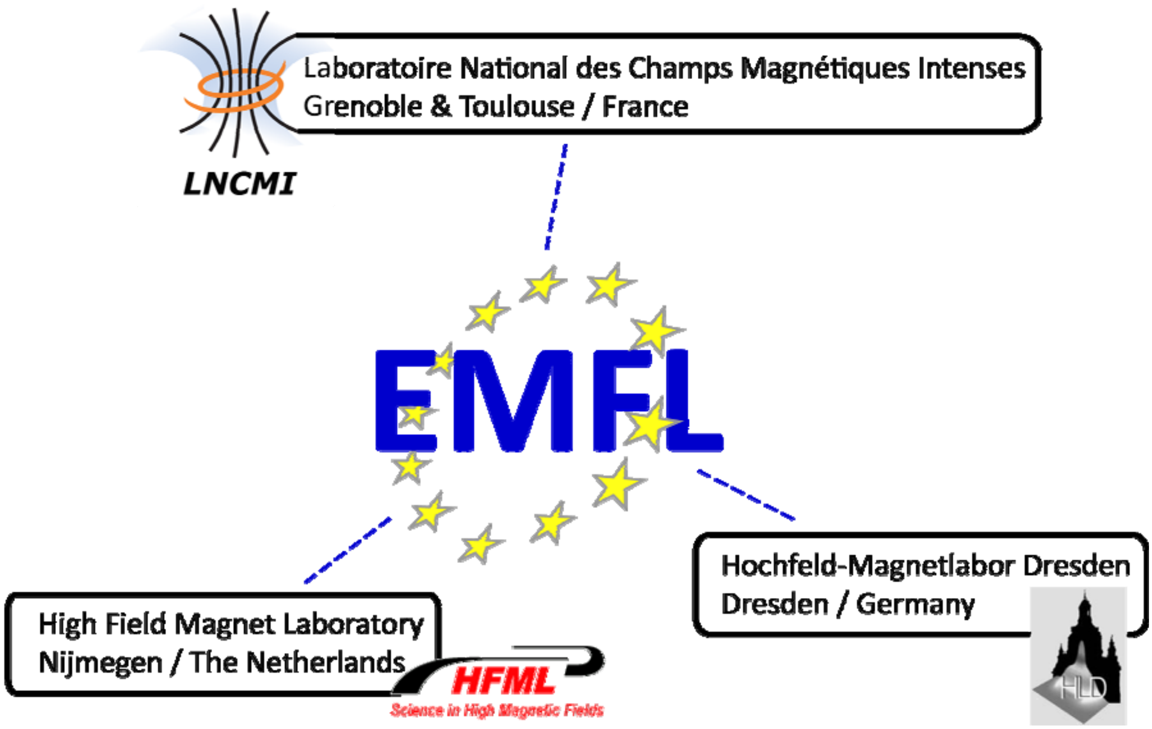
Proposal for the creation of a distributed European Magnetic Field Laboratory



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Research in high magnetic fields

Introduction

High magnetic fields are one of the most powerful tools available to scientists for the *study,* the *modification* and the *control* of the state of matter. Europe has always played the leading role in the development and application of high magnetic fields, both static and pulsed. In the 20th century, the research in this domain has been an extraordinary asset allowing many new discoveries of primary interest both for their scientific and their technological impacts, and in total 14 Nobel prizes in physics, chemistry and medicine have been attributed to research related to magnetic fields.

The basic reason lies in the unique property of the magnetic field to act universally on the charge and the spin of particles like electrons, protons and neutrons, i.e. it constitutes one of the few fundamental thermodynamic parameters (like temperature) which changes the state of matter in a controlled way. Magnetic fields are particularly interesting since the induced changes are almost without exception reversible since magnetic fields basically do not add kinetic energy to the system. Since these spin and orbital degrees of freedom control most of the electronic and magnetic properties of matter, it is natural to use the magnetic field to investigate and/or modify these properties. The modification very often leads to phase transitions, which represent a large fraction of the activities at the research facilities dedicated to high magnetic fields. In general, the higher the field, the more clearly the changes of states are observed or the larger the number of observed transitions to new fundamental states of matter becoming visible. Magnetic fields constitute a transverse technology which is useful in a very wide range of applications and of interest of a very wide user community. Commercially available magnets are often not sufficient; many of the pioneering discoveries are quite often made in the highest available magnetic fields at dedicated facilities. Therefore there is a continuous drive towards higher magnetic fields, despite the severe technological challenges and the increasing costs.

Superconducting magnets are currently limited to fields just above 20 Tesla, and their progress to higher fields is very slow and extremely costly. The maximum field achieved with superconducting magnets has hardly increased in the past twenty years. For higher fields, resistive magnets or mixed resistive/superconducting magnet, called hybrids are the only possibility, reaching nowadays 45 Tesla in continuous mode and 89 Tesla in pulsed mode. Progress in resistive high magnetic fields was more rapid than with superconductors. The increase in maximum fields achieved over the last 20 years with hybrids (31T to 45T), resistive magnets (25T to 35T) and pulsed magnets (60T to 90T) is much faster than the slow advance of superconducting technology (20 T to 23 T). Generating high magnetic fields with non-superconducting magnets requires injecting large electrical powers into coils, containing the resulting huge Lorentz forces and cooling away the dissipated power. In order to reach such very high fields, these coils are operated very close to their mechanical and thermal limits. Designing, building and operating such magnets requires very specialized knowledge and experience that is not industrially available, together with dedicated extremely high electrical power supplies and cooling capacities. Generating state of the art high magnetic fields can therefore nowadays only be done with dedicated large facilities.

State of the art

Europe has currently four mid-scale infrastructures that have the necessary installations, knowledge and manpower to operate resistive static and pulsed fields; the Laboratoire National des Champs Magnétiques Intenses (Grenoble static fields, and Toulouse pulsed fields), the Hochfeld-Magnetlabor Dresden (pulsed fields) and the High Field Magnet Laboratory (Nijmegen, static fields). All these laboratories are involved both in science (in house research and as user facility) and magnet technology. In Japan, the situation is similar, with several mid-scale installations all over the country although there these installations put more emphasis on materials research and less on general user operation. However, the state of the art in high field science and technology is dictated by the United States' National High Magnetic Field Laboratory (NHMFL, on three sites: Tallahassee (FL), Gainesville (FL) and Los Alamos (NM)). This national facility surpasses largely the manpower and budget of Europe's four high field facilities put together.

In order for Europe to remain competitive, it is urgently necessary to reinforce and coordinate Europe's high field activities to an effective size comparable to that of the NHMFL. Conscious of this necessity, the four laboratories mentioned above have started to collaborate within several FP6 projects, and have recently concluded a formal agreement of collaboration.

Implementation of an even more structured collaboration between them is currently hampered by the particular constraints that the different national and local funding agencies of these laboratories impose, and by the lack of financial means to do so.

Position of the EC

The four user facilities behind the EMFL proposal have collaborated in the FP6-I3 EuroMagNET and are collaborating in the FP7-IA EuroMagNETII. The latter project was selected for EC funding, with the condition that the partners should set out to develop a lasting structure and sustainable integration and that a stronger commitment of the public authorities should lead to a growing independence of EC funding. The EC service responsible for research infrastructures (DGXII) has announced that existing Integrating Activities will no longer be eligible for continued funding and that it will give preference to the funding of new IAs. This implies that starting from 2013, the four facilities will no longer receive funding to open their installations to non-national users.

Executive summary

It is therefore proposed to create the European Magnetic Field Laboratory (EMFL) consisting of the four existing high field facilities (LNCMI-G, LNCMI-T, HLD, HFML) which, with additional means, should operate as a distributed European research infrastructure.

EMFL missions

The missions of the EMFL will be:

1) to develop, construct and operate world class high field magnets.

2) to do world class in-house scientific research in very high magnetic fields

3) to act as a European user facility, for the scientists of the participating countries, and for other scientists through European Transnational Access support.

4) to act as the European centre of excellence for different magnetic field based material characterisation techniques in very high fields, like NMR, EPR and ICR.

5) to act as a European magnetic field production expertise centre for the development of applications of materials and techniques related to very high magnetic fields. In this role special magnets may be developed for other parties.

Requirements

In order to realize theses missions, the EMFL will need:

1) a formal structure that would allow to distribute and coordinate the technological and scientific activities of the partners and that can represent the EMFL politically.

2) supplementary financial and human resources to bring Europe's high field activities to a level that is competitive with that in the United States and that will guarantee Europe to play in the future an important role in this domain.

Partners

Currently the EMFL initiative is actively supported by the Centre National de la Recherche Scientifique (France), the Forschungszentrum Dresden (Germany) and the Radboud University (Nijmegen, the Netherlands), being the operators of Europe's major high field facilities. The project is however open to participation by all European countries and research organisations interested in using high magnetic fields for research. The exact organisational form of the EMFL, that still remains to be decided (see below) will explicitly allow for the adhesion of additional partners at any phase of the project. All forms of participation are open for negotiation, like buying access quota or stationing staff at the four facilities.

ESFRI Roadmap project 'EMFL'

Introduction

The basic motivation behind the creation of the European Magnetic Field Laboratory is to provide European researchers with the same possibilities for research in high magnetic fields as their colleagues in the United States, where a world leading multi-site national laboratory covers all aspects of high magnetic field research. This ambition can be realized by collaboration, coordination and reinforcement of the four existing mid-scale European high field facilities within one distributed European high field infrastructure, the EMFL.

Basic structure

1) The EMFL must be a legal entity, preferably by European law, able to apply for and receive funding, to own equipment and buildings and to hire temporary staff.
2) The EMFL should be created, owned and funded by partners from several European countries, for a certain contract period (e.g. 10 years) which can be renewed. It should be overseen by a Governing Council in which all the partners are represented, weighted to their contribution.
3) The EMFL should have one Executive Board, responsible for the everyday operation of all the member facilities.
4) Scientific access to the EMFL installations will be decided by an independent external Selection Committee on the basis of proposals.

Legal form

The exact legal and administrative form of the EMFL, compatible with the above requirements, has not yet been established. Possible forms under consideration are a European Cooperative Society (SCE) or a European Economic Interest Grouping (EEIG). The EC has recently created a special legal structure for European research infrastructures (ERIC) that will be considered for the EMFL.

Executive board

The EMFL Executive Board will consist of the facility directors and one of them will act as the EMFL Executive Director, on a rotation basis. The Executive Board will discuss past performance and future plans with the Governing Council on a yearly basis. Furthermore it will be seconded by an external Scientific Council and a User Council.

The EMFL Executive Board will have the everyday control over

- all human and financial resources related to the magnet design and construction activities of the EMFL
- the production of the magnetic field access units of the EMFL installations (magnet hours for DC installations, magnet pulses for pulsed installations)
- a given contingent of scientific and technical staff and the necessary financial resources to assure the hosting of external users and the development of scientific instrumentation
- all resources attributed to the EMFL by third parties

Financial aspects

Large investments have been made recently in the new high field installations in Wuhan (pulsed fields) and Heifei (static fields) in China, and in the upgrade of the pulsed field installation in Kashiwa (Japan). Large investments are also being planned for the NHMFL in the USA. The European facilities do not have the financial means to maintain their international competitively, both in terms of investments and operating budget. In order to remedy this, the following reinforcements of the European high field infrastructures are proposed, for a total investment cost of 120 M€

- Upgrade of the Grenoble installation to 40 MW. Estimated costs: 40 M€
- Construction of a 50 T hybrid magnet. Estimated cost: 25 M€
- Construction of a 40 T low vibration hybrid magnet. Estimated cost 20 M€
- Upgrade of the Nijmegen site (improve cooling power). Estimated cost 5 M€
- Upgrade of the Dresden site (increase energy, additional magnet cells). Estimated cost 15 M€
- Upgrade of the Toulouse site (mobile generator modules, building extension). Estimated cost 15 M€

In addition to these investments, an increase in manpower and operating budget of the four sites is necessary. In total around 50 additional positions and 8 M€ additional annual budget are requested. These reinforcements will bring the EMFL approximately to par with the NHMFL and will guarantee that Europe can recover the leading role in high magnetic field research.

ESFRI Roadmap Update proposal

Whereas the upgrade plans for ESRF and ILL, in which the creation of a high field facility on the ESRF/ILL site has a prominent position, have recently been elaborated in the FP7 Design study ESRFUp (end date April 2009) the plans for the creation of the EMFL are not yet as advanced. The EMFL proposal has been integrated into the ESRFI Roadmap Update by the end of 2008. A FP7-Infrastructures-Preparatory Phase Project Call for Proposals, dating 30th of July 2009, dedicated to the new Roadmap Update proposals, will be used to submit a proposal for the elaboration of all legal, administrative, financial and technical issues related to the creation and operation of the EMFL. This proposal is currently being written by CNRS, FZD and RU and has a deadline of 3rd of December 2009.

Neutron and X-ray scattering in high magnetic fields

Grenoble is the only place in the world where an advanced neutron source, a synchrotron and a high magnetic field facility are in close proximity. In the context of their upgrade programs, ILL and ESRF are currently considering the creation of a joint high magnetic field facility that would allow for X ray and neutron scattering experiments in 30+ T fields. The technical feasibility of such an installation has been established in the context of the ESRFup Design Study, but the decision whether to realize it will be taken in 2010/2011.

The directors of ILL and ESRF fully support the creation of the EMFL as described above, and consider it to be an essential partner in the realization of the new high field facility on the ILL/ESRF site. After ample discussion with the ILL and ESRF directions, two possible organisation forms, which already exist on the ILL/ESRF site, seem suitable to all parties for a joint EMFL-ESRF-ILL high field project:

1) *The Collaborating Research Group (CRG).*

The ILL provides a framework in which CRGs can build and manage instruments on ILL beam lines to carry out their own research programs. CRGs are composed of scientists from one or more external research organizations, and often multinational, carrying out a joint research program centered on a specific instrument. CRGs build and manage their own private instruments on ILL beam lines to carry out their own research programs. They enjoy exclusive access to these instruments for at least half of the beam time available. The remainder is reserved for the ILL or external use.

The CRGs provide their own scientific and technical support and cover the general operating costs of these instruments. If there is demand from the user community and the resources are available, the beam time reserved for ILL can be made accessible to users via the subcommittees.

At the ESRF, experiments can benefit from the use of the radiation generated by the bending magnets (BM) in the storage ring. These sources, although less intense than the insertion device (ID) sources, can, with appropriate focusing optics, produce very useful x-ray intensities. These BM sites are operated by CRGs. The ESRF provides x-rays free of charge to the CRG beam lines in return for use of the instrumentation on them, for 1/3 of the scheduled beam time. It should be noted that the lower BM X ray fluxes as compared to ID X ray fluxes would result in longer measurement times, which for high field experiments results in correspondingly higher costs because of electrical power consumption.

The CRG option for the EMFL has the very attractive feature to be able to run the entire high magnetic field science program within the same Institute, with obvious advantages from a scientific, operational and budgetary point of view. The disadvantage would be the BM position at the ESRF, and the need for the EMFL to develop its own expertise in X ray and neutron scattering, with the corresponding costs for instrumentation, detectors etc, for the ESRF case.

CRG Implementation
The EMFL will operate a CRG at ILL and ESRF. To this aim it will build and run a high field installation on the ILL/ESRF site that will have special purpose magnets on dedicated ESRF and ILL beamlines and general purpose magnets (EMFL-NX). Part of the capacity of the power supply and cooling installation will be reserved for ILL/ESRF operation, the remainder for general purpose high field experiments. The ILL and ESRF pay for access to this high field CRG installation under a long term contract, like they do already with many other CRGs.

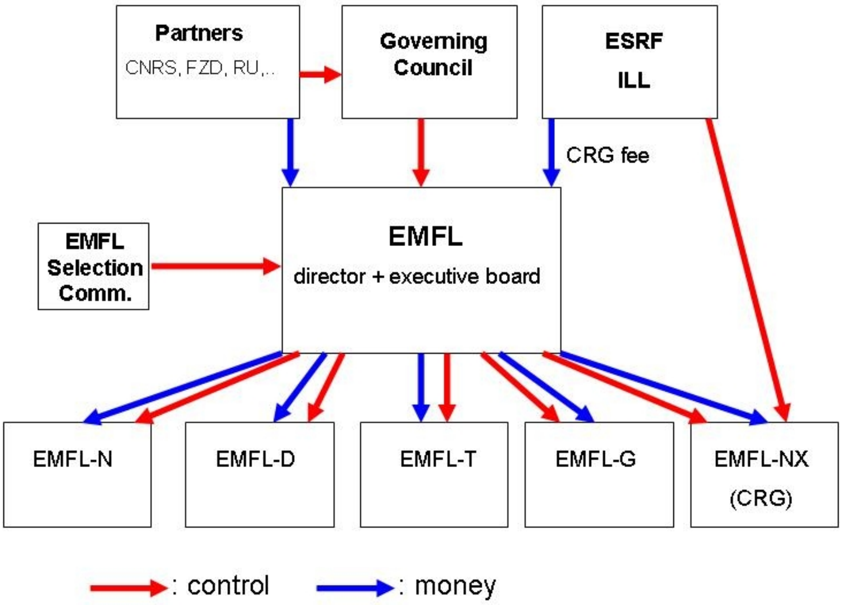

Fig. 1 Possible structure of the EMFL-ESRF-ILL project; CRG option

2) *The Partnership option*.

The Partnership for Structural Biology (PSB) is a joint effort of the ESRF, the ILL, the Grenoble Outstation of the European Molecular Biology Laboratory (EMBL) and the Institut de Biologie Structurale. It brings together expertise in state-of-the-art molecular biology with the investigatory power of synchrotron radiation, neutron scattering and nuclear magnetic resonance necessary to pursue an integrated European program in structural biology. A similar partnership between EMFL, ESRF and ILL could be envisaged.
For the EMFL, the Partnership option has the advantage that the EMFL itself will not have to build up the expertise to build, run and operate neutron and X-ray scattering beam lines, and that the high magnetic field activities could be more easily extended toward other scattering techniques (eg. XMCD or resonant nuclear scattering at the ESRF) existing at ILL and ESRF.

Partnership implementation
The ILL and ESRF on the one hand, and the EMFL on the other hand, will together design, build and operate a new high field installation on the ILL/ESRF site, including the necessary magnets for beam scattering and general purpose applications, under a long term agreement that defines the obligations and rights of each of the partners.

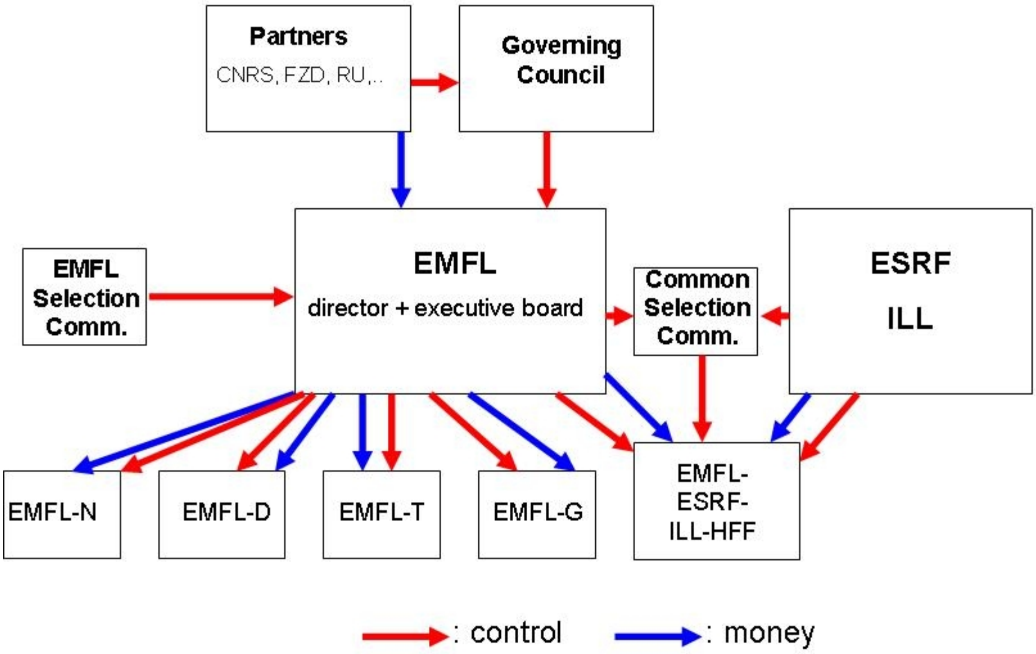

Fig. 2 Possible structure of the EMFL-ESRF-ILL project; Partnership option

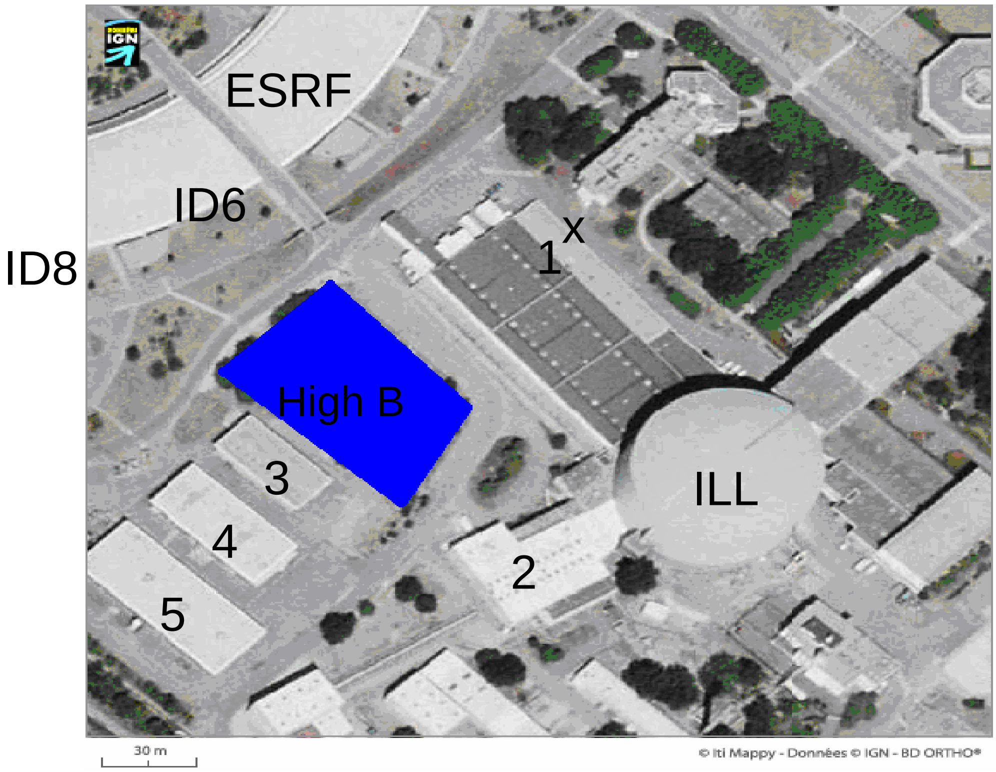

Figure 3 Possible implementation of the joint EMFL-ILL-ESRF high field facility