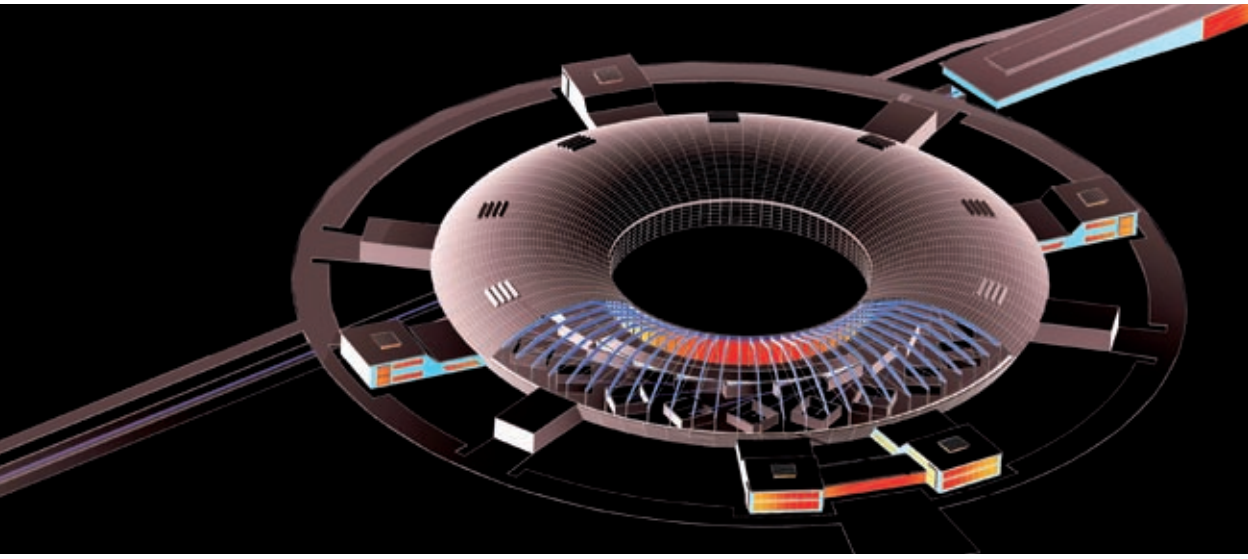
Vetenskapsrådet

AN INTERNATIONAL EVALUATION OF THE MAX IV TECHNICAL CONCEPT



VETENSKAPSRÅDETS RAPPORTSERIE 5:2006

AN INTERNATIONAL EVALUATION OF THE MAX IV TECHNICAL CONCEPT

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VETENSKAPSRÅDET
(Swedish Research Council)
103 78 Stockholm
Sweden

ISSN 1651-7350
ISBN 91-7307-085-8

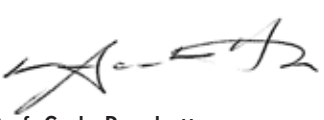
Cover Photo: SWECO FFNS
Graphic Design: Erik Hagbard Couchér, Swedish Research Council
Printed by CM Digitaltryck, Bromma, Sweden 2006

To the Swedish Research Council

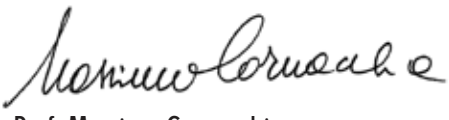
The Committee for Research Infrastructures (KFI) at the Swedish Research Council (Vetenskapsrådet) decided in May 2005 to evaluate the technical and scientific case of a proposal by the MAX Laboratory in Lund for a new synchrotron radiation facility named MAX IV. For evaluation of the technical concept a panel of international experts was appointed with a Swedish chairperson as well as a Swedish secretary. A site visit at MAX-lab took place 21-22 November, 2005.

The present document reports the assessments of the expert panel. By signing, the international experts take full responsibility for the report. The chairperson and the 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, 2005



Prof. Carlo Bocchetta

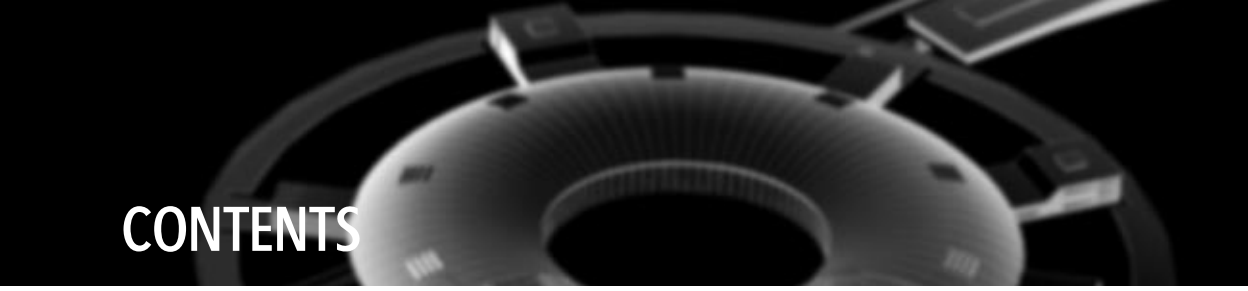


Prof. Massimo Cornacchia

Prof. Leonid Rivkin

Prof. Örjan Skeppstedt
Chairperson

Dr. Per Karlsson
Secretary



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SUMMARY

The review panel has carefully scrutinized the technical part of the MAX IV proposal as described in the report "The MAX IV accelerators", which was extracted from the Conceptual Design Report (CDR) and presented orally to the panel by the MAX-lab staff and associates at the site visit.

The panel finds the design concept sound. It offers a source with brightness an order of magnitude higher than other third-generation synchrotron radiation sources and it is judged by the panel to be a basis for detailed design study. In particular, the panel endorses the multi-ring concept as well as complementing the rings with a linac-based Free Electron Laser (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 of further and deeper studies of such areas.

The panel assesses 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 its 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 congratulates 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.

PROCEDURE FOR THE EVALUATION

The plans for the MAX IV project were presented to the Committee for Research Infrastructures (KFI) of the Swedish Research Council at the Committee's second meeting on April 5, 2005. MAX-lab submitted in May 2005 a proposal for the funding of a Detailed Design Study of MAX IV with 28 MSEK. The Committee decided the same month that the technical concept for MAX IV should be evaluated. The proposal was funded with 4 MSEK for 2006 in November. In order for the proposal to qualify for further funding the Committee decided that also the scientific case for MAX IV must be evaluated.

The Committee has appointed a Review Panel to scrutinize the technical concept. Professor Örjan Skeppstedt, former director of the Manne Siegbahn Laboratory, was appointed chairman of the Panel with Dr. Per Karlsson from the KFI staff as secretary.

The international expert members of the Review Panel were:

Prof. Carlo Bocchetta, Elettra, Trieste, Italy
Prof. Massimo Cornacchia, SLAC, Stanford, USA, retired
Prof. Leonid Rivkin, the Swiss Light Source, Villigen, Schweiz

Short CV's for the experts can be found in Appendix 2.

The terms of reference for the evaluation are presented in Appendix 1.

The Review Panel made a site visit to MAX-lab on November 21-22. The first day of the visit included presentations by representatives from MAX-lab and Lund University as well as a tour of the lab. On the second day the Panel put questions to the MAX staff and worked with the report. The Agenda of the visit is shown in Appendix 4.

Before the site visit, the Panel received material about the project: "The MAX IV Accelerators" (a description of the technical design of the accelerators) and a cost estimate of MAX IV (Appendix 3).

THE MAX LABORATORY

MAX-lab is a Swedish National Laboratory for research using synchrotron radiation and high-energy electrons as well as for research in accelerator physics. The laboratory is based upon a linac injector, a 550 MeV storage/pulse-stretcher ring, MAX I, and a 1.5 GeV third-generation storage ring, MAX II. The construction of a new linac-based injection system has been finalized and is now delivering an electron beam of 420 MeV (the final energy will be 500 MeV). A 700 MeV storage ring, MAX III, is under commissioning.

MAX-lab presently accommodates over 600 scientists representing scientific groups from more than a hundred industries, academic and government laboratories from 30 countries. Most users come from the Nordic countries.

Synchrotron radiation research at both MAX I and MAX II is done in a large variety of disciplines including surface science, semiconductor physics, materials science, atomic and molecular physics, chemistry, biology, medicine and environmental science.

At the 550 MeV MAX I storage ring there are five beamlines for synchrotron radiation research in the infrared through VUV photon energy range. At the 1.5 GeV MAX II storage ring, eleven beamlines are in operation and used for experiments in the VUV and soft X-ray regions with radiation provided by undulators, multi-pole wigglers and also bending magnets. The new 700 MeV storage ring is optimized for the UV spectral region and will also provide IR radiation. Until now, three beamlines have been funded for the MAX III storage ring, two of them utilizing undulator radiation and one bending magnet radiation.

MAX-lab is operated by Lund University (LU) under a contractual agreement with the Swedish Research Council. The Council is responsible for the main operating budget, the scientific programs and periodic reviews of the activities. As host university, LU is responsible for employee relations and for covering the housing costs of the laboratory, including rental costs and cost for electricity and water consumption.

Background for the MAX IV proposal

Scientific demands have challenged the staff at the MAX-lab to propose a new synchrotron radiation facility intended to deliver spontaneous as

well coherent radiation of very high quality over a broad spectral range from IR radiation, VUV radiation 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 about the scientific case for the MAX IV facility. The workshop was arranged 27-29 September 2004 by the MAX-lab user organization and MAX-lab, and attracted some 400 participants. Most of the time of the workshop was devoted to eight parallel workshops covering Life Sciences, Environmental Science and Geosciences, Structural Chemistry, Materials Science and Engineering, Nanoscience and Condensed Matter Physics, Surfaces and Interfaces, Atomic and Molecular Physics, and Medical Imaging and Therapy. The documentation from this workshop will form the basis for the scientific case to appear in the full Conceptual Design Report (CDR), which will be available in the beginning of 2006.

The MAX IV accelerator proposal

The accelerator design is based on the scientific needs discussed in the workshop mentioned in the preceding paragraph. The proposed accelerator system is described in the accelerator part of the CDR, which was made public and printed as a separate report in October 2005. This part of the CDR is the basic documentation of the MAX IV accelerators presented for the Review Panel.

The proposed accelerator system consists of two storage rings, operated at around 1.5 and 3 GeV respectively. The two rings have the same dimensions and a new design of the magnetic lattices allows them to be placed on top of each other. The primary sources for synchrotron radiation will consist of undulators and wigglers, which will cover a photon energy range from below one hundred eV up to several tens of keV. The plan is also to complement the two new rings by moving the 0.7 GeV MAX III ring, presently under commissioning at the MAX Laboratory, to the proposed new site of the MAX IV facility. The MAX III ring will be the primary source for IR and UV radiation and extends the photon energy range for undulator radiation down to a few eV. A linac is chosen for injection. The linac will also be used to generate short X-ray pulses and coherent radiation. In the first step, a device based on spontaneous emission will be developed for the generation of ultra-short pulses. In the next step the construction of a Free Electron Laser (FEL) is planned.

TECHNICAL ASSESSMENT OF THE MAX IV PROPOSAL

The proposed facility is a highly advanced concept addressing the need for both very high average brightness and extremely stable sources of synchrotron radiation together with the upcoming need for coherence and ultrashort pulses. This is achieved by a complex consisting of three storage rings and a Free Electron Laser (FEL) fed by a single linear accelerator. The Panel strongly endorses the multi-ring concept to optimally cover the spectral range based on the proposed technological choices.

Drawing on highly successful development of third-generation synchrotron radiation sources world-wide, the proposed set of rings offers a source an order of magnitude brighter over an unprecedented spectral range. Overall, the design concept is sound and is judged by the Panel to be a solid basis for detailed design study.

The linac-based FEL utilizes normal conducting RF technology, as adopted by LCLS at Stanford and at FERMI in Trieste, both currently under construction. It offers outstanding performances to complement those of the storage rings. These are: femtosecond pulses, ultra-high peak brightness and coherence.

The demand for the high repetition rate option of the FEL has to be carefully examined in a future detailed consideration of the scientific case, as it requires a degree of linac flexibility that may affect the FEL performance. It critically defines the architecture of the facility and poses challenging technical questions related to the use of the linac both as an injector to the storage rings and as an FEL driver.

Innovative solutions were presented to the Panel. Naturally, such a significant step in performance places challenging demands on all aspects of accelerator physics and consequent technology. This requires a higher degree of control of the electron beam than what has been achieved to date. The group is aware of these challenges and some of the engineering ideas proposed in the present concept already address them.

The integration of magnets and girder into one piece reduces the sensitivity to vibrations and greatly simplifies the alignment. The use of the precision-machined integrated magnet design has been tested and implemented in the new MAX III ring, as well as in the new injector. The resulting ring structure is extremely compact and provides the strong focusing of the electron beam required for the enhanced performance. The use of the solid iron

technology simplifies the design and reduces the cost. However, the reproducibility and quality of the magnets must be studied further. MAX III, built with this technology, is presently under commissioning and will help validate this concept.

The use of the emerging technology of NEG coated vacuum chambers throughout the machines is an essential part of the proposed concept. It is being implemented in part in the present synchrotron light sources under construction and is establishing itself quickly as a mature technology.

The present needs of the project are covered adequately by the in-vacuum undulator technology commercially available today.

Environmental factors like thermal stability and ground vibrations are crucial for the attainment of the desired performance. This is also true for the specifications of conventional facilities.

Costs

The Panel appreciates that the preliminary budget is based to a high degree on recent construction experience (MAX III and the new injector) and price quotations from industry. The projected cost of the facility appears to be on the low side, when compared to that of a conventional third-generation synchrotron light source. However, this laboratory has demonstrated the capacity to build accelerator components in a cost-effective way. University support has played an important role in this context. The detailed design study will consolidate the budget and additional human resource requirements.

APPENDIX 1

Terms of reference

Evaluation of the technical concept for the MAX IV facility

Introduction

MAX-Lab is a Swedish National Laboratory for research with energetic electrons and synchrotron radiation. At present two electron storage rings for synchrotron radiation are in operation, MAX I at 550 MeV and MAX II at 1.5 GeV. A third ring, MAX III, which will be operating at 700 MeV, is presently being built.

MAX-lab is proposing to build a new high-performance synchrotron radiation laboratory, MAX IV, where the main components will be two electron storage rings with ultra-low emittance and, in a second step, a UV soft X-ray Free Electron Laser. The technical design of MAX IV shows several new and interesting concepts, which to our knowledge have not been fully implemented earlier.

The present evaluation is to examine in detail the technical proposal for MAX IV and evaluate 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" consisting of three members. All members will be internationally recognized experts in the field, with broad views and expertise. None of the members shall be personally engaged in MAX-lab.

The chairperson of the Review Panel, appointed by the Swedish Research Council, heads the review and is the rapporteur of the Panel. A research officer from the Swedish Research Council acts as the co-ordinator of the review.

The members of the Review Panel will receive an honorarium according to the regulations of the Swedish Research Council. Travel and living costs in connection with the review will be reimbursed or paid by the Swedish Research Council.

Documentation

- The technical concept for MAX IV
- "Our future light source". MAX-lab report.
- Estimated budget for construction and running of MAX IV

Review schedule

The review shall be made during fall 2005 and the Panel shall have at least one site visit at MAX-lab. A preliminary report shall be presented to the Swedish Research Council not later than December 1, 2005. A printed version of the report will be made public before February 15, 2006.

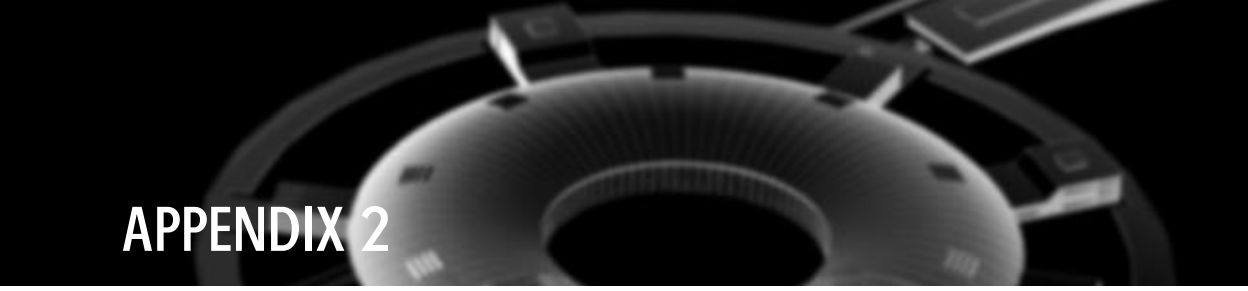
Review procedure

The Review Panel shall investigate the general technical/scientific merits of the 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 developments within accelerator physics/technology shall be examined. The potential technical risks of the project shall be identified. The figures of merit of the MAX IV laboratory and the cost-effectiveness shall be compared to other recently funded synchrotron radiation laboratories.

The Review Panel is asked to give specific recognition to the following issues:

- The overall feasibility of the project, including the technical 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.
- The technical feasibility of building two rings on top of each other and the possible technical risks of the new design. Analysis of scientific and technical advantages and drawbacks of the two-ring concept compared to a single ring construction.
- The feasibility of the injector system to serve two electron storage rings in a top-up mode while at the same time constituting the basis for a free electron laser.
- Comment on the scientific/technical aspects of, in a second step, focussing on cascaded optical klystrons compared to the SASE option.
- Comment on the advantage/disadvantage of combining a synchrotron radiation laboratory with a FEL facility.
- Particular issues that would need further studies or prototyping before any decision on the construction of the facility.
- Analysis of cost benefits of the two-ring concept. In particular the extra costs involved in building two rings compared to building one.
- 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.

- Evaluate the estimated running costs of the facility.
- Identification of critical points during the project that prospective funding agencies need to be aware of.



APPENDIX 2

Short CV's for the experts

Dr. Massimo Cornacchia

- Accelerator Physicist, retired. Current address: 1113 S. Curley St., Baltimore, MD 21224, USA.
- Born in Florence, Italy, in 1938.
- Doctorate from Rome University, Italy.

Special Assignments:

Accelerator Physicist at the Daresbury Nuclear Physics Laboratory, Daresbury, England (1965-1971); Accelerator Physicist at CERN, Geneva, Switzerland (1971-1977);

Visiting Scientist, Stanford Linear Accelerator Center, USA (1978); Leader of the Accelerator Physics Group, Brookhaven National Laboratory, USA (1979-1983); Leader of the Exploratory Studies Group, Lawrence Berkeley Laboratory, USA (1983-1987); Project Leader of Trieste Synchrotron Construction project (1987); Deputy Project Leader of the Advanced Light Source, Lawrence Berkeley National Laboratory, Berkeley, USA (1987-1988); Head of Storage Rings Group, Stanford Linear Accelerator Center, USA (1988-1991); Associate Director for Accelerators, Stanford Synchrotron Radiation Laboratory, USA (1991-2004); Leader of the Linac Coherent Light Source Project (1996-2000); consultant with the FERMI Free-Electron Laser Project at Trieste Synchrotron (Italy), (2004-present).

Fellow, American Physical Society (1996-present).

Special Scientific Interests:

Theory, operation and development of Synchrotron Radiation Sources and Free-Electron Lasers; non-linear dynamics in particle accelerators.

Dr. Carlo J. Bocchetta

- Director of Accelerator and Light Sources Sectors, Sincrotrone Trieste, Area Science Park, S.S. 14km. 163.5, Basovizza, I-34012 Trieste, Italy

- 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-present), Sincrotrone Trieste, Italy; Project Leader of FERMI, Sincrotrone Trieste, Italy (2004-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 technical panel for EU FEL R&D, European Strategy Forum for Research Infrastructure (ESRFI), EU (2002); Machine Advisory Committee, SESAME Light Source, Jordan, Auspices of UNESCO (2002-2007); 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); Elected board member of European Physical Society Interdivisional Group on Accelerators (EPS-IGA) (2004-2010); Physical Review Special Topics – Accelerators and Beams, editorial board (2005-2007).

International Conference on Accelerator and Large Experimental Physics Control Systems, Conference Local Organiser (1997-1999); Scientific Programme Committee EPAC 2004, Session Organiser: 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 electron machines.

Dr. Leonid Rivkin

- Head of the Accelerator Development and Operation Department, Paul Scherrer Institut, CH-5232 Villigen PSI, Switzerland.
- Born in Odessa, USSR, in 1954.
- AB in Physics, Harvard; Ph.D. in Physics, Caltech, USA.

Special Assignments

Fellow, American Physical Society (2004-present). Member of the Editorial Board of the Physical Review Special Topics – Accelerators and Beams (2001-2004).

Chairman of the Facilities Based Light Sources Symposium, Conference I: Photons, Lasers and Quantum Statistics, EPS13, Bern, Switzerland (2005). Chairman of the Elected Board of the Interdivisional Group on Accelerators of the European Physical Society, Member of the EPS Council (2002 – 2004).

Member of the Organizing Committee of the European Particle Accelerator Conference (1994-present). Member of the PAC2003, PAC2005 and PAC2007 Program Committees. Member of the PAC2005 Organizing Committee.

Member of the DESY Machine Advisory Committee (2003-present). Chairman of the SOLEIL Project Machine Advisory Committee (2001-present). Member of the NSSRC External Review Committee (2004).

Member of the Advisory Committee and Program Committee of the CERN Accelerator School (1993-present). Member of the Program Committee of the Joint Universities Accelerator School (2000-present).

Special Scientific Interests

Accelerator physics aspects of design, construction, commissioning and operation of electron storage ring-based synchrotron light sources and damping rings for electron-positron high-energy linear colliders. Accelerator physics aspects of high-brightness, short-pulse electron sources for X-ray Free Electron Lasers.

APPENDIX 3

Short summary of the MAX IV budget

In this document we present a cost estimate for the MAX IV facility, with main emphasis on the accelerators. The present estimates are in certain cases based on actual quotations. In other cases they are based on our recent experience from MAX II and MAX III. For some items, however, the estimates are still less certain. We have then made the estimates such that they should go down rather than up as the detailed design progresses. We have included personnel costs in the estimates. To the extent that the present MAX-lab personnel can be used in the build-up the corresponding costs are not included.

The total cost for the accelerators and the first phase of beamlines is estimated to be in the range 1200-1400 MSEK excluding building. The total operation cost will be around 120-140 MSEK plus housing. The costs for the Free Electron Laser are not included.

The planning of the first phase of beamlines is ongoing and the costs connected with it have not yet been analyzed in detail. At this stage we estimate the cost of the first phase of beamlines to be around 500 MSEK. MAX III will be moved to the MAX IV site with one existing IR microscopy and spectroscopy beamline and two modern low-energy photoemission beamlines that are now under construction. For the 1.5 GeV ring there will be a mixture of totally new beamlines and beamlines which are either directly transferred from MAX II or transferred and rebuilt. In this way, five or six soft X-ray beamlines can be included at the 1.5 GeV ring in the first phase at an estimated cost of 100-120 MSEK. For the 3.0 GeV ring, at least six beamlines are planned for the first phase. One of these will be a transferred magnetism beamline. This beamline is presently being built up at MAX II. In addition to this, an SPPS (Sub-Picosecond Pulse Source) beamline is planned at the Linac as part of the first phase. There will thus be some 15 beamlines already in the first phase.

Lund as above

Nils Mårtensson
Director

Breakdown of the MAX IV machine costs

Rings	3 GeV	1.5 GeV
Magnets including power supplies	30	30
Vacuum	30	30
RF	30	10
Diagnostics	15	15
Control system	15	15
Mounting, cabling	10	10
Injection, transport	10	10
Subtotal	140	120

3 GeV Linac	
Injector	10
Linac structures	40
Modulators	50
SLED	10
Waveguides. Low-level RF	10
Diagnostics	5
Control	10
Mounting, cabling	5
Vacuum	5
Quads	3
Chicanes	5
Subtotal	**153**

MAX III relocation	5
Project services	150

Includes all staff, engineering (not beamlines), overheads, computer, health and safety, utilities and general maintenance costs

Total costs	**568**
Contingency 25%	**142**
Total	**710**

APPENDIX 4

Time schedule for the site visit at the MAX Laboratory, 21-22 November 2005

Monday 21 November

10.00 **Introductory remarks and presentation of the MAX Laboratory**
Göran Bexell, Vice Chancellor, Lund University (not yet confirmed)
Nils Mårtensson, Director, MAX Laboratory
Mats Fahlman, Chairman, Association of MAX-lab users

11.00 **Internal meeting of the Review panel**

12.00 **Lunch**

13.00 **Presentation of the technical concept of the MAX IV facility**
The presentation will be made by Nils Mårtensson, Mikael Eriksson and the staff of MAX-lab. (Parts of the presentation material – Power-point files etc. – will be distributed by e-mail to the review panel before noon Friday 18 November.) Appropriate time will be reserved for questions and discussions.

18.00 **Dinner**

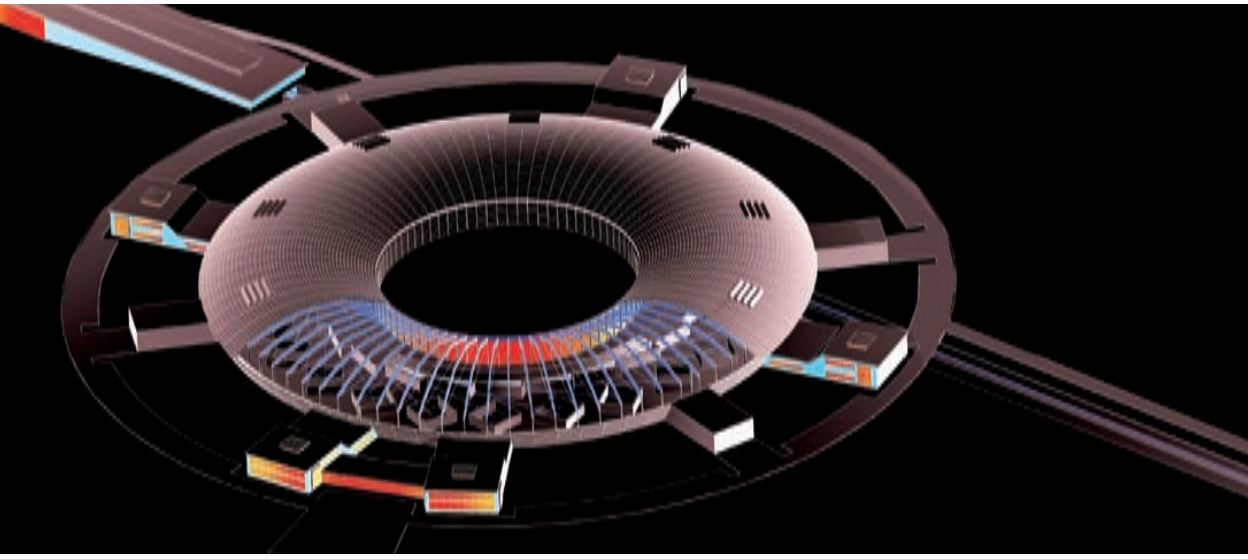
20.00 **Internal meeting of the Review panel**

Tuesday 22 November

09.00 **Internal meeting of the review panel**
The staff of MAX-lab will be available for further discussions and answering questions according to requests from the review panel.

The goal is to have a draft of a report of the evaluation ready before the end of Tuesday. The whole panel is present until around 5 p.m., but if necessary part of the panel can work also in the evening.

Synchrotron radiation is a useful tool in many scientific fields including nanoscience and condensed matter physics, materials science and engineering, structural chemistry, environmental science and geosciences, life sciences and medical imaging and therapy. 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. A panel of international experts has scrutinized the technical part of the MAX IV proposal and the result of their evaluation is presented in this report."



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ISSN 1651-7350
ISBN 91-7307-085-8