to decide how to work and prioritise with respect to industrial use and impact.

Over the year we have met with Swedish research institutes to discuss their role relative to MAX IV. It is clear from these discussions that their mission definitely would benefit from increased use of synchrotron based techniques. It has been suggested that Research Institutes of Sweden, RISE, should take a more active role in implementing an increase of the use of synchrotron based techniques in Swedish industries in order to give them a more competitive edge. These discussions will continue in 2016. In November MAX IV Laboratory and SP Technical Research Institute of Sweden arranged a course in Lund on how synchrotron based techniques can be used for industrial applications in metallic materials applications. The course had a dozen participants from the automotive, packaging and metals industry.

On 1 September Magnus Larsson joined the MAX IV Laboratory to work full time as Industrial Liaison Officer. Magnus comes from Topsoe Fuel Cell in Denmark where he worked as Program Manager for customer and partner activities with the aim to bridge the customer's product development with the internal research intense technology development.

As ILO Magnus Larsson will be leading the efforts in establishing the Industry Liaison Office at MAX IV Laboratory with an initial focus on getting traction in the forestry industry investments in MAX IV. Other industry sectors already showing an interest in the possibilities presented by MAX IV are Food and Packaging, Metals and Nano Technology. Life Science, Pharma and Material industries have a long history and experience from using synchrotron based methods at MAX-lab already. Experience gained from these collaborations will serve as model for how we set up the practical work with industry. Discussions with a selected number of companies are ongoing regarding industry user agreements and access conditions. Other important focus areas are collaboration with the Swedish universities and their industry activities in particular, formalising the relations to the RISE institutes and engaging other mediating companies that are working on getting access for industry to synchrotron based methods.

The University Reference Group (URG) serves as a forum for coordination of the strategic plans on research, education and innovation of Swedish universities with those of the MAX IV Laboratory. URG consists of two representatives from each of the twelve funding universities, one of whom is closely connected to the management of the representing university. URG has an advisory role and reports primarily to the MAX IV Laboratory management. In 2015 URG met in Lund once in April and once in November.

6 International and national collaborations

MAX IV Laboratory is collaborating with many other synchrotron facilities to exchange scientific and technological ideas. These collaborations are crucial for the development of beamlines and accelerators at MAX IV. An example of such fruitful collaborations is the one with Jagellonian University in Krakow, Poland, which in September was crowned with success as the Solaris synchrotron was inaugurated. Solaris is a copy of the new small, 1.5 GeV, storage ring at MAX IV Laboratory.

A list of international agreements and collaborations put in place during 2015 is found in the Appendix.

The management and staff of MAX IV Laboratory are active on the international scene of synchrotron radiation science as for example members of advisory committees for other facilities.

In 2015 MAX IV Laboratory entered a collaboration with Linköping University and the National Supercomputer Centre with the aim to enable and facilitate access for Swedish scientists to state-of-the-art high performance computer (HPC)-optimized software for structural biology. The project, called PReSTO, will provide a well-maintained, interactively accessible and near-complete set of software for structural biology data evaluation and interpretation.

7 Financial report with comments

The result and budget for operations at MAX IV Laboratory 2015 can be found in table 1. Comments to the outcome are found below the table.

Table 1 Result and budget for 2015

kSEK	2015	BUDGET
Lund University	47 357	47 000
VR	198 940	199 297
TOTAL REVENUES	**246 297**	**246 297**
DIRECTOR	**-127 286**	**-117 114**
Staff cost	-108 795	-94 591
Director´s reserve	-676	-1 250
Director´s groups	-3 657	-4 354
Phase 1 NLF deficit	-2 549	-2 800
MAX IV satellites	-1 000	-3 000
Projects	510	0
Lund University OH	-11 119	-11 119
ADMINISTRATIVE DIVISION	**-95 112**	**-97 869**
Administrative director	-1 884	-2 576
MAX-lab rent & facility	-24 555	-28 050
MAX IV rent (incl maintenance rent)	-49 442	-48 200
Building services	-17 925	-16 018
Finance, HR & Office Services	-1 306	-3 025
MACHINE DIVISION	**-13 618**	**-17 837**
Machine director	-749	-678
Accelerators operation	-3 582	-6 180
Engineering	-4 857	-4 527
RF	-1 080	-952
Helium	-3 350	-5 500
SCIENCE DIVISION	**-13 314**	**-13 477**
Science director	-2 085	-2 210
DanMAX	0	-1 000
Beamline operation	-7 607	-7 422
IT & Controls	-4 558	-3 945
Beamtime sales	936	1 100
TOTAL COST	**-249 330**	**-246 297**
RESULT 2015	**-3 033**	**0**

Staff: The staff deficit is -14 204 kSEK, due to unbudgeted IT consultants, temporary positions, as well as prolongations of positions not in budget, which were needed to build and commission the MAX IV Phase I project in time.

MAX IV Satellites: The cost of 1 000 kSEK concerns PReSTO (Linköping University). Originally three satellites were budgeted for.

Projects: Net result of remaining depreciations of old I811 VR project and financial closure of the 20 MSEK "VR20 project".

MAX-lab rent & facility: Budget estimation by LU Byggnad 2 MSEK too high. Lower electricity cost 1.5 MSEK.

MAX IV rent: Temporary office modules and cost for D-building extension.

Building services: Increased depreciation cost on major investment due to reduction of economic lifetime.

HR: Lower relocation cost than estimated.

Accelerator operations: The budget for the new group AFSG (Accelerator Facility Steering Group) was determined according to "Operations application 2014–2018".

Helium: A problem with high helium consumption of the I811 wiggler was solved, hence cost below budget.

Science Director: Dismantled equipment at MAX-lab: -590 kSEK

DanMAX: Final agreement not yet in place.

IT & Controls: Cost for licences.

The result: The deficit of -3 MSEK fits well in the overall planning for 2014–2018.
Agency capital: We continue to have good control of the Agency Capital, for the year 2015 we have a negative closing balance of -5.5 MSEK.

8 Communication & Outreach

MAX IV Laboratory operates an active outreach program and has been welcoming visitors from schools, companies, universities and the general public from Sweden as well as from abroad to both MAX-lab and to the MAX IV site. The interest for study visits has increased considerably over the years, from 1 500 visits in 2010 to more than 6 000 in 2015. In connection with the Annual User Meeting in September, MAX IV Laboratory arranged an open seminar for the general public with talks on synchrotron based methods how they can be used.

The communication group at MAX IV Laboratory consists of three fulltime employees responsible for study visits, website, events and general outreach through press and media.

During the year a network of communication staff at Swedish universities has been established with the aim to engage and update the different universities on the activities at MAX IV Laboratory. The network also provides a channel into the universities to help get in touch with potential new users at their different organisations.

Appendix – International agreements and collaborations 2015

DESY (Coordinator), Kurchatov Institute, Forschungszentrum Juelich GmbH, B.P. Konstantinov Petersburg Nuclear Physics Institute, Fac. For Antiproton and Ion Research in Europé GmbH, Joint Institute for Nuclear Research, Helmholtz-Zentrum, Technische Universitaet Muenchen, Institut Max von Laue - Paul Langevin, ESS, IERS, European X-ray Free-Electron Laser Facility GmbH, AISBL, CEAEA, Russian Academy of Sciences, CERN, Budker, A.V.Shubnikov Institute of Crystallography, LU	654166 - CREMLIN Consortium Agreement (CREMLIN: Connecting Russian and European Measures for Large-scale Research Infrastructures)
University of Oulu	Cooperation Agreements for the construction of Scientific Instrumentation and of an insertion device to be used at the MAX IV Laboratory between The MAX IV Laboratory and University of Oulu
TTY Foundation	Cooperation Agreements for the construction of Scientific Instrumentation and of an insertion device to be used at the MAX IV Laboratory between The MAX IV Laboratory and TTY (Tampere University of Technology)
University of Turku	Cooperation Agreements for the construction of Scientific Instrumentation and of an insertion device to be used at the MAX IV Laboratory between The MAX IV Laboratory and University of Turku
ESRF	Secondment Agreement between ESRF and MAX IV Laboratory
Budker Institute of Nuclear Physics	Amendments to Specific Scientific Collaboration between MAX IV Laboratory and Budker Institute of Nuclear Physics of SB RAS for the Design and Construction of Dipole Pulsed Magnets for the MAX IV Facility (Amendment 6 dd April 4th, 2015, Amendment 7 dd May 15, 2015, Warranty Certificate, Amendment 8 dd May 28, 2015)

Universiteit Utrecht, European Molecular Biology Laboratory, Diamond Light Source Ltd, Consorzio Interuniversitario Risonanze Magnetiche di Metallo Proteine, Johann Wolfgang Goethe Universitaet Frankfurt am Main, NKI - Stichting Het Nederlands Kanker Instituut-Antoni Van Leeuwenhoek Ziekenhuis, Masarykova univerzita, Agencia Estatal Consejo Superior de Investigaciones Cientificas, Forschungsverbund Berlin E.V.,SOLEIL, LU, Universiteit Leiden, LUMC-Academisch Ziekenhuis Leiden, ESRF, Centre National de la Recherche Scientifique, Instruct Academic Services Ltd, Aarhus Universitet, ESS, Eötvös Lóránd Tudományegyetem, Instituto de Tecnologia Quimica e Biologica-Universidade Nova de Lisboa, Oulun Yliopisto, University of Patras, Weizmann Institute of Science	iNEXT Consortium Agreement + EU Horizon 2020 grant agreement No 653706
ALBA	Collaboration Contract No. 10/15 between The Consortium for the Construction, Equipping and Exploitation of the Synchrotron Light Source and The MAX IV Laboratory (CELLS)
CERN (host organization)	Memorandum of Understanding for the Future Circular Collider (FCC) Study hosted by CERN
European X-ray Free-Electron Laser Facility Gmbh (XFEL), DESY, Elettra-Sincrotrone Trieste, Extreme-Light-Infrastructure Delivery Consortium (ELI-DC), ESRF, Helmholtz-Zentrum Dresden-Rossendorf e.V (HZD), LU, Paul-Scherrer-Institute (PSI), Fyzikalni Ustav av CR V.V.I (ELI-BEAMS), ELI-HU Kut. es Fejl. Nonprofit kft (ELI-ALPS), Institutul National de Cercetare-Dezvoltare Pentru Fizica si Inginerie Nucleara "Horia Hulubei" (ELI-NP)	EUCALL European Cluster of Advanced Laser Light Sources / Consortium Agreement
Danmarks Tekniske Universitet (DTU - Coordinator), The University of Manchester, Ludwig-Maximilians-Universitaet München (LMU), LU, Novozymes A/S, Wyatt Technology Europé GmbH, Medimmune Ltd, Københavns Universitet (UCPH), MAX IV Laboratory, Nanotemper	PIPPI Consortium Agreement (PIPPI: Protein-excipient Interactions and Protein-Protein Interactions in formulation)