Medium-Term Scientific Programme

for the period 2006 to 2010

ESRF

MEDIUM-TERM SCIENTIFIC PROGRAMME 2006-2010

1. Introduction

In accordance with § 11.2 of the ESRF statutes, “the Director General shall regularly submit to the Council…a medium-term scientific programme and financial and staff plan”.

Consequently Management presents at each fall meeting of the Council its perspectives for the further development of the radiation source and the scientific infrastructure. The present document, covering the period 2006 to 2010, is similar in its content and structure to those presented the previous two years. Updates have been made to the two main sections, the Machine and the Experimental Programmes, and the new refurbishment programmes have been included.

2. Machine Development and Refurbishment Programme

2.1. Insertion Devices and Beamline Front-Ends

The largest potential for increased brilliance in the near future is linked to the upgrade of insertion devices and their associated beamline front-ends. Over the next years, the 10-mm high and 5-m long aluminium chambers will continue to replace the existing 16-mm high ID chambers. To benefit from the smaller gap, a large number of existing magnet arrays will be replaced by arrays with shorter periods.

New in-vacuum undulators as well as revolver structures will be built and installed. A revolver structure can accommodate two sets of undulator magnet arrays. One of them will typically be a fully tuneable undulator, the other one will be optimised for a specific photon energy range with 2 to 3 times larger brilliance and flux than available at the tuneable undulator.

An upgrade of the insertion device beamline front-ends has become necessary in order to handle the heat load from the simultaneous operation of three in-air undulator segments or two in-vacuum undulators at the present current of 200 mA and up to 300 mA in the near future. The front-end upgrade started in 2001 and will continue over the next years at the rhythm of 4 front-ends per year. In addition, some of the ion pumps, ion pump controllers, gauges and cabling will need to be replaced.

The estimated cost is 6.0 M€.

2.2. LINAC, Injection/Extraction and RF (radio frequency)

It is expected that over the next five years, a new electron gun will be developed and put in operation on the linac. Several 40 kV as well as klystron focusing power supplies will be purchased. The control will need to be upgraded and new diagnostics will be developed. A number of pulsed power supplies in use for the kicker will be refurbished.

Concerning the RF transmitters, the major cost is expected to be the purchase of a 352 MHz cw klystron, a new circulator load, a few arc detectors and the replacement of ancillary power supplies on the transmitters.

There is at present some uncertainty concerning the long-term availability of 352 MHz 1.3 MW klystrons. Those klystrons were heavily used on the LEP ring at CERN, and because they were the only type available at this power level and commercially available from three companies in the world, ESRF and APS have both selected this type of klystron. All other synchrotron labs are using 500 MHz klystrons. In 2000 the LEP was shut down and as a result two of the companies manufacturing these high-power klystrons have stopped this activity, thus leaving the third one, the company Thales, in a monopoly situation. All light sources are facing this difficulty and many intermediate-energy light sources have started to develop alternative solutions either based on Inductive Output Tubes (IOT) [ELETTRA and Diamond] or Solid-state amplifiers [SOLEIL]. These new solutions are being developed to replace the 200-300 kW medium energy klystrons and their technical and economical applicability at the level of 1.3 MW is still unknown. The ESRF is watching this evolution very carefully. It may need to adapt to the rapidly changing industrial world and possibly invest in a new technology of high-power RF sources in the event that the present type of klystrons could no longer be delivered by industry.

The estimated cost is 2.0 M€.

2.3. Vacuum Chambers, Pumps and Gauges

A number of additional 10-mm gap insertion device vacuum chambers made of aluminium will be purchased. Following the water leak experienced on the cell-15 crotch absorber, investigations have shown that all normal crotches will develop the same corrosion and it has been decided to change all crotch absorbers. A series manufacture is being initiated and it is expected that all crotches will be replaced within 2-3 years from now. Another corrosion problem has been identified since 1994 on the quadrupole chambers. A new design of such chambers has been initiated in recent years and fully tested. It is estimated that quadrupole chambers for three cells will need to be manufactured over the next five years to replace leaking chambers. Two additional bending magnet chambers with increased slot aperture will be manufactured in order to allow a 10-mm-gap operation of the helical undulators. A number of ion pumps, ion pump power supplies, programmable logic controllers, temperature controllers, gauges, gauge controllers and metal valves will need to be replaced.

The estimated cost is 4.0 M€.

2.4. Control, Power Supplies and Diagnostics

The replacement of VMEs by Compact PCI system will continue whenever it is economical. For the resulting VMEs, an upgrade of the processors will be made as well as a mutation from the outdated operating system OS9 to Linux. The bandwidth of the network will be further increased to accommodate the larger number of controllers and PLCs directly connected to Ethernet.

The AC power supplies driving the booster use GTOs (Gate Turn-Off), of a type which is no longer available worldwide. Spares have been acquired, but a study followed by a series production will be initiated in order to replace the GTOs with more modern components such as Isolated Gate Polar Transistors.

In view of the aging of the system as well as the recurrent damage of the diesel engines, a major upgrade of the HQPS system is envisaged that would eliminate the need for diesel engines and clutch, and allow the operation of the ring to a higher current.

The estimated cost is 4.0 M€.

2.5. Machine Infrastructure

The machine infrastructure is now thirteen years old and will need refurbishment over the next few years. These measures include:

- Compressed air production refurbishment
- Replacement of SRE (deionised water circuit) exchangers
- Installation of new cable trays in the technical gallery and the buildings MTBN, MTBS, SRDC and SRRF
- Refurbishment of the control cabinets for the tunnel air conditioning system, the tunnel lighting, and the tunnel electrical distribution
- Refurbishment of the Heating/Ventilation/Air-Conditioning and its associated remote building management system
- Continuation of the replacement of 1400 valves in the SRE network
- Installation of an additional high voltage distribution
- To allow a further development of the ID06 beamline, the laboratory space for the beamline Front-End group will need to be re-allocated in a new building to be built inside the ring next to the technical gallery.

The estimated cost is 2.6 M€.

2.6. Special Projects

2.6.1. Cryogenic Undulators

The latest developments concerning superconducting undulators have shown that this technology could extend the undulator spectrum towards higher energies, beyond what is presently achievable from in-vacuum permanent magnet undulators. Nevertheless there are still a number of technical difficulties to be solved.

A research and development project for the design and industrial procurement of a superconducting undulator is part of the I3 Consortium of Synchrotron Radiation Sources and Free Electron Lasers presently supported by the EU FP6. This undulator is to be tested under beam in the ID06 straight section.

Another option to increase the performances of an undulator consists in cooling the magnets of an in-vacuum permanent magnet undulator to 120 K where the NdFeB material presents a higher remanence as well as higher coercivity. It is planned to convert an existing permanent magnet undulator into a cryogenic undulator and develop the associated field measurement instrumentation.

The total estimated cost is 2.0 M€.

2.6.2. HOM Damped RF Cavity

The development of storage ring RF cavities takes a lot of time. Very few of the recently built synchrotron radiation facilities have developed their own cavities, most of them have rather adopted an existing design. Following the tests made on the SOLEIL cavity at the ESRF, it appears that such a cavity is not optimised for a future current upgrade (up to 500 mA) of the ESRF because it has a single coupler limited to 200 kW and occupies a whole straight section. The damping of Higher Order Modes (HOM) is certainly very efficient but somewhat over-designed for the ESRF needs at 500 mA. For comparison, the present cavities (based on the LEP-CERN design) have two power couplers and as a result a power of 640 kW can be fed into the cavity per straight section, which corresponds to about 450 kW to the electron beam (to be compared with the 200 kW of the SOLEIL type cavity).

As a result, in collaboration with BESSY and ALBA, the RF group is presently looking at alternative solutions based on a sequence of single cell cylindrical cavities equipped with HOM dampers. A detailed numerical study has been launched and a prototype will be built in the year to come.

The design and construction of a prototype of such a cavity is presently estimated at around 1.5 - 2 M€.

3. Refurbishment and Development of beamlines and instrumentation

The general ideas contained in the detailed Medium-Term Scientific Plan presented in November 2002 are reflected in the continuous refurbishment of the large portfolio of ESRF beamlines and the new scientific exploitations that are made possible:

- By adding new end-stations on existing beamlines, and by full refurbishment of beamlines operating since ten years. This includes: 1) Completion of ID27 – the new High Pressure Beamline, 2) Start of the refurbishment of the Surface Scattering beamline ID03, 3) Continuation of the refurbishment of the Material Science beamline ID11 and of the Microfocusing Beamline ID13, including their lengthening outside of the Experimental Hall for improved focusing capabilities, and 4) By refurbishment of ID26, which is being equipped with a high flux high throughput Resonant Raman Scattering setup for chemical analysis.
- By improving the beamline optics, sample environment, detector and data analysis capabilities to keep up with the source improvement and with the developments in beamline instrumentation.
- By the realisation of a new beamline complex for high heat load tests and experiments under pulsed high magnetic fields on ID06.

In the context of the refurbishment programme, a new Multilayer Laboratory is being constructed and will become operational in 2007/2008. New detector programs are being launched, among which are pixel detectors, a new generation of FReLoN cameras using four times larger CCD chips, a new gas-filled detector development in collaboration with ALBA – the Spanish Synchrotron Facility, and the development of an Avalanche Photo Diode array, which is being considered as a common project together with other synchrotron facilities as HASYLAB, APS and Spring8.

The ESRF beamlines, supported by their individual scientific case and thoroughly reviewed every five years, are highly specialized in their range of scientific application and technical performances. Each one reflects the specific requests of their user community. In accordance with Council and SAC recommendations, the ESRF Management is engaged in the vigorous programme outlined below to keep ESRF beamlines at forefront performances and attractive to the user community.

3.1. Optimal use of Beam Intensity

The performance of the ESRF radiation source considerably exceeds initial specifications. Most importantly, the total current may soon be by a factor of three higher than originally planned and the undulator gaps can already be reduced to 6 mm, a factor of three lower than originally planned. The two effects combined generate an increase of beam intensity that, around 10 keV, can reach a factor of thirty. As an immediate consequence, basic components have to be upgraded, such as increased lead shielding in experimental hutches, front-ends and vacuum isolation (diamond windows) between beamlines and machine, primary slits, beam attenuators and filtering systems, beam monitoring, beam shutters, and in a certain number of cases new high heat load monochromators etc. Only a few beamlines are capable of operating with maximum brilliance. A refurbishment programme of almost all the other undulator beamlines is underway, and should be completed within the next four years. A rough cost estimate is of the order of 300 k€ per beamline (the technical choices must always be adapted to the specificity of the beamline).

On approximately 50% of the beamlines other basic components (such as a liquid nitrogen cooled crystal monochromator) have already been upgraded, but further beamlines (approximately seven) are on the waiting list. This upgrade (monochromator and liquid nitrogen cooling system) costs 500 k€ per beamline and is also planned to take place during the next four years.

New and improved monochromators are planned for the 2006/2007 period on ID20, ID32, ID03 and ID06. A similar refurbishment activity is going on for beamlines using diamond monochromators, and will benefit from recent results on highly perfect diamond crystals, which are becoming available in lateral dimensions exceeding few mm. This is the outcome of collaboration between ESRF, other synchrotron facilities, academic institutions (University of Witwatersrand) and industry (Element6).

An investment of ~12 M€ over five years will be required to upgrade beamlines in order to fully benefit from the available beam intensity.

3.2. *Beam Focusing, X-ray Optics, and Sample Environment Issues*

3.2.1. Background

In the Foundation Phase Report it was expected that a "micro-focusing beamline" could deliver a beam size of ~30 µm, and that most beamlines would operate a beam of about ~1 mm dimension. Today, the "micro-focusing beamlines" deliver X-ray beams of less than 100 nm size. A "standard beamline" operates routinely with sub-millimetre beam-sizes. The pressure from scientists and users to have routine beams of 10 µm at less (down to 1 µm) is enormous. The reasons for this are multiple:

a) Small crystals (protein crystals, novel materials, nano-structures, quantum confined structures);

b) Exotic thermodynamic conditions:
   - Pressures up to 3 Mbar (diamond anvil cells to reach earth inner core pressure),
   - Temperatures up to 5000 K (laser heating to reach earth inner core temperatures) and down to sub-Kelvin,
   - Magnetic dc fields up to 10 T and maybe higher,

   and combinations of such conditions;

c) Advanced techniques:
   - Coherent X-ray spectroscopy (requiring small or "pin-hole" beams),
   - Combinations of imaging techniques with X-ray scattering and absorption techniques (see Medium-Term Scientific Plan 2002-2007) to develop new X-ray methodologies, and their application to diverse scientific programmes.

These points have major consequences on beamlines, some of which are highly specific to the particular beamline programme, while others are of a more general nature. Among these some general issues associated with i) Optics, ii) Beamline Set-ups, iii) Sample Environment and iv) Sample Manipulation are further developed in the following paragraphs.

3.2.2. Optics

The ESRF Optics Group, in collaboration with the ESRF scientists and the ESRF users, has set important standards in X-ray reflective, refractive and crystal optics. Among the large number of effective solutions compatible with the many requirements of a performing X-ray beamline, there are two particularly crucial achievements: Kirkpatrick-Baez (KB) micro-focusing systems based on multilayer mirrors, and compound refractive lenses. These developments provide solutions adapted to the requests of beamlines to obtain optimal performances at specific energies – spanning from 0.3 keV to 300 keV (four decades) – compatible with the geometrical constraints of very diversified set-ups.

During 2005 an internal nanofocusing board comprised of ESRF scientists and engineers was created. The board had as its mission to assess present and future needs on a five-year timescale for issues to be addressed for the development of focussed beams of a size below 1 µm. The aim is to create a programme harmonizing R&D on X-ray optics projects that will benefit from developments carried out at the ESRF and elsewhere. One of the first projects is the realisation of a pilot nano-tomography station on ID22. The estimated cost is 2 M€.

A typical solution successfully used on many ESRF beamlines is based on a KB and/or a refractive lens system (typically for beam collimation at the front-end): its cost varies from 200 to 500 k€ per beamline, even though the multilayer mirrors are fabricated by the ESRF multilayer deposition laboratory. The increasing demand for such multilayers has motivated the construction of the new Multilayer Laboratory, which will become fully operational in 2007/2008. The level of activity of the new Multilayer Laboratory will be intense (similar to that of the crystal-cutting and polishing laboratory) to provide with increased throughput devices more perfect and of larger dimensions than those available today worldwide.

The budgetary consequences of this situation are that approximately 1.5 M€/year have already been allocated to micro-focusing devices delivered to beamlines. A major refurbishment of both the multilayer deposition laboratory and of the associated metrology laboratory, where a new long-trace profile-meter is necessary (as mentioned in the previous MTSP), has been started in 2004. A new laboratory and office building has been constructed to house the new multilayer deposition laboratory. The deposition system has been ordered and will be delivered in 2006. The upgrade of the metrology laboratory is planned for the 2006/2007 period. This programme is estimated at ~2.5 M€ over the next three years.

Other optical devices such as wave-guides and zone-plates are increasingly exploited at the ESRF. They are not fabricated at the ESRF, but the ESRF is involved in their design with external academic and industrial partners, and with other synchrotron radiation facilities. Investments on these items are planned for the next five years at the level of ~2 M€, considering also the infrastructure necessary for the characterization and exploitation of these devices.

Finally, the operation of the crystal fabrication, cutting, polishing and etching facility, the maintenance of its machines and the purchase of crystals, mostly float-zone silicon and germanium ingots, sum up to a yearly cost ~250 k€ for this laboratory.

The total costs over 5 years to upgrade optics in order to fully benefit from micro-focusing are estimated at ~13 M€, including the nano-tomography pilot station.

3.2.3. Long beamlines

The development of micro-focusing devices is obviously in line with the present worldwide efforts towards nano-sciences and nano-technologies. Schemes to obtain 100 to 10 nm beam-sizes imply demagnification ratios of the source down to 1:1000 or even 1:10 000. This is possible thanks to collimation procedures and high-quality optical devices (multilayers, lenses…) of moderate sizes. However, in order to overcome optical aberrations and to keep the distance between the optical device and the sample to acceptable levels (0.1 to 1 m minimum) the ideal beamline length should be 1 km. On the average, ESRF beamlines are typically 50 m long, and only two of them reach a length of ~150 m. In the future we see a scientific interest in several beamlines of at least 100 m length. As a pilot project we have started the extension to about 100 m of ID11, the Material Science beamline housing the 3D-Microscope, and ID13, the Microfocus Beamline. Both beamlines should acquire routine operation capability with *nano*-sized X-ray beams, which implies a major refurbishment of the hutches and optics. This upgrade programme was started in 2005 and we hope to complete it for 2007/2008. Other beamlines are also being considered for routine enhanced focusing capabilities. In addition, we shall explore the possibility of constructing very long beamlines (we have the physical space to extend a few beamlines to 300-600 m).

We estimate that ~10 M€ over five years is needed for the development of long beamlines, in order to fully benefit from micro-focusing.

3.2.4. Sample Environment

During its construction phase, due to manpower and budgetary constraints, the ESRF did not make a structured planning of sample environment-related issues; the actions were left to the initiative of the scientists in charge of the various beamlines. For several years, increased user demand and the individual character of almost all beamlines are highlighting the need to invest in highly sophisticated sample environment items on an increasingly standard basis. This is the reason why the ESRF in 2003 created a sample environment laboratory with five staff, to interact and coordinate efforts across beamline groups on sample issues involving high-pressure, high- and low-temperatures, high-magnetic and electric fields, and a combination of these parameters. The sample environment laboratory is now fully operational and is contributing to many challenging user projects on ESRF beamlines.

These projects are increasingly in demand, not only on diffraction beamlines but also on spectroscopy, inelastic and coherent-scattering beamlines. This again is strongly related to the micro-focusing capabilities, since the possibility of having the whole X-ray intensity concentrated in a few μm^3 volume allows samples to be studied in thermodynamic conditions that are impossible to be reached in larger volumes. Large investments are currently being made on these items; they often involve significant purchases within the In-House Research budget, for the future benefit of the general ESRF users. Typically we are devoting 2 M€/year directly related to sample environment issues.

We plan to invest ~10 M€ over five years on sample environment issues to fully benefit from micro-focusing to study small samples in very exotic thermodynamic conditions.

3.2.5. Sample Manipulation

Another very important development area, often neglected in present discussions on nano-science and nano-technologies, is the positioning of micro-and nano-samples in the X-ray beam and their vibration isolation from the surrounding environment. Therefore, the ESRF has launched the design of active vibration-isolation tables. Various high-tech industrial companies are investigating piezo-based micro-manipulators for micro- and nano-positioning. The budgetary consequences depend on the level at which the ESRF engages itself in this endeavour. Collaboration with other synchrotron centres, universities, research institutions and industry will be sought, as well as from local authorities and the European Union. Nevertheless the ESRF itself must commit its own resources to positioning techniques, which are crucial for the success of any experiment exploiting micro- and nano-imaging capabilities.

At present, ESRF is actively investigating a long-term collaboration with MINATEC in nano-imaging and nano-manipulation. MINATEC is a newly created micro- and nano-technology park in the Grenoble area where academic institutions, basic research laboratories and microelectronics development units associate their interests in nano-technology. Among the characterisation tools required by this development, Synchrotron Radiation plays an important role in associating spectroscopic capabilities with imaging at nanoscale. ESRF and MINATEC are considering a common nano-characterisation laboratory on the ESRF premises and the development of an Infrared Scanning Near Field Optical Microscope (IR SNOM) on ID21 together with an X-ray Photoelectron Microscope (X-PEEM) on ID03. These new facilities will open new research opportunities to the ESRF users.

We expect to invest ~8 M€ over five years to develop micro- and nano-positioning capabilities for samples, and active vibration-compensation systems.

3.2.6. Focussing, Optics, Sample Environment (Summary)

In summary, the success of the ESRF programme in the growing areas of nano-science and nano-technologies will be strongly related to a structured programme of developments in X-ray optics, beamline development, the conception and realization of new sample environments, and sample manipulations capable of exploiting X-ray beams with micron to 10 nano-meter dimensions.

We expect that, in the coming five years, the ESRF will need to invest approximately 41 M€ in these crucial areas.

3.3. Beamline Automation

The increased use of ESRF X-rays as an analytical tool for state-of-the-art experiments has developed into almost "routine" protocols. A typical example is provided by the macromolecular beamlines, where many experiments are repetitive, i.e. follow a very similar protocol for different crystals of macromolecules. These crystals are increasingly small (often less than 100 µm sizes), must be at cryogenic temperatures, and, to minimize radiation damage, they must be in the beam for as short a time as possible – for alignment and to collect data. These operations, if performed manually, require times longer than the actual experiment and are often subject to human error. To use beam time more efficiently, beamline automation programmes have been started worldwide: these imply smart protocols, careful beam positioning and the use of intensity-monitoring systems to drive the protocols, automatic sample exchange and alignment procedures. These programmes are already at an advanced stage at the ESRF. They are one of the unique features of the new and refurbished protein crystallography beamlines (seven stations, including the new PSB beamline ID23). We plan to continue to automize the MX beamlines over the next years and to export the technical and software developments to other beamlines, particularly the high-energy materials science and imaging beamlines such as ID11, ID31, ID15, ID19 and ID22. The newly developed automisation procedures are being considered to be standardized to internationally recognized standards (as ISO 9000).

We expect to invest ~5 M€ over five years for beamline automation programmes.

3.4. Detectors

Detector development has always evolved at a slower pace than source and optics developments. The ESRF has followed closely new technical developments that could promote new and better performing X-ray detectors. Today's challenge is the development of large-area, high-efficiency, high-count-rate X-ray detectors. Furthermore, fast silicon-based detectors, and gas detectors for space (100 µm) and time-resolved (10 µs) experiments are increasingly in demand. In this area, very large investments are necessary, requiring budgets that are well above any one Institute's resources. As a consequence, worldwide collaborations are underway on different detector projects. Examples of collaborations involving the ESRF include:

i) PIXEL Detector: This challenging project involves the construction of a large-area pixel detector and will have an impact on almost all X-ray beamlines. The ESRF is actively involved, in collaboration with many other institutes interested in this development, which is not at all limited to synchrotron radiation based applications, but also extends to the medical world and to the high-energy physics community.

ii) Avalanche photodiodes and advanced electronics: these are presently being developed at the ESRF, in a collaboration involving other European and American synchrotron centres.

iii) Space and time-resolved gas-filled detectors: currently under development for muscle diffraction and other applications in soft-condensed matter research, notably in collaboration with the Daresbury and the new Spanish synchrotron laboratories.

These crucial developments, together with the increasing demand from the beamlines for better detectors, particularly for large-area detectors, have imposed a spending profile for detector purchases and developments at the ESRF of approximately 1.5 M€/year for the last few years. We do not expect this demand to decrease during the next five years.

We plan to invest ~10 M€ over five years to purchase and continue to develop improved detectors for the ESRF beamlines.

3.5. Data acquisition, visualisation, analysis, transfer and storage

The exploitation of micro-beams, used for imaging, including micro-tomography in all its forms, diffraction (e.g. macromolecular crystallography, powder diffraction and diffraction in materials science, chemistry), time-resolved experiments (diffraction, small-angle scattering from muscles, etc.) is possible thanks to the increasing availability of efficient large-area detectors.

One consequence is that currently new detectors on certain ESRF beamlines are producing a quantity of data of the order of Terabytes/day. This poses increasing problems for cost-and time-effective procedures for data acquisition, visualization, analysis, transfer and storage. Computers and storage devices have to be continuously upgraded, and considerable efforts must also be made on "smart" software developments and hardware and network architectures.

The ESRF is spending approximately 1 M€/year on the upgrade of beamline computer systems; and we do not expect this number to decrease during the next five years.

Presently the ESRF is considering a critical review of its data handling and storing capabilities to reach a comprehensive spending plan for the next 5-10 years in this area.

We expect to invest ~5 M€ over the next five years to purchase and continue to develop improved data acquisition, visualisation, analysis, transfer and storage on the ESRF beamlines.

3.6. Beamline Control System

The ESRF beamlines are operated on the basis of VME technology and the VME crates are run by the OS9 operating system. This has been a very reliable and effective choice, which is still performing very well for some beamlines. However, this system is becoming obsolete after approximately 20 years since its initial conception: the OS9 is no longer supported and new VME-based card developments have also been almost completely abandoned. The new network-based, multi-task, multi-user, remote log-on demands and applications already pose serious problems on certain beamlines. The ESRF is working on a renovation of the control systems of both beamlines and machine, where the VME will be retained as a viable option in the new PCI based technology.

This strategy offers a solution to those high-throughput beamlines for which the present system is obsolete, and matches budgetary constraints. A beamline upgrade to a new control system is strongly beamline-dependent but an average investment of approximately 0.2 M€ per beamline is likely to be needed. The control systems of ID31 and ID23 have been implemented and proven that the concepts of the new control system are successful.

Considering that we plan to renew the control system of approximately three beamlines per year, we expect an investment of ~3 M€ over the next five years.

3.7. New projects

The full exploitation of the beam intensity and stability available today – expected to improve further in the near future thanks to increased ring current and the development of new insertion devices – already impose financial resources that go beyond the funding level presently available. Consequently, the ESRF must seek resources also from other sources: new Associate Members, industrial income, collaborations, EU funding, etc.

However, besides the upgrade, refurbishment, and the development programmes outlined above, there are also important new projects lined up in our MTSP. Their scientific value has been recognized, but they cannot be pursued actively at present due to the lack of human and financial resources. Management is seeking alternative resources (e.g. EU funding). Specific projects in this category are:

a) Pulsed High-Magnetic Field project;
b) High-energy photoemission project;
c) Time-resolved and pump-and-probe experiments on scattering and spectroscopy beamlines;
d) Micro-fluidics.

4. Summary

This paper indicates how Management intends to continue to improve the performances of the ESRF radiation source and the beamlines in order to maintain the ESRF at the forefront of what is technically and scientifically achievable. At the same time the budget that the ESRF would need over the next five years for this task is estimated.

All the items outlined above reflect projects presented or announced in the previous Medium-Term **Scientific** Plans. However, the present Medium-Term **Financial** Estimates cannot support all planned projects, notably those discussed briefly in paragraphs 3.4 and 3.7.

In summary, for the next five years the Machine programme would require a budget for refurbishment and capital investments of approximately 22 M€ (i.e. 4.4 M€/year) while the corresponding budget for the Beamlines and Experiments programme is estimated at 76 M€, corresponding to approximately 15.2 M€/year.