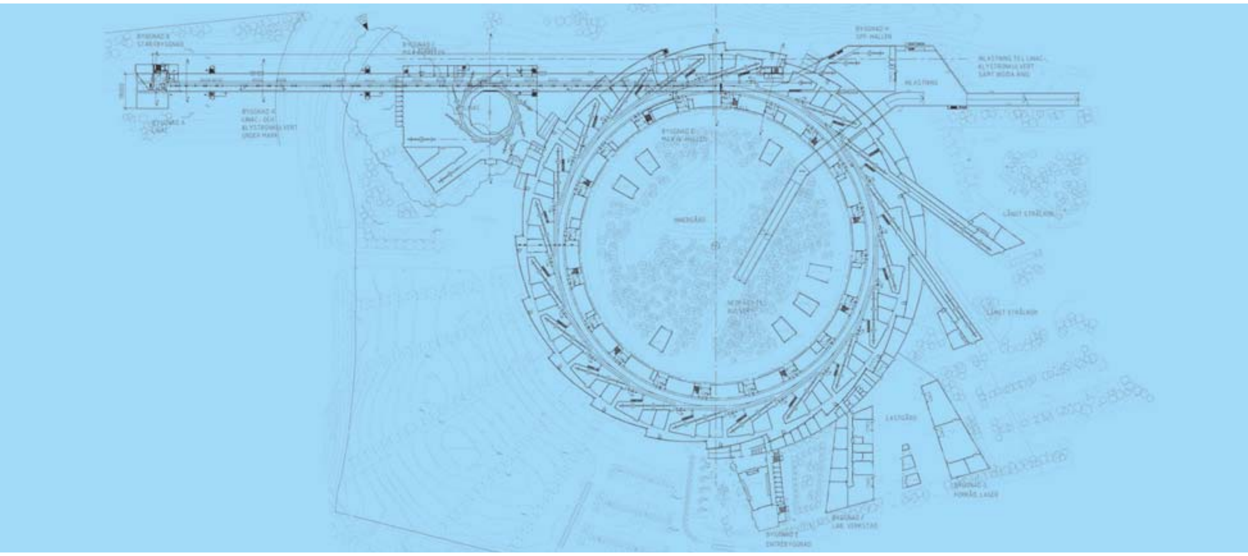
Vetenskapsrådet

EVALUATION OF THE MODIFIED MAX IV PROPOSAL 2009



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EVALUATION OF THE MODIFIED MAX IV PROPOSAL 2009

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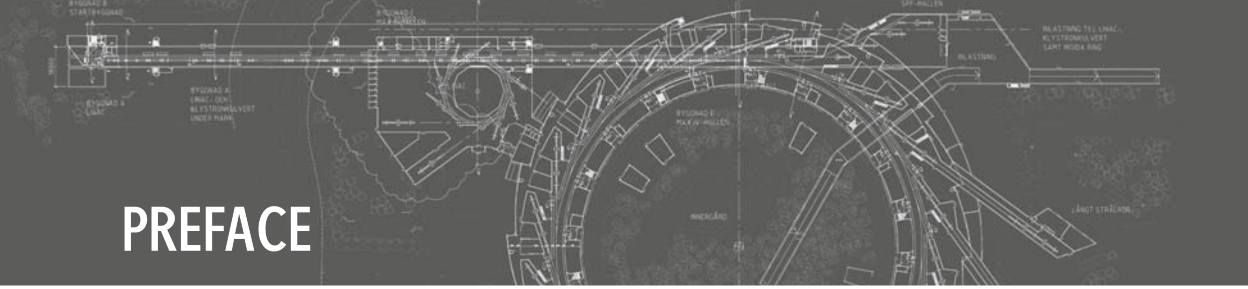


PREFACE

The Council for Research Infrastructure (RFI) at the Swedish Research Council has the overall responsibility to ensure that research infrastructure of the highest quality is expanded and exploited. Specifically, the Council advertises and evaluates applications, participates in international collaborations and works on monitoring and assessments. As part of the overall responsibility for research infrastructures RFI oversees, evaluates and provides funds for the operation and development of the national synchrotron facility the MAX-laboratory in Lund, Sweden.

The MAX-lab first presented the proposal to build MAX IV to the Swedish Research Council in 2005. MAX IV is planned to be the next generation synchrotron radiation facility and will replace the existing facilities at the MAX-laboratory consisting of the MAX I, II and III storage rings and a number of beamlines. The project was scrutinized by international evaluation panels from both technical and scientific perspectives in 2005 and 2006, showing that the proposed MAX IV facility would offer a world leading and unique synchrotron radiation source. Since then, preparations have been made for the construction of the MAX IV facility including a redesign of the facility in order to further improve the performance and better meet upcoming user needs.

On April 27th 2009, a Memorandum of Understanding was signed between the Swedish Research Council, the Swedish Governmental Agency for Innovation Systems (Vinnova), Lund University and Region Skåne, defining the start of the MAX IV project. These stakeholders represent a large fraction of the first phase investment costs and asked that the Swedish Research Council initiated an additional evaluation of the modified design for MAX IV. An international Expert panel was appointed and performed the evaluation in the fall of 2009.

The members of the Expert panel were Prof. Chi-Chang Kao, National Synchrotron Light Source, USA, Prof. Sine Larsen, University of Copenhagen, Denmark and Prof. Carlo Bochetta, Instrumentation Technologies, Slovenia. Prof. Örjan Skeppstedt, Stockholm University, was appointed Chairman of the expert panel and Dr. Tove Andersson, Research Officer, Swedish Research Council, acted as coordinator and secretary of the review.

The Swedish Research Council would like to express its sincere gratitude to the Expert panel for devoting their time and expertise to this important task.

The Swedish Research Council would also like to thank the representatives of MAX-laboratory, the user community and Lund University for providing the necessary background material and giving informative presentations at the meeting with the panel.

Stockholm 2010-05-06

Lars Börjesson
Secretary General, Council for Research Infrastructures
Swedish Research Council

PROCEDURE FOR THE REVIEW

The MAX-laboratory in Lund, Sweden, is a synchrotron radiation facility serving a broad Swedish and international user community. In 2005 the MAX-laboratory submitted a proposal to the Swedish Research Council to develop and expand MAX-lab into a next generation synchrotron facility by the name MAX IV. The Swedish Research Council evaluated both the technical concept and the scientific case of the proposal (in 2005/2006) resulting in recommendations to build MAX IV. In April of 2009, the four organizations Vinnova, Lund University, Region Skåne and the Swedish Research Council agreed to form a consortium together to fund the first phase of construction of MAX IV. Since the design of MAX IV had been changed significantly from the initial design, the consortium asked that the Swedish Research Council also evaluate the new design, to make sure the technical and scientific cases were still sound (See Appendix 1: Terms of Reference).

An international evaluation panel was appointed for this review, with a Swedish Chairman, *Prof. Örjan Skeppstedt*, Stockholm University, and secretary, *Dr. Tove Andersson*, Swedish Research Council. The members of the international panel were:

Prof. Chi-Chang Kao, National Synchrotron Light source, Brookhaven laboratory, USA

Prof. Sine Larsen, Department of Chemistry, University of Copenhagen, Denmark

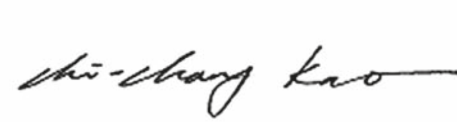
Prof. Carlo Bocchetta, Instrumentation Technologies, Slovenia

Short CV:s for the panel members can be found in Appendix 2.

The panel received a background report from MAX-lab together with some additional material in October 2009, and met on 12–13 November, 2009. The program for the meeting included presentations and discussions with MAX-lab staff and user representatives as well as some time to plan and start writing the report.

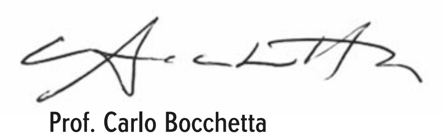
The present document presents the views and assessments of the panel members. By signing they take full responsibility for the report. The Chairman and secretary confirm that the work was conducted in accordance with the statutes of the Swedish Research Council and that it was performed in an impartial manner.

December, 2009



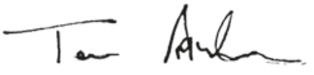
Prof. Chi-Chang Kao

Prof. Sine Larsen

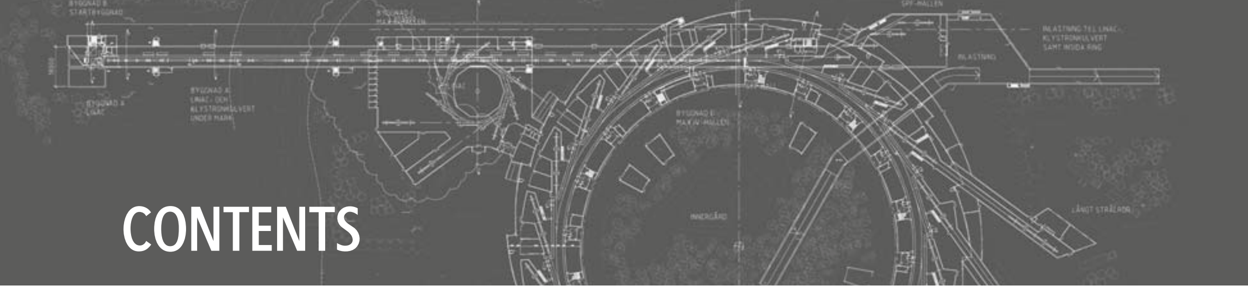


Prof. Carlo Bocchetta

Prof. Örjan Skeppstedt
Chairman



Dr. Tove Andersson
Secretary



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EXECUTIVE SUMMARY

The Review panel has scrutinized the revised design of the MAX IV facility as described in the Background Report, dated September 2009, provided by MAX-lab. The revised accelerator and technical design as well as the science case were carefully compared to those described in the MAX IV Conceptual Design Report from 2005.

The panel finds the revised design technically feasible and that it improves the original proposal significantly. The MAX IV project team has used the past four years to refine and improve the technical and infrastructure aspects of the project. The revised design with the lowest emittance in the world will make MAX IV the brightest storage ring in the world.

The new design was triggered by the scientific demands by the user community in Sweden and the Nordic and Baltic countries. The larger 3 GeV and the smaller 1.5 GeV ring will create new improved scientific opportunities.

The revised design has been made with emphasis not to increase costs. The panel finds that a number of cost saving measures compensates for some additional costs following the revised design. However, it cannot be excluded that the combination of many innovations in the construction of the machine could lead to unexpected expenses. The panel therefore recommends increasing the contingency somewhat.

The time-frame outlined for the project is comparable to similar projects in the world, assuming the remaining construction funds are made available in time.

Since the selection and funding of beamlines are not yet in place, there is a risk that the uniquely performing MAX IV will not have world leading beamlines that match the machine when it starts operation, if ongoing negotiations about further funding are not successfully finalised within a not too far future. The panel furthermore observes that procedures for selection of and definition of beamline projects are not very well defined. Such procedures should be established as soon as possible.

BACKGROUND OF THE EVALUATION OF THE MODIFIED MAX IV PROPOSAL

The MAX IV Conceptual Design Report

Scientific demands have challenged the staff at the MAX-lab to propose a new synchrotron radiation facility intended to deliver spontaneous as well as coherent radiation of very high quality over a broad spectral range from IR radiation, VUV and soft X-rays to hard X-rays. The proposal was first described publicly in the MAX-lab report "MAX IV – Our Future Light Source, a brief introduction" which was used as background material for a workshop with about 400 participants in 2004 about the scientific case for the MAX IV facility, which formed the basis for the Conceptual Design Report (CDR). The CDR constituted the written background for a technical evaluation in 2005 and a scientific evaluation in 2006.

The proposed accelerator system in the CDR consists of two storage rings, operated at around 1,5 and 3 GeV respectively. The two rings were to have the same circumference of 287 m and a new design of the magnetic lattices allows them to be placed on top of each other. The primary sources for synchrotron radiation consist of undulators and wigglers, covering a photon energy range from below one hundred eV up to several tens of keV. It was also proposed to complement the two new rings by moving the existing 0,7 GeV MAX III ring from the present MAX-lab to the new MAX IV location. The MAX III ring is the primary source for IR and UV radiation extending the photon energy range for undulator radiation down to a few eV. A Linac chosen for injection should also be used to generate short X-ray pulses and coherent radiation. In the first step, a device based on spontaneous emission is proposed to be developed for the generation of ultra-short pulses. In the next step the construction of a Free Electron Laser (FEL) is planned.

Technical evaluation 2005

In November 2005, an international expert panel evaluated the Technical concept of MAX IV presented in the 2005 MAX IV Conceptual Design Report (CDR). The result of the evaluation is described in the Report "An International Evaluation of the MAX IV Technical Concept" dated December 2005.

Summary of the International Evaluation of the MAX IV Technical Concept, December 2005

The Panel found the design concept sound. It offers a source with brightness an order of magnitude higher than other third-generation synchrotron radiation sources and it was judged by the Panel to be the basis for a detailed design study. In particular, the panel endorsed the multi-ring concept as well as complementing the rings with a linac-based FEL.

The Panel has identified some areas for further study, to be accounted for in a future Detailed Design Report (DDR). Such areas are e.g. reproducibility of the magnets, control of the electron beam, and the proposed use of a linac both as injector to the storage rings and as a FEL driver. Environmental factors have to be further investigated. The panel found in the discussions during the site visit that the management of MAX-lab is fully aware of the need for further and deeper studies of such areas.

The panel assessed the preliminary budget for the proposed facility to be on the low side when compared to that of a conventional third-generation synchrotron light source. However, the laboratory has demonstrated the capacity to build accelerator components in a cost-effective way. The detailed design study has to consolidate the budget and additional human resource requirements.

The panel congratulated MAX-lab on the innovative design concept and was impressed by the presentations of it by several experts (including a few PhD students). The panel appreciated the strong interest and support by Lund University, which is identified as crucial for the success of the laboratory and the MAX IV proposal.

Scientific evaluation 2006

In October 2006, an international expert panel evaluated the scientific case of MAX IV presented in the 2005 MAX IV Conceptual Design Report (CDR). The result of the evaluation is described in the Report "Scientific Evaluation of the MAX IV Proposal" dated November 2006.

Summary of the Scientific Evaluation of the MAX IV Proposal, November 2006

The Panel found that the innovative and cost-effective design, building on the experiences made in the construction of existing MAX-lab synchrotron rings, offers possibilities for a world-leading and unique light source. In particular, the high brilliance, the high flux of the storage rings and the ultrafast capability provided *by the linac will allow a unique combination of having spatial resolution into the nanometer range and the study of dynamics into the femtosecond regime.*

The Evaluation Panel was unanimous in its conclusion that the scientific case for the MAX IV facility is very strong, representing a site for interscientific advances and an important resource for upgraded industrial research in the Nordic and possibly Baltic countries. The Evaluation Panel is clear in its recommendation to the Swedish Research Council:

MAX IV should be funded to the level requested, and the funding should commence as soon as possible.

The Swedish Research Council's assessments of the MAX IV proposal and the forming of a consortium for starting a fast development of MAX IV

On basis of the technical and scientific evaluations 2005 and 2006 as well as on considerations by its committees, scientific councils and its board, the Swedish Research Council informed in spring 2007 the government about its assessment that the MAX IV facility should have a large positive influence on Swedish research as well as research within a larger region comprising at least the Nordic countries. The Research Council proposed that the Swedish government as soon as possible should investigate possibilities for the financing of the project within Sweden as well as from other countries.

On demand of the Government the Research Council wrote a report (in Swedish) in the summer of 2008 concerning the conditions for construction of the proposed facility. The Council expressed in this report again its general assessment of the MAX IV project that the facility should have a large positive influence on Swedish research as well as research in a larger region extended at least to the Nordic countries. MAX IV could be a world-leading synchrotron-light facility for cutting-edge research in several disciplines as nano- and materials science, structural biology, geology and environmental science. The project was judged to be technically and scientifically mature. The technical documentation and cost estimations were assessed to be realistic.

In particular the Research Council reported:

- Mainly all Swedish universities give strong support for the MAX IV proposal and express intentions to co-operate in the construction of beam lines, research and education. MAX IV should also be of importance for several of the universities' strategic efforts.

- There are considerable regional commitments regarding the ground for location of the new facility, planning work, investments and operation costs.
- There is a large interest among researchers, institutes and universities in the Nordic and Baltic countries to participate in the MAX IV project and to use the facility for research. MAX IV is seen as a strategic important research facility of world class. There are good conditions for a close Nordic and Baltic co-operation. Possibilities for developing MAX IV to an international research facility with considerable participation from these countries should be further explored.

The Research Council recommended that a decision about the funding of MAX IV should be taken soon to utilise the potential and the lead in time that the MAX IV project has in the international competition, in order to utilize today's competence in the laboratory and to realize the existing interests for participation in the Nordic and Baltic countries.

The Swedish Government made positive statements in its Research and Innovation Bill from October 2008 about the need of MAX IV for the Swedish science community and asked in December 2008 the University Chancellor, Anders Flodström to present the conditions for a decision of funding of the construction of MAX IV. Supported by Flodström's report and on the basis of the evaluations and assessments described above, the Research Council together with Vinnova, Lund University and Region Skåne signed at the end of April 2009 a common declaration to form a consortium for starting a fast development of MAX IV. In the document the consortium partners declared their agreement about a start of construction during 2010 at the latest.

As MAX-lab now has submitted to the Research Council an updated version of the MAX IV proposal with some significant changes (see next section) compared to the CDR, the Research Council together with their consortium partners Vinnova, Lund University and Region Skåne have decided to complement the earlier two evaluations from 2005 and 2006 with the present one addressing both the technical and scientific merits of the modified MAX IV proposal compared to the CDR.

THE MODIFIED MAX IV PROPOSAL

The MAX IV design work has continued after the completion of the CDR with funding from the Swedish Research Council. One important part was to continue the planning of the scientific program and the layout of the beamlines. In 2007 and 2008 the MAX IV workshops "Science at MAX IV" and "New Directions for MAX IV" were arranged in order to get continued input from the user community. A major outcome of this work was that the number of straight sections at the 3 GeV ring was considered to be too small. This limitation would affect both the hard and soft X-ray regimes. There was a demand for more beamlines in the hard X-ray regime. Furthermore several soft X-ray beam-lines would benefit from being placed at the suggested 3.0 GeV ring instead of the 1.5 GeV one. Hence, the relationship on the demand of beamlines on the suggested two rings was unbalanced.

The design of the MAX IV facility has therefore been revised. The unique properties of the storage rings in the CDR have been kept and even improved (especially for the new 3 GeV ring) but the relationship between the different rings has been changed. In the revised design a larger, 528 m circumference, 3 GeV ring with 20 cells is combined with a new 96 m circumference 12 cell storage ring. The smaller ring will be operated at 1.5 GeV. This storage ring will serve the IR & UV user communities as well as hosting most of the soft X-ray beamlines. Thus, it will replace the 1.5 GeV ring from the CDR as well as the MAX III storage ring. The revised MAX IV design reflects better the demand of beamlines and offers improved performances over almost the entire energy range and for the vast majority of the planned beamlines.

TECHNICAL EVALUATION

The original design had two rings of equal circumference, 287 m, with beam energies of 3.0 and 1.5 GeV placed on top of each other and the transfer of the MAX III accelerator to the new MAX IV site. The rings had 12 straight sections. The revised design now proposes two rings of different circumference, 528 and 96 m for the 3.0 and 1.5 GeV rings respectively, and no re-location of the MAX III accelerator. The electron beam energies in both revised rings remain as originally proposed. The number of long straight sections in the 3.0 GeV ring has been increased to 20 with the provision of 40 short straight sections of 1.5 m length. The injector has remained the same. The injection process has been simplified since beam extraction at 700 MeV for the MAX III ring is no longer required. The 1.5 GeV ring is placed outside the larger 3.0 GeV ring. The Linac injector is at a tangent to both rings. The revised design has not affected the performance of the Linac nor has it affected the realisation of the short pulse facility or of the linac driven FEL. The change to buildings and supporting infrastructures does not introduce a significantly large increase in volume, since the average length of beamlines is the same. There is provision for long beamlines that extend beyond the main experimental hall. The linear increase of the 3.0 GeV ring is offset by a corresponding decrease in the 1.5 GeV ring. The housing of the 1.5 GeV ring is partially offset by the simplification of ring tunnel infrastructure and access. In general the scaled costs related to real estate and auxiliary services (HVAC, power and water) has essentially remained constant, if not reduced, through optimisation when compared to the original design. The overall layout of the facility permits additional long beamlines at a later stage. There is ample space for expansion of the injector in both the forward and backward direction. In the later case re-routing an access road is required for full exploitation of available land. The combined power requirement of the accelerators is similar to the original proposal.

Concerning the new 3.0 GeV ring, the principal changes are: an increase in circumference, an increased number of straight sections, a change from a 5 bend achromatic arc to a 7 bend with weaker magnetic fields and the use of damping wigglers in two diametrically opposite long straight sections. During the period since the review of the conceptual design, the project team has gone into greater detail and made decisions on a number of key technologies. These include, increased detail of self supporting multipole magnets machined from solid iron, the use of 100 MHz RF cavities, details and layout of RF power systems and the use of NEG coated vacuum chambers through-out the accelerators. The layout of RF cavities and power distribution has been simplified in the revised design allowing greater use of long straight sections. Curved NEG coated dipole vacuum chambers have been manufactured and tested on the MAX II ring with positive results. The emittance of the new 3.0 GeV lattice with damping wigglers has led to a noticeable reduction in the horizontal emittance from 0.864 to 0.336 nmrad. This is further reduced to 0.24 nmrad when a full complement of insertion devices is operated, making MAX IV the most brilliant storage ring light source in the world. The new lattice has been optimised by a team of world experts and includes innovative techniques in the control of beam dynamics and takes machine physics to new regimes. The 7 bend lattice uses strong magnetic gradients without compromising magnetic field quality. As in the original design this is done with the use of small aperture magnets. Dipole, quadrupole, sextupole and octupole fields are used in a combination that maximises the dynamic aperture and energy acceptance and makes the lattice insensitive to asymmetries and insertion devices. The synchrotron radiation from the wigglers is also used for experiments. The types of insertion device and their technical characteristics are similar to the original design and have benefitted from community developments. The weaker magnetic field in the dipoles excludes them from being used as radiation sources. This is offset by the greater number of insertion devices. Furthermore, the revised 3.0 GeV design allows the possibility to use the 1.5 m long short straight sections for additional insertion devices. This, however, could affect the performance of the machine and requires optimisation. Beam lifetime is determined by the vacuum pressure and by large and small angle intra-beam scattering. The ultra-low emittance of the 3.0 GeV ring allows operation in a novel regime where the Touschek lifetime increases as the emittance decreases. As with the original design the vacuum chamber has a small cross-section, a consequence of the small bore magnets. NEG coated vacuum chambers were proposed in the original design. The project team has since then successfully demonstrated the original use of dipole coated vacuum vessels on a light source (MAX II). Stability of ultra-low emittance light sources is essential for performance. This aspect has been further examined in the revised design in terms of passive and active control and although challenging poses no risk to the project. Similarly, the control of beam driven instabilities is adequately covered and in some cases alleviated with the revised design.

Regarding the 1.5 GeV design, the most notable impact of the revised design is an increase of beam emittance. This affects the source characteristics and is discussed in greater detail in the scientific evaluation. The revised design has a smaller circumference and uses magnets with stronger fields and gradients. The project team has optimised the multipole magnets for increased performance. The ring benefits from the use of the same technology proposed for the 3.0 GeV ring. The straight section lengths are shorter but more of them can be used and they are still adequate for the proposed combined science program of MAX IV. The ring will be housed in a dedicated building compared to the original building that shared shielding and experimental floor with the 3.0 GeV ring. The majority of services and associated infrastructure can still be shared between the two revised rings. The ring characteristics allow transfer of the MAX III beamlines. In addition key MAX II beamlines including bending magnet sources can now be relocated to the 1.5 GeV MAX IV ring.

The revised design and the technologies utilised are within the competence of the MAX-lab team. Key technologies have been demonstrated feasible with their utilisation on operating MAX-lab accelerators and else-where. The lattice design has been performed by a team of world experts and places the performance of MAX IV at the pinnacle of all storage ring synchrotron radiation facilities. The panel judges the revised design to be a positive enhancement to the MAX IV facility and recommends its in-corporation.

Since the last review there have been significant developments and landmark results from the construction and operation of linac driven FELs (in particular the LCLS). The MAX IV project is in a strategically important position to further pioneer additional developments and exploit the exceptional science permitted by FELs. A recommendation is made to accelerate the construction of the Linac and associated infrastructure for the FEL.

SCIENTIFIC EVALUATION

Overview

To continue planning the scientific program and beamlines of MAX IV, workshops on "Science at MAX IV" and "New Directions for MAX IV" were held in 2007 and 2008, respectively, to solicit input from user community. A major outcome from these two workshops is that there is a demand for more beamlines in the hard x-ray regime, and that some soft x-ray beamlines would benefit from being located at the 3 GeV ring. In response to the user demand, the design of MAX IV has been revised. In the revised design, the most significant change is to enlarge the size of the 3 GeV storage ring to include more straight sections to allow more x-ray beamlines and some soft x-ray beamlines, and to use a smaller and separate 1.5 GeV storage ring to host IR, VUV and most of the soft x-ray beamlines. Both rings will be served by the Linac for top-off injection, similar to the original design. Consequently, there is no change to the ultra-fast program.

Overall, the new 3 GeV ring design, with the increased multiplicity of the lattice, 20-cells, and the use of several innovative ideas, will make MAX IV the brightest storage ring among the existing and planned synchrotron facilities in the world. Furthermore, the total number of straight sections has been increased to 19 from 12, and the infrastructure of the proposed facility has been rearranged to allow the construction of several long beamlines. In combination, these changes have enhanced the scientific potential of the 3 GeV ring significantly. In fact, the performance of many of the proposed beamlines on the 3 GeV ring will be world-leading as a result of the improved brightness. The emittance of the new 1.5 GeV ring, due to the reduced circumference, is not as low as that of the original design. However, it is still very competitive with storage rings with similar energy in the world, and presents a significant improvement over MAX III and MAX II. In fact, for UV and most of the soft x-ray spectroscopy beamlines, the new 1.5 GeV ring will still be a world-class source. In summary, the revised MAX IV design has accomplished the goal of providing an improved and better balanced facility to satisfy the needs of user community.

Scientific program on the 3 GeV ring

In this section, changes made on specific scientific programs and beamlines/endstations on the 3 GeV ring will be discussed.

The suite of nine beamlines (2 nanofocussing, 2 macromolecular crystallography, high resolution powder diffraction and small/wide angle scattering, microfocus spectroscopy, very high resolution soft x-ray spectroscopy, magnetism, materials science and extreme sample conditions) suggested in the CDR from 2005, are still the basis for beamline planning on the new 3 GeV ring. The improved performance of the new 3 GeV ring will certainly make nanofocussing and very high resolution soft x-ray spectroscopy world-leading. The increased brightness will also benefit all other beamlines. Consequently, it is essential that the design of these beamlines be re-examined to make sure they set more aggressive goals to take full advantage of the revised design.

In addition to those nine beamlines, several new beamlines and endstations are proposed in the revised proposal. The first is a dedicated small angle x-ray scattering (SAXS) beamline, including solution scattering for biological systems. The creation of a dedicated beamline for SAXS is an excellent idea. It will help MAX IV meet the growing demand of SAXS/WAXS experiments and the separation from powder diffraction experiments will avoid compromises in the construction of the beamline. The proposed SAXS beamline will clearly benefit from the increased brightness of the revised design to reach smaller momentum transfer and shorter time-scale for solution scattering. More importantly, after the tremendous success of macromolecular crystallography at synchrotron facilities, solution SAXS is a field ripe for take-off and could have enormous scientific impact, complementary to macromolecular crystallography.

A second proposal is to use a wiggler as the source for the powder diffraction beamline, and to combine that with x-ray spectroscopy capabilities, e.g. x-ray absorption spectroscopy and/or x-ray Raman scattering. Using the wiggler as the source and extending the usable x-rays to 100 keV will allow wider range of in-situ measurement and the investigation of bulk materials with industrial interest. There is clearly a growing interest as well as demand in high energy x-ray scattering worldwide, and the Nordic countries have a long tradition in this area. This revision will certainly strengthen the materials science program as well as the industrial program at MAX IV. Adding spectroscopy capabilities to this beamline, will require careful evaluation of the beamline optics and assessment of the scientific case. For example, beamline optics could be significantly simplified if the energy is fixed at high energy for powder diffraction and quite complicated if one needs to tune from a few keV all the way to 100 keV. In addition, x-ray absorption spectroscopy probes a few micron of the sample where high energy x-ray powder diffraction could sample much thicker sample, so there is a mismatch of the probing volume. On the other hand, including x-ray Raman scattering to the beamline is easier because it is essentially a fixed energy experiment, in particular if efficient, high energy x-ray analyzer could be developed.

A third proposal is a high throughput, lower resolution tomography/imaging beamline in addition to the two nanofocussing beamlines. High throughput, high resolution (not ultimate spatial resolution) imaging available at third generation synchrotron facilities has made tremendous impact in materials science, life science, archeology and paleontology over the last decade. Currently, the growth of the use of synchrotron radiation in these fields is severely limited by the availability of beamtime. There is no doubt that new applications in other fields will continue to appear. The key for this instrument is to optimize detector, sample scanning hardware, and data analysis software, and to optimize the trade-off between spatial resolution and throughput to make MAX IV a unique facility.

The fourth proposal is the possibility of a beamline for x-ray photon correlation spectroscopy (XPCS). Since the figure of merit for XPCS is proportional to the square of the brightness of the source, the improved brightness of the revised design of the 3 GeV makes it an ideal source for both soft and hard x-ray XPCS. XPCS in principle measures dynamical structure factor and complements inelastic light, x-ray and neutron scattering in the momentum and time scale probed. XPCS provides a natural linkage between MAX IV and the proposed European Spallation Neutron Source, and the use of XPCS can be very attractive for the Nordic neutron scattering community.

The fifth proposal is the possibility of constructing a dedicated undulator-based High Kinetic Energy Photoemission (HIKE) beamline. With an increasing number of straight sections in the revised design, this is clearly a good idea. HIKE with high energy resolution is an extremely challenging experiment. Using undulator as the source for HIKE at MAX IV will make this instrument world-leading. Furthermore, HIKE is likely to benefit from the long and successful history of technical developments for photoemission at MAX-lab. Since HIKE will require a tunable high-resolution x-ray monochromator, it is possible to co-locate medium energy resolution inelastic x-ray at the same beamline. There is also a scientific argument for co-locating both instruments since they both aim to provide electronic structure information, and might serve two overlapping user communities.

Finally it is proposed to relocate some of MAX II hard x-ray beamlines. This option should be evaluated carefully to make sure it makes scientific sense and is really cost effective. The improved performance of the revised design puts very high demand on the optics for all undulator beamlines at MAX IV so it is likely that a major upgrade will be necessary for the existing MAX II beamlines. Relocating them to the short straights or the 1.5 GeV ring (using superconducting high field devices) to provide additional capacity for beamlines with high demand seems to be a better option.

Scientific program on the 1.5 GeV ring

Because of the increase in emittance and shortening of the straight sections in the revised design, significant effort has been made to optimize the ring energy for the soft x-ray program described in the CDR. The final ring energy of 1.5 GeV is a reasonable choice. It will satisfy the requirements of most of the soft x-ray programs. In the following, changes made on specific scientific programs and beamlines/endstations on the 1.5 GeV ring will be discussed.

In the CDR, four new beamlines and four relocated beamlines were proposed for the 1.5 GeV ring, and three new beamlines were proposed for MAX III. Consideration has been given to re-examine some of these beamlines in the context of the revised design. It is important that all proposed beamlines are re-examined, in particular the IR beamlines since they might be affected in a negative way by the revised design.

Among the ones discussed in the revised proposal is a ultra-high resolution VUV scattering beamline. It is intended to complement the very high resolution soft x-ray spectroscopy beamline on the 3 GeV ring. It is important that these two beamlines coordinate their scientific program and overlap in energy range carefully. The second is the soft x-ray nanoscience and spectroscopy beamline. At this point, it is not clear if this beamline should also be located on the 3 GeV ring. Obviously, the 3 GeV ring is a better source if highest spatial resolution is the goal for this beamline. On the other hand, optimization of scientific program could lead to an instrument with different resolution and/or energy range requirement. The third is soft x-ray spectroscopy and surface reaction beamline. It is mainly a flux driven experiment and the new 1.5 GeV ring is adequate. There is also some discussion about an environmental science beamline in the range of 1-3 keV, and a coherent imaging beamline. Both are good ideas and uniquely suitable for MAX IV. Finally, there is some discussion on relocating beamlines from MAX II. Since the requirements for optics on the new 1.5 GeV are not as stringent as those on the new 3 GeV, moving beamlines from MAX II is probably a good solution to bring on more beamlines quickly. However, detailed analysis is still needed.

CONCLUSIONS

- The revised design is technically feasible and significantly improves the original proposal. The concepts and technologies adopted are based on the original CDR. The project team has verified the planned key technologies using the accelerators at MAX-lab and from developments elsewhere in the community. The panel feels comfortable that the revised machine design can be realised within the stated time frame. The project team has used the past four years to further refine and improve the technical and infrastructure aspects of the MAX IV project. This has involved fundamental and innovative research. World experts have taken part in both the revision of the design and in the validation of the technologies.
- Comparison of the scientific cases between the modified MAX IV proposal and the CDR: The new design was triggered by the scientific demands by the user community covering scientists not only from Sweden but also from the Nordic and Baltic countries. The larger 3 GeV ring, the smaller 1.5 GeV ring and decision not to move MAX III will create new improved opportunities for the users of MAX-lab. The increased number of beamlines at the high energy ring is a benefit not only for the experiments using hard x-rays but also creates possibilities for better performing beamlines using soft X-rays. The decision not to move MAX III will not have negative consequences for the broader user community. Significant changes (decreased emittance, increased number of beamlines, increased beamline length, possibility for several long beamlines, more space around the beamlines) all contribute to make the new design of MAX IV more attractive both to the existing and to new user communities. The revised design with the lowest emittance in the world makes MAX IV the brightest storage ring facility in the world.
- Is the cost estimate for construction and operation of the new design realistic? The revised design has also been made with emphasis not to increase costs. (A summary of the cost estimates for the MAX IV accelerators is given in Appendix 3.) It contains many cost saving innovations for the machine part, like magnets and associated power supplies, vacuum system, RF system. It cannot be excluded that the combination of many innovations in the construction of the machine could lead to unexpected expenses. Therefore it would be prudent to increase the contingency. The combined "footprint" of the larger 3 GeV and smaller 1.5 GeV ring has not led to significant increases in the infrastructure costs. There is less transparency in the budget for the beamlines, which obviously is a result

of the unfinished negotiations with new possible funding bodies within Sweden and support from the Nordic countries. The additional expenses created by reconstructing the MAX III beamlines at MAX IV seem to be compensated by the savings by not relocating MAX III. No additional costs for beamline construction have arisen due to the new design. The low emittance could lead to cheaper beamline optics.

- Is the time-frame for construction realistic? The time-frame outlined is comparable to similar projects. Most of the key-technologies to be used have already been tested at MAX-lab, e.g. self supporting magnet structure, 100 MHz RF cavities and power stations, NEG coated vacuum vessels for dipole magnets.
- Since the selection and funding of beamlines for MAX IV are not yet in place, there is a risk that the uniquely performing MAX IV will not have world leading beamlines that match the machine when it starts operation. It is therefore important that ongoing discussions/negotiations about further funding of beamlines are successfully finalised within proper time in order to be able to start the planned vigorous research programme already at the beginning of the operation.
- Proper procurement procedures are important for keeping the costs low, but for a high-tech project like MAX IV ultimate performance may in many cases overrule cost aspects. It is therefore recommended that also for procurement the MAX IV management, which clearly has the best competence for delicate considerations, has full responsibility.
- MAX IV's brightness is unprecedented and surpasses all existing and presently planned storage ring light sources. The machine costs are less than those of facilities of comparable performance.

OBSERVATIONS AND COMMENTS

There is a very good contact and interactions between the MAX-lab and its user community, which is comprised of scientists from Sweden and the other Nordic countries.

In order to provide efficient user support to the increasing number of users from new scientific areas MAX IV must have sufficient staffing.

Procedures for selection and definition of beamline projects should be established as soon as possible.

Establishment of a Project Management team with well defined responsibilities among its members should take place as soon as possible.

Organizational procedures for engagement of the Nordic countries in the MAX IV project should be established.

The rapid development of Free Electron Lasers and above all the enormous scientific potential that these new light sources offer should be taken into consideration in the construction of the Linac.

Construction of the ambitious MAX IV while operating the existing MAX-lab is demanding, and represents a challenge in recruitment and organization of the staff.

SAMMANFATTNING PÅ SVENSKA

Granskningspanelen har granskat den omarbetade designen för anläggningen MAX IV såsom bakgrundsrapporten från MAX-lab från september 2009 beskriver den. Panelen jämförde den reviderade acceleratordesignen och den tekniska designen samt det vetenskapliga underlaget med de som beskrivs i konceptdesignrapporten för MAX IV från 2005.

Granskningspanelen konstaterar att den reviderade designen är tekniskt genomförbar och väsentligt bättre än det ursprungliga förslaget. Projektteamet bakom MAX IV har använt de gångna fyra åren till att förfina och förbättra de tekniska och infrastrukturella delarna av projektet. Den reviderade designen, som har den lägsta emittansen i världen, kommer att göra MAX IV till världens mest intensiva röntgenkälla.

Den nya designen är sprungen ur de vetenskapliga behov användarna i Sverige och de nordiska och baltiska länderna har. Den större ringen på 3 GeV och den mindre på 1,5 GeV kommer att skapa nya och bättre möjligheter för forskningen.

En viktig aspekt vid revideringen av designen var att kostnaden inte skulle öka. Granskningspanelen konstaterar att ett antal kostnadsbesparingar kompenserar för de kostnadsökningar som revisionen fört med sig. Det kan emellertid inte uteslutas att kombinationen av många innovationer i maskinens konstruktion kan leda till oväntade kostnader. Panelen rekommenderar därför att den ekonomiska bufferten ökas något.

Tidsramen för projektet är jämförbart med liknande projekt i andra delar av världen, under förutsättning att återstående bidrag för konstruktionen blir tillgängliga i tid.

Eftersom valet och finansieringen av strålrör ännu inte är färdiga finns en risk att den högpresterande MAX IV inte kommer att ha världsledande strålrör som matchar maskinen när den tas i drift, om inte de pågående förhandlingarna om ytterligare medel framgångsrikt slutförs inom en inte alltför avlägsen framtid. Panelen noterar också att procedurerna för att välja och definiera strålrörsprojekt inte är särskilt välbestämda. Sådana procedurer borde slås fast så snart som möjligt.

APPENDIX I: TERMS OF REFERENCE

Evaluation of the MAX IV proposal

Introduction

The Swedish research council, together with Vinnova (The Swedish Governmental Agency for Innovation Systems) Lund University and the Region of Skåne have decided to start the MAX IV. Both the technical and scientific case for MAX IV were evaluated by international review panels and both reviews[1] were very positive.

The original MAX IV proposal constituted design and construction of two electron storage rings for synchrotron radiation, the relocation of an existing storage ring (MAX III), a Linac for injection and short pulse experiments, and the first 15 beam lines and experimental stations. The Linac is also planned to be used for a future VUV/X-ray Free Electron Laser.

MAX-lab has now submitted to the Research Council an updated version of the proposal. The most significant difference compared to the earlier proposal is that the two-ring concept has been changed to a larger 3 GeV ring and a separate 1.5 GeV ring. As a consequence of this decision the MAX III ring will not be moved to the new site.

The present evaluation is to examine the new proposal for MAX IV and assess its merits. After completion, the results and conclusions of the review will be made public in a written report.

Review Panel

The review will be conducted by a "Review Panel". All members will be internationally recognized experts, with broad views and expertise. None of the members shall be personally and actively engaged in MAX-lab.

The chairperson of the Review Panel is Professor Örjan Skeppstedt. Professor Skeppstedt heads the review and is the rapporteur of the Panel.

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1 An international evaluation of the MAX IV technical concept, Vetenskapsrådet Rapport 5:2006; Scientific evaluation of the MAX IV proposal, Vetenskapsrådet, Rapport 20: 2006.

A research officer from the Swedish Research Council acts as the co-ordinator of the review. Members of the Council for Research Infrastructures (RFI) may attend the evaluation as observers.

Review schedule

The review shall be made during the fall 2009 and the Panel shall have one meeting with the MAX-lab representatives. A preliminary report shall be presented to the Swedish Research Council not later than December 1, 2009.

Review procedure

The Review Panel shall investigate the general scientific/technical merits of the new design for the proposed MAX IV laboratory as well as the proposed budget and time-frame for completing the project. In particular, the strengths and weaknesses of the new technical and scientific programme shall be examined and compared to the one proposed and evaluated earlier.

The main issues the Research Council would like to address are:

- is the new design technically feasible? A comparison to that of the previous design should be done.
- a comparison of the scientific case for the new design compared to the previous one.
- will the new design fulfil the demands of the Swedish and Nordic/Baltic scientific communities? Significant changes in scientific opportunities and capacities compared to previous design should be pointed out.
- is the cost estimate for construction and operation of the new design realistic? A comparison to the cost estimate of the previous design should be done.
- is the time-frame for construction realistic?
- any significant scientific, technical, organisational and economical risks or shortcomings of the project should be pointed out.
- the figures of merit of the MAX IV laboratory and the cost-effectiveness shall be compared to other recently funded and planned synchrotron radiation laboratories.

The Review Panel is asked to comment on these issues in a comparative way to bring out the advantages/disadvantages with the new design compared to the previous one.

In the appendix some of the relevant issues that were assessed in the previous evaluations of the original MAX IV project are mentioned. The panel may wish to comment on any of these specifically.

Documentation for the review

- Proposal for a modified design of Max IV from MAX-lab
- The original MAX IV Conceptual Design Report, available at http://www.maxlab.lu.se/maxlab/publications/max4/MAX-IV-CDR.pdf
- An international evaluation of the MAX IV technical concept, Vetenskapsrådet Rapport 5:2006
- Scientific evaluation of the MAX IV technical concept, Vetenskapsrådet Rapport 5:2006
- Any other complementary documentation from MAX-lab.

Issues that were addressed in the evaluations of the technical and the scientific case of the original MAX IV proposal

General issues

- The new areas of science that can be investigated due to the unique and improved qualities of the synchrotron light specified in the new MAX IV design should be clearly identified. Any scientific, technical, organisational, and economical risks or shortcomings of the project should be pointed out. The figures of merit of the MAX IV laboratory and the cost-effectiveness shall be compared to other recently funded and planned synchrotron radiation laboratories.

Technical issues

- The technical feasibility of the project, including the design, the construction of the facility, as well as the expertise at the laboratory and suppliers of essential equipment or expertise.
- An analysis of the technical/scientific merits of the concept and a comparison to those of other latest-generation synchrotron radiation sources. In particular the panel should comment on the feasibility to obtain the high performance of the new 3 GeV ring and make an analysis of the stability of the beam.
- Particular issues that would need further studies or prototyping before any decision on the construction of the facility.
- The estimated time and manpower needed to finalize the construction of MAX IV. The estimated total costs of building the facility.
- Give an estimate for the manpower, indicating critical competences, needed to run MAX IV.

Scientific issues

- Evaluate, from an international point of view, the scientific value of the proposed project for physics, chemistry, biology, engineering and other relevant disciplines.
- Evaluate the scientific justification of the proposed project in the context of international scientific programmes of existing and planned laboratories with similar aims of research.
- In particular the review panel is asked to make a statement about the choice of electron energies for the two new storage rings in view of the proposed scientific program and the fact that MAX III will not be transferred to the new site.
- Give a statement about the experiments that will benefit most from the high brilliance of the storage rings and in particular identify experiments that may reach a unique performance.
- Comment on if any important scientific developments and applications within synchrotron radiation research are missing in the proposal.

Infrastructure issues

- Estimate the potential for the MAX IV laboratory to attract international users.
- Comment on the potential benefits of having a synchrotron radiation source of the MAX IV-kind in Sweden, including the impact on the industrial and public sector.
- Comment on the parts of the proposed research program that may attract industrial users and if so also indicate the industrial sector. The panel is asked to investigate the possibility for small and medium size companies to use the laboratory. For larger industrial users, which already successfully are using synchrotron radiation, the panel is asked to comment on the new research possibilities that MAX IV may give.
- Evaluate the appropriateness of the time schedule for the proposal.

Financial and organisational issues

- Evaluate the estimated building and construction costs for the new facility and compare the costs with the old MAX IV proposal.
- Evaluate the estimated running costs of the facility and compare the costs with the old MAX IV proposal.
- Evaluate the demands for personnel, equipment, and operating costs at the proposed laboratory and compare the costs with the old MAX IV proposal.
- Give an estimate for the manpower, indicating critical competences, needed to run MAX IV including beam lines and experimental stations.

- Assess the proposed organisation for construction and operation of the facility.
- Identify critical points during the project that prospective funding agencies need to be aware of.

APPENDIX II: SHORT CV:S OF THE EXPERTS

Dr. Sine Larsen

Professor, Department of Chemistry, University of Copenhagen, Universitetsparken 5, 2100 Copenhagen, Denmark.
Born in Copenhagen 1943.
M.Sc. University of Copenhagen; Honorary Doctor of Science, University of Lund.

Special assignments

Postdoctoral appointment at Massachusetts Institute of Technology, USA (1970–1971); Associate Professor at the Danish Technical University (1971–1974); Associate Professor Department of Chemistry, University of Copenhagen (1974–1994); Director of Centre for Crystallographic Studies, University of Copenhagen (1994–); Full Professor in structural chemistry at University of Copenhagen (1997–); Director of Research, European Synchrotron Radiation Facility Grenoble, France (2003–2009)

Chairman, Chemical Central Institute, University of Copenhagen (1977–1978); Chairman Department for Physical Chemistry (1987–1994); Deputy Dean, Faculty of Science, University of Copenhagen (2002–2003); Member of the Danish Natural Science Research Council (1989–1993); Deputy chairman of the Danish Natural Science Research Council (1991–1993); Member of CERC3, Chairman of European Research Council's Chemistry Committees (1990–1994); Deputy Chair CERC3 (1992–1994); Chairman, Danish Research Council's Committee for Scientific Instrumentation (author of a report in Danish) (1994–1995); Member of the Board for the Danish Council for Strategic Research (2004–2008); Chair of working group of the Danish Council for Strategic Research for a survey of the need for Large Research Infrastructures, a report in Danish and English (2004–2006).

Member of the Danish National Committee for Crystallography (1984–); President Danish Chemical Society (1998–2001); Member of the board for coordination for research in biotechnology, University of Copenhagen

(1999–2003), chairman of the board from 2001; Member of the board for the Swedish-Danish Cassiopeia beamline at MAX-lab Lund (1999–2008); Member of the Editorial Board for Crystallography Reviews (1993–); General Secretary and Treasurer International Union of Crystallography (1996–2005) and ex officio member of all the commissions of the Union; Member of an international evaluation panel of Norwegian University Chemistry (1996–1997); Member of the Scientific Advisory Committee for the Norwegian FUGE program 1999–2007); Member of the Scientific Advisory Council for the Italian synchrotron Elettra (2005–); Vicepresident of European Crystallographic Association (2006–2009); Member of the Science Advisory Council for the Spanish synchrotron ALBA (2007–); Member of the Forschungskommission for the Paul Scherrer Institut, Switzerland (2008–); Elected president of the International Union of Crystallography (2008–); Member of RIKEN Spring 8 Advisory Council (2009). Member of the Scientific Advisory Council for the European X-FEL (2010–);

Special scientific interests

Structural chemistry of chiral molecules; structural aspects of the function of enzymes in nucleotide metabolism and carbohydrate active enzymes; applications of synchrotron radiation in structural biology and soft condensed matter science.

Dr. Chi-Chang Kao

Chairman, National Synchrotron Light Source (NSLS), Brookhaven National Laboratory.
Director, Joint Photon Sciences Institute, Brookhaven National Laboratory and Stony Brook University.
Adjunct Professor, Physics Department, Stony Brook University.
Born in Taipei, Taiwan, in 1958.
Ph.D. in Chemical Engineering, Cornell University, USA.

Special assignments

Interim Chairman, NSLS (2006); Deputy Chairman, NSLS (2005–2006); Associate Chairman for User Science, NSLS (2001–2005); Senior Physicist, BNL (2001–); Physicist with tenure, BNL (1997–); Physicist, BNL (1994–1997); Associate Physicist, BNL (1992–1994); Assistant Physicist, BNL (1990–1992); Postdoctoral Research Associate, BNL (1988–1990).

Member, Scientific advisory Committee, Taiwan Photon Source; Member, Scientific advisory Committee, Brazilian Light Source; Member, Scientific advisory Committee, Pohang Light Source; Member, Scientific Advisory Committee, Stanford Synchrotron Radiation Laboratory; Member, Scientific Advisory Committee, Swiss Light Source; Chair, Linac Coherent Light Source (LCLS), Proposal Review Panel; Member, Advisory Committee of Carnegie-DOE Alliance Center (CDAC) (2004–); Member, the College of Reviewers for the Canadian Research Chairs program (2003–); Member, Advisory Committee of COMPRES – "the Consortium of Materials Properties Research in Earth Science"(2002–); Advisor, Taiwan Synchrotron Radiation Research Center /SPring-8 project (1999–).

Member, International Program Committee. The 9th International Synchrotron Radiation Instrumentation Conference (SRI2009), Member, International Advisory Committee. The 6th International Conference on Inelastic X-ray Scattering (IXS2007), May 7–11, 2007, Awaji, Japan; Member, International Advisory Committee, The 9th International Conference on Surface X-ray and Neutron Scattering (9SXNS), July 16–20, Taipei, Taiwan; Member, International Advisory Committee, The 13th International Conference on X-ray Absorption Fine Structure (XAFS13), July 9–14, Stanford, CA.; Member, Technical Program Committee, The Ninth International Conference on Synchrotron Radiation Instrumentation (SRI2006) Meeting, May 28–June 3, 2006, Daegu, Korea.

Special scientific interests

Development of new experimental techniques using synchrotron radiation, and their applications to condensed matter physics and material sciences, in particular, soft-x-ray resonant magnetic scattering for magnetism and magnetic material research, and high-resolution inelastic x-ray scattering for electronic structures of condensed matters under extreme conditions.

Dr. Carlo J. Bocchetta

Executive Director at Instrumentation Technologies, Solkan, Slovenia.
Born in Bournemouth, UK, in 1955.
B.Sc. in Chemistry and Ph.D. in Quantum Molecular Dynamics, Bristol, UK.

Special assignments

Royal Society/NATO post-doctoral fellow in Many Body Physics (1983–1985); ICTP-SISSA fellow in Many Body Physics (1985–1987), International Centre for Theoretical Physics, Italy; ANSALDO, Genoa, Italy (1987–1989); Deputy group leader of Accelerator Physics (1989–1994), Group leader of Operations and coordinator of Technical Groups (1994–1996), Vice-director of Accelerator Division (1996–1997), Co-director of Accelerator and Technical Services Division (1997–2001), Director of Accelerator Sector (2001–2002), Director of Accelerator and Light Sources Sectors (2002–2007), Sincrotrone Trieste, Italy; Project Leader of FERMI, Sincrotrone Trieste, Italy, (2004–2007); Executive Director of the Technical Division, Instrumentation Technologies (2007–present).

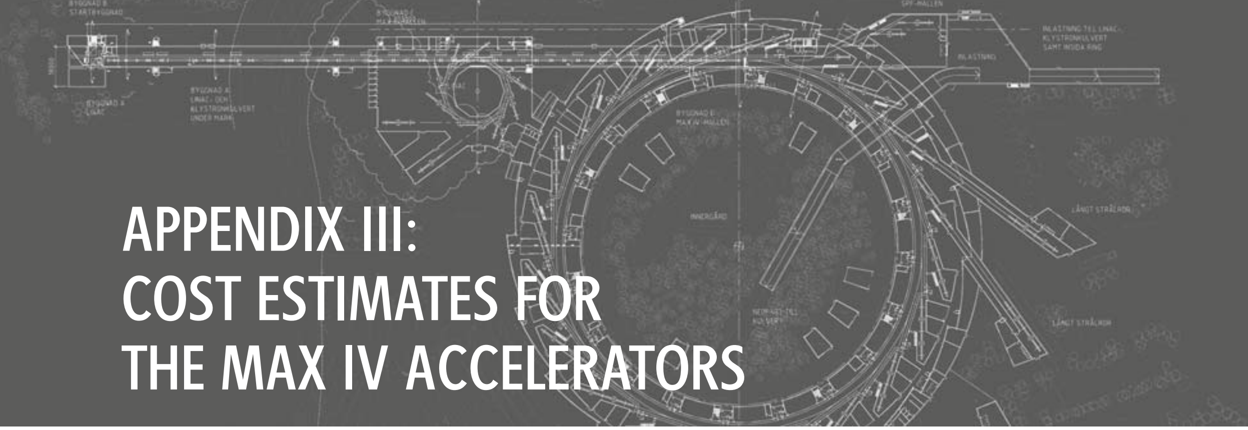
Machine Advisory Committee, SOLEIL Light Source, France, (2001–2006); Technical Advisory Committee, Diamond Light Source, United Kingdom, (2001–2006); SPARC project, INFN, Italy, Sincrotrone Trieste representative; Member of ESFRI technical panel for EU FEL R&D (2002); Machine Advisory Committee, SESAME Light Source, Jordan, Auspices of UNESCO, (2002–present); TESLA Collaboration, Sincrotrone Trieste representative; Co-opted board member of European Physical Society Interdivisional Group on Accelerators (EPS-IGA), (2002–2004); International Advisory Committee, 4GLS, United Kingdom, (2003–2006); Machine Advisory Committee, Spanish Light Source, Spain, (2003–2008); Machine Advisory Committee, DESY, Germany, (2004–2007); Accelerator Systems Advisory Committee, NSLS-II, Brookhaven, USA (2006–2009); Elected board member of European Physical Society Interdivisional Group on Accelerators (EPS-IGA), (2004–2010); Physical Review Special Topics Accelerator and Beams, editorial board, (2005–2007). Advisory Board Member of the ESFRI project EUROFEL (IRUVX-PP) (2008–2011).

International Conference on Accelerator and Large Experimental Physics Control Systems Conference Local Organiser (1997–1999); Scientific Programme Committee EPAC 2004, Session Organiser on Technology Transfer and Industry, (2002–2004); Free Electron Laser Conference Local Organiser

(2004); Scientific Programme Committee EPAC 2006, Session coordinator: Synchrotron Radiation and FELs, (2004–2006); ERL2005 International Program Committee (2004–2005); Free Electron Laser Program Committee (2004–2005); Linac Conference Program Committee (2005–2006).

Special scientific interests

Accelerator physics of synchrotron radiation sources and free electron lasers; Accelerator technology: linear and circular machines; beam stabilisation systems.



APPENDIX III: COST ESTIMATES FOR THE MAX IV ACCELERATORS

The cost estimates for the accelerators in the MAX IV are seen below. The first estimate is made in October 2006, just before the Swedish Research Council evaluation of the two rings on top of each other.

The next cost estimate was done November 2007; a more elaborate linac injection system was then introduced so the cost for the linac increased by 30 MSEK. The present design of a larger 3 GeV ring was introduced, and the MAX II and MAX III ware planned to be transferred. The latter operation was cost-neutral.

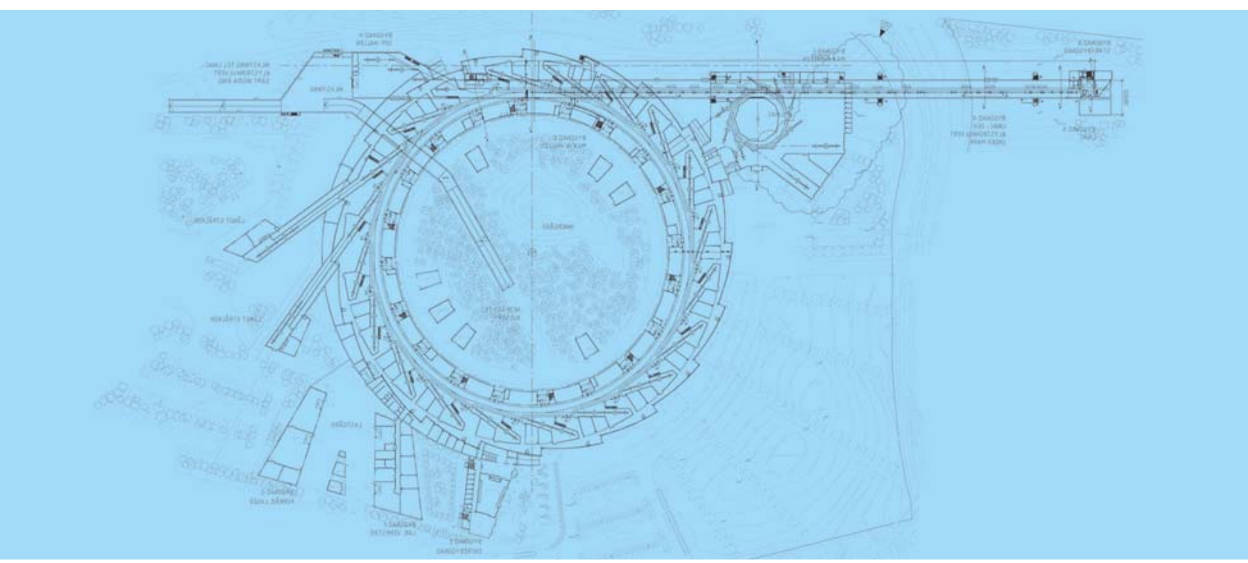
The next adjustment was made June 08.

The last cost estimate has been done in June 2009. The crown had weakened 10% at this time. A new 1.5 GeV ring was introduced, replacing the transfers of the MAX II and MAX III rings. The cost increment due to this was 13 MSEK (73–60 MSEK).

Table 1. Cost estimates for the accelerators in the MAX IV project.(MSEK)

	October 2006	November 2007	June 08	June 09
Linac injector	152	182	188	207
3 GeV Ring	135	202	220	238
1.5 GeV Ring	115			73
MAX II, MAX III		50	60	
Cost accelerators	402	434	468	518
Contengency 25%	100	108.5	117	130
Project services	150	150	170	187
Total	**652**	**692.5**	**755**	**835**

Synchrotron radiation is today a versatile and widespread scientific tool. The MAX-laboratory in Lund has proposed a new synchrotron radiation facility, named MAX IV, intended to deliver spontaneous as well as coherent radiation of very high quality over a broad spectral range. The technical design and scientific case of the proposal were evaluated in 2005 and 2006 and indicated that the proposed MAX IV facility would offer a world leading and unique light source of importance to competitive science in a wide range of scientific disciplines. Since then, preparations have been made for the construction of the MAX IV facility, including drafting of a modified technical design of the facility in order to better meet upcoming user needs. A panel of international experts has scrutinized the new technical design of MAX IV and their conclusions and recommendations are presented in this report.



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