

Report of the Working Group for the Strategic Mission of the ESRF October 2012

EXECUTIVE SUMMARY

By fulfilling the objectives determined at its creation, the ESRF has established itself as one of the world's leading synchrotron radiation facilities and has been at the forefront of international research for over 20 years. In today's context, with a number of new facilities and new light sources being built, the mission of the ESRF is even more relevant than ever. The physical, materials and biological sciences, whether fundamental, applied, or industrial, require more brilliant and more focused beams to go into the heart of matter with nanometer spatial resolution. The grand challenges of energy, health and environment can only be addressed if cutting edge tools are provided for the research needed to approach them.

Key areas of research are identified, including coherent diffraction imaging and microscopy in the mesoscopic scale, spectroscopy with nanometer spatial resolution, and time-resolved studies in the millisecond to sub-nanosecond scale, together with a high power MHz laser pump-probing programme.

In recent years, new concepts for accelerators have emerged leading to the possibility of building storage rings with an increase in brilliance of two orders of magnitude and a reduction of beam size to the micrometer range. The ESRF has been one of the leaders in the development of these new concepts and is working on a Machine upgrade proposal that is pivotal in maintaining the facility as world-leading in hard X-ray spectroscopy, diffraction and imaging. This new source, with unmatched brilliance and beam size, will take full advantage of the beamlines currently being built in the Upgrade Programme.

The realization of this project is vital to maintain Europe in its present leadership position in the development and operation of synchrotron radiation facilities for users. The ESRF has the unique resources of expertise that are required for such a challenging enterprise. In addition, the ESRF has most of the resources and infrastructures needed for the full implementation and exploitation of the upgraded source, yielding the best value for money for Europe to establish itself as the leader of this new generation of synchrotron radiation facilities. The European and international ambitions that have been the basis of the ESRF's success will establish in this project a new *raison d'être*.

As an international organization, the ESRF allows the sharing of costs and risks among its members. The implementation of new technologies for enabling new science always implies major challenges to be overcome, technical implementation on one side and new discoveries on the other side. These have been at the root of the creation of the ESRF and it should remain so.

The ESRF has attracted the best scientists from all around the world to perform experiments that have been widely acclaimed, from the award of Nobel Prizes to the frequent appearance on the front cover of top scientific journals. This can only continue if the ESRF maintains its world-leading position in terms of beam performance. Similarly, the importance of access to the ESRF is widely recognized by industrial partners that rely on its excellence to contribute to and maintain their competitiveness.

When looking ahead at the forthcoming 20 years, the working group for the Strategic Mission of the ESRF (SME-WG) considers that it is essential to underline the crucial importance that a strong ESRF will have in the performance of new photon sources that are being built in Europe and around the world. Close partnerships with the European X-FEL and national sources will be essential for the optimization of the use of the resources devoted to the development of the ESRF.

It is our firm belief that, in line and in continuation with the ongoing Upgrade Programme, the ESRF Council must support constant and ambitious evolutions of the facility in all areas of its activity but most critically today in the transformation of its sources and accelerators to match what can now be envisaged in terms of beam properties which represents a quantum leap forward in performance (see figure below).

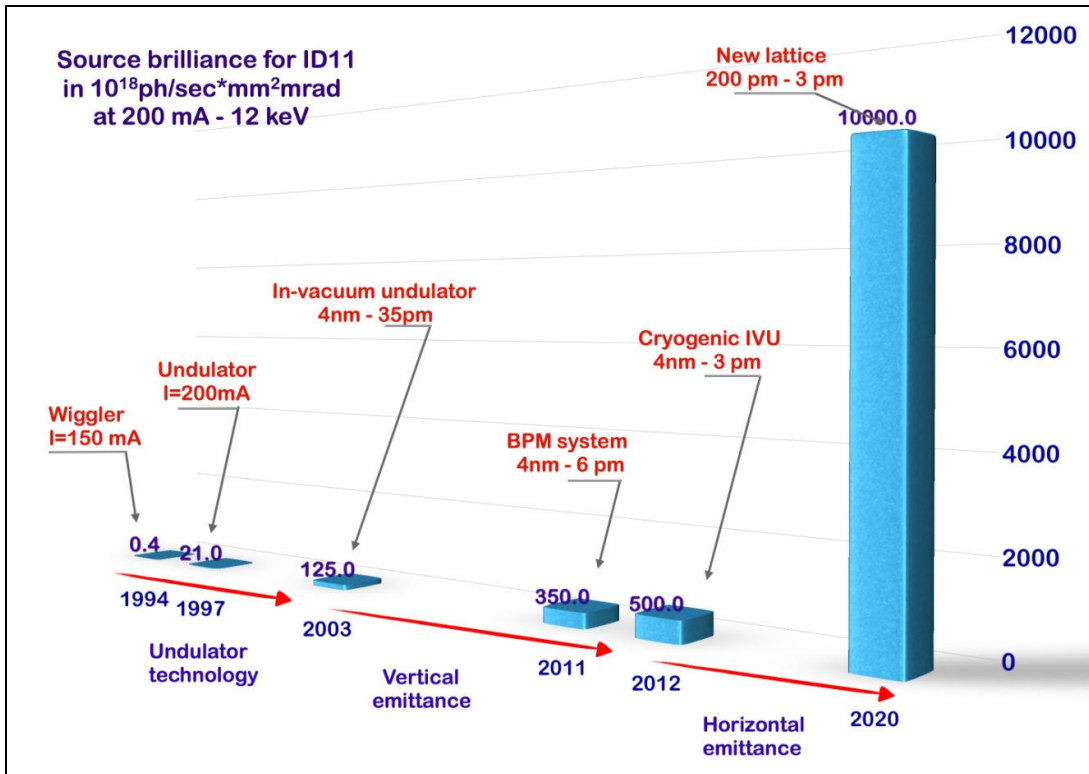


Figure 1. Evolution of source brilliance for ID11 beamline since its opening in 1994. Two parameters have so far contributed to increase brilliance, undulator technology and improved vertical emittance. The transformation of the ring that can be envisaged today will mostly improve horizontal emittance with a dramatic increase in brilliance.

INTRODUCTION

This report has been written in answer to the demand of the ESRF Council made at its spring 2011 meeting when it was decided to create a working group to consider the long-term mission of the ESRF in the European and international context beyond upgrade Phases I and II and, typically, up to 2030. (The Terms of Reference are given in appendix 1.)

The ESRF has established itself as one of the world's leading synchrotron radiation facilities, and has been at the forefront of international research for over twenty years, particularly in the hard X-ray regime. It started operation in 1992 and its performance has been constantly improving since that time, leading the way among third generation synchrotron radiation facilities both in terms of technical performance and scientific production. Many key indicators substantiate this affirmation, such as the award of Nobel Prizes (Chemistry 2009 and 2012), the very high quality and quantity of its scientific output (~1900 publications per year, including ~200 per year in high impact journals) and the frequent appearance on the front cover of top scientific journals.

During its ~20 years of operation, upgrading of the source has led to an increase in brilliance by two orders of magnitude and in reliability with 99% beam availability in the last three years. Constant upgrading of the beamlines has been performed in part by the procurement of state-of-the-art commercially available equipment and particularly by strong in-house research and development programmes. The ongoing Upgrade Programme is creating a new generation of beamlines of unprecedented capabilities. In particular, the extension of the Experimental Hall is enabling the installation of long (>100m) beamlines crucial for the improvement in spatial resolution. Important investments are also being made to further enhance the reliability of the Machine.

Many factors have contributed to the overall success of the ESRF. The major one is certainly the extremely competent and highly committed staff that the ESRF has been able to attract and train during its existence. A second factor is the international nature and organization of the ESRF. This has enabled the facility to attract highly qualified engineers and scientists from all over the world, particularly from Europe, and is creating a unique forum for exchange between scientists and synchrotron specialists from all nations.

Today, the building of new photon sources based on innovative and highly performing technologies, the rapid evolution of research communities, both in academia and in industry, and the profound transformation of the European economic and political landscapes are creating a very challenging context for the future of the ESRF. In addition, the forthcoming rapid staff turnover which is linked to the age pyramid of ESRF employees and to the retirement of many of the people who built the facility also constitutes a major challenge for the facility. It also offers an opportunity to adapt the future competences of ESRF staff to the needs that can be foreseen in view of the anticipated technical and scientific long term developments.

The ESRF has contributed very significantly to the development and visibility of European science in the last 20 years. With proper and ambitious actions from its Members, and possibly also from the European Union, it has the potential to continue to play a leading role worldwide over the next twenty years.

The following sections will describe the findings and the recommendations of the working group on the seven topics that have been identified in the Terms of Reference given by the ESRF Council.

SPECIFIC TOPICS

TOPIC 1. CAPACITIES AND SPECIFICATIONS OF THE ESRF AND OF OTHER MAJOR EXISTING, PLANNED OR ENVISAGED PHOTON SOURCES

In 2025, apart from the ESRF, a number of modern storage ring based synchrotron radiation facilities will be available for the large and multidisciplinary European user community: ALBA (Spain), Anka (Germany), BESSY II (Germany), Diamond (UK), Elettra (Italy), Max IV (Sweden) and SOLARIS (Poland) under construction, Petra III (Germany), Soleil (France), Swiss Light Source (Switzerland). These facilities serve their national user community and try to attract the best groups from the international community. Several of them will be operated in conjunction with X-ray free-electron laser facilities offering new opportunities for time-resolved studies of dynamics with atomic scale resolution: Elettra + FERMI, Petra III + FLASH/ European XFEL, Max IV + Swedish FEL, SLS + SwissFEL. The capacity provided by X-FELs is complementary in nature and unique in reaching femtosecond time resolution for the study of the dynamics of matter at X-ray wavelengths. X-FELs provide orders of magnitude higher peak power and shorter pulses which lead to unique opportunities for single-particle single-shot experiments. Concerning source coherence properties, the gap between X-FELs and synchrotron radiation facilities is expected to close. X-FELs have a reduced capacity for users compared to circular accelerators. In condensed matter research, radiation damage and space-charge problems are a challenge for X-FELs and high brightness synchrotrons, and future emphasis for the ESRF should thus be on studies where high repetition rates with a moderate number of photons per pulse is essential, and where stability (e.g. pulse energy, pulse length and time structure) and high average power are required.

Strategic recommendations

- The ESRF has to continue to serve European and international science through unique beamlines and a storage ring upgrade project which open entirely new opportunities for science, e.g. unprecedented brilliance in the hard X-ray region.
- The future strategy should continue to support the high photon energy regime studies: this would maintain and strengthen the ESRF's complementarity to other national facilities. One important area lies in the combined exploitation of nanometer *hard* X-ray beams in diffraction and spectroscopy applications.
- Key areas are coherent diffraction imaging and microscopy in the mesoscopic scale, spectroscopy with nanometer spatial resolution, and time-resolved studies in the

millisecond to sub-nanosecond scale, including a high power MHz laser pump-probing programme, and new high throughput analysis methods.

TOPIC 2. DEVELOPMENTS IN SOURCE AND ACCELERATOR ISSUES AT THE ESRF AND ELSEWHERE

Rapid and innovative developments in the concept of an ultimate storage ring are currently taking place and will result in the construction of new rings or to the transformation of existing rings with unmatched reduction of the horizontal emittance (e.g. MAX IV in Sweden and SPring-8 in Japan) that will begin operation between years 2015 and 2020, providing all new ultra-brilliant synchrotron X-ray beams. The ESRF ring is based on a design that was made thirty years ago. The upgrades that were made in the last twenty years and which have led to the improvements in performance indicated above, were achieved without modifications of the lattice layout of the ring. However, due to the experience and the competences of its staff, the ESRF is already playing a leading role in the reflection being given to future storage ring based light sources with a substantial reduction in horizontal emittance by two orders of magnitude and a substantial increase in brilliance.

The successful combination of high brilliance, a high degree of coherence, relatively short pulses and a high-duty-cycle would open exciting new scientific perspectives and ensure a long term future for the ESRF as an outstanding research tool, complementary with free-electron lasers and competitive with respect to ERLs.

Strategic recommendations

- The ESRF must play a leading role in the global reflection that is being given to future storage ring based X-ray sources.
- The proposed ESRF Machine upgrade plan for the transformation of its storage ring into an ultra low horizontal emittance Machine is the most cost-effective proposal currently made worldwide and all efforts should be made to realize such an upgrade within the time frame of the forthcoming Phase II of the facility. This would be in coherence with the ongoing Upgrade Programme.
- Long term sustainability of the operation costs of the upgraded Machine should be carefully taken into consideration at an early stage.

TOPIC 3. DEVELOPMENTS OF BEAMLINE EQUIPMENT

The development of beamline equipment is of utmost importance because it is these instruments with which the users interact primarily. Only state-of-the-art equipment will attract world-class users. Demands on all aspects of such equipment will rise significantly. However, the ESRF can benefit from developments driven by current FEL projects in the fields of optics, detectors and data handling.

The ongoing Upgrade Programme is already strongly contributing to maintaining the ESRF in a leading position on new beamline design and instrumentation. The new upgrading of the source will favour the full exploitation of the capabilities of the upgraded beamlines. It will

also present new challenges, particularly in terms of detector development, data handling and optics.

Strategic recommendations

- The ESRF should implement a far-reaching instrumentation development programme enabling new science which will become possible with the new source capabilities. Specific emphasis should be given to detectors, data handling, sample environment and positioning issues, together with integrated approaches to instrument control.
- Coherently with the ongoing Upgrade Programme, high priority should be given to the funding for the instrumentation programme.
- The ESRF should develop this programme in a strong collaborative spirit with the other European synchrotrons and with the European X-FEL, whenever possible. SAC must be duly involved in the development and implementation of this strategy.

TOPIC 4. EVOLUTION OF USER COMMUNITIES AND FIELDS OF RESEARCH LIKELY TO BENEFIT FROM SYNCHROTRON RADIATION

The scientific communities involved in the study of matter require, more and more, a continuum of the investigation tools that cover all dimensions of space, energy and time. The upgrading of the ESRF accelerators, together with the possibility to combine techniques with dramatically enhanced spatial, spectroscopic and temporal resolutions, will have a very strong impact on the user communities as it will open up new experimental capabilities to explore matter with unprecedented depth. There may, of course, be a natural tendency in the user communities to base the evaluation of the needs on experiments that have already proven to be highly productive in similar scientific contexts. The impact of new technical developments on existing communities may therefore look quite uncertain. The ESRF's scientific Management, together with the SAC, will therefore have a critical role in the diffusion of these developments within the user communities.

Other types of facilities (FELs, lasers) are also opening up new perspectives for future photon-based research. These developments are clearly complementary to the future capacities that will be achieved by new generation storage rings.

Strategic recommendations

- Novel areas of research must be supported by a strong user community. New access opportunities should be identified by attracting strong user groups which have the potential to enable new scientific capabilities and to raise the long-term funding required to pursue forefront science in unexplored territory.
- A prospective evaluation of the needs of users (scientific case) has to be conducted in parallel with any plan to drastically change the properties of the facility, for example the brilliance and coherent fraction or the energies of the photons that can be produced.
- The SAC should be instrumental in this evaluation of the needs, in the identification of new communities of synchrotron users and in the follow-up of the evolution of the existing communities.

TOPIC 5. POSITION OF THE ESRF WITHIN ERA AND IN THE INTERNATIONAL CONTEXT

The ESRF has been established as an international facility, operated by its twelve Member Countries and funded by the contributions of its nineteen Member and Scientific Associate Countries. Although the ESRF is, by name and vocation, European, it has no statutory link to the European Union (EU) or to the European Commission (EC). It should be noted that 16 of the 19 countries participating in the ESRF are members of the EU. Overall, the ESRF is a leading reference for users at a global level.

The policy for access to the facility is determined by the ESRF Council. The rule has always been to grant access on the basis of the scientific excellence of proposals evaluated by independent panels of peer experts. In order to reconcile the level of access given to scientists from each Member or Associate Country to the funding provided by them, an *a posteriori* calculation of just return ("*juste retour*") is made every year and adjustments are made either through additional financial contributions or through limitations of access. National facilities all have similar access procedures. However, access for non-national teams is generally very open in order to attract the best science to the facility.

Five percent of the ESRF's beam time is set aside for discretionary access allocation by the Management of the facility. This has been largely used by the Management to grant access to top-level proposals coming from scientists from non-Member or non-Associate countries, and to develop proprietary industrial use.

The ESRF plays a leading role in important international infrastructure associations (EIROFORUM – the association of European international research organizations, the Three Way Meeting – the association of the four high-energy synchrotrons worldwide – APS in the United States, SPring-8 in Japan, PETRA III in Germany and the ESRF; etc.).

Strategic recommendations

- The ESRF should reinforce synergy through appropriate collaborations and associations with the European XFEL and with other European facilities. European and international science excellence should fully benefit from the opportunities offered by the ESRF.
- The interactions and collaborations between the ESRF and national European facilities should continue to grow in a cooperative-competitive spirit as this will drive a continuous improvement of all the facilities.
- Access for scientists from non-Member countries should be encouraged and promoted. The value of having high-profile experiments carried out in Europe at the ESRF by scientists from abroad should be recognized at all levels of governance. New schemes of collaboration and associations with international partners should be envisaged in the spirit of a Global Research Infrastructure policy.
- The ESRF should strengthen its current access mode to further favor partnerships to build up, which will create new opportunities for science and for ESRF users.

TOPIC 6. CONTRIBUTIONS TO INNOVATION AND INDUSTRIAL NEEDS

Since its beginning, the ESRF has always placed a high priority on the service to industrial users. Proprietary research, aiming at product development and often generating IP, is performed on a pay-for-service basis (based on actual costs). The income generated has amounted in recent years to between 2% and 4% of the total budget of the ESRF. A small team of scientists, engineers and technicians are employed by the ESRF to answer the needs of industrial users.

Industry, however, also participates in basic publishable research mostly in collaborations with academic laboratories. Since these collaborations are most often submitted to programme committees by the academic laboratories involved in the collaboration, the exact percentage of projects that involve some form of collaboration with industry is not known precisely and may amount to 25% of the total number of projects.

Interviews revealed that no industrialist wanted to make a long-term forecast (>10 years) of the evolution of their needs either in terms of volume or in terms of techniques required. In most cases, they suggested that we discussed the long-term vision of the scientific needs in their domains of research with their academic collaborators. Several industrialists underlined nevertheless the major impact that the increase in brilliance and resolution of the upgraded source will have on their programmes, particularly in hard X-rays.

The attitude of industry towards research is changing notably due to the sharp increase in cost and complexity of research, particularly at the pre-competitive level. This results in the outsourcing of the most upstream research to academic laboratories, to the participation in research centers joining with academia (e.g. Fraunhofer and Carnot Institutes) and shared platforms between several companies, with the participation of academic laboratories (e.g. Technological Research Institutes).

On the other hand, industrialists are very aware that their future competitiveness is closely linked to innovation-producing research and are thus very keen to develop joint projects.

Strategic recommendations

- The ESRF should strengthen further its policy in the field of innovation and industrial collaborations, and consider, on a timely basis, the evolving needs of industrial access to the facility.
- The ESRF should develop and foster long term agreements and programmes with joint industry-academy platforms and research centres.

TOPIC 7. NEEDS FOR EDUCATION AND TRAINING

Education and training are important factors for the future of the ESRF and synchrotron science in general. Indeed, the facility plays a unique role in the European and international context. The training given to its PhD students and Post-Doctoral fellows is of exceptional value to the other facilities that have the chance to hire some of the ESRF's former trainees. This is particularly true in accelerator and X-ray science. The high technology shared by apprentices during their training at the facility is also highly appreciated by industry when it comes to hiring new staff.

The development of the ESRF, outlined in this report, will maintain the facility at the forefront of research and this will make the training at the ESRF and by the ESRF even more indispensable than before, for the dissemination of the techniques it develops and of its expertise both in Europe and abroad. This was in the initial mission of the ESRF and it should remain so.

Training for future users of the facility is carried out in programmes such as HERCULES, which is unanimously well-appreciated. Some universities are also developing teaching programmes for the use of large-scale facilities and the participation of ESRF staff is highly praised.

Strategic recommendations

- The ESRF must continue to have a strong involvement in the education and training of young scientists and users and in the transmission of technical and scientific expertise developed at the facility for the science and technology community at large. This is of key importance to maintain acquired know-how in technical areas such as accelerator technologies and X-ray optics.
- The ESRF should continue, and strengthen, its PhD and Post-Doctoral programme, thereby contributing directly and indirectly to attracting young scientists and technologists to the area of synchrotron radiation science, for the benefit of all European facilities and for the overall advancement of the analysis of matter.
- High visibility should be given to this function in the ESRF's external and internal communication.
- Education in the use of the facility at the undergraduate level could be beneficial, along the lines used at DESY.
- Here also, partnerships with other institutions to broaden further the scope and to share the challenges and opportunities should be considered.

GENERAL STRATEGIC RECOMMENDATION

- **The working group is convinced that the progress of the ESRF can be pursued well beyond its current capabilities in order to remain world-leading in synchrotron radiation science for the foreseeable future. This can be achieved with the best value for money in the global context due to its accumulated expertise and its continuously upgraded equipment.**
- **The working group has identified several key issues that must be addressed to achieve this goal, in particular, the upgrading of the accelerators and sources to the new levels of brilliance that can be envisaged today. It therefore strongly recommends to the ESRF Council, to the SAC and to the Management to take the necessary steps in order to establish, in a timely manner, the technical challenges and the financial envelope required for its implementation.**
- **The ESRF must continue to play a central role in the development of synchrotron science in Europe and worldwide by developing new schemes of collaboration and associations with international partners, particularly X-FELs, other European sources and industry.**