agence d'évaluation de la recherche
et de l'enseignement supérieur

Section des unités de recherche

AERES report on the unit:

Laboratoire National des Champs Magnétiques Intenses (LNCMI) – UPR 3228

under the supervisory authority of the following institutions and bodies:

CNRS

INSA - Toulouse

University Paul Sabatier – Toulouse

University Joseph Fourier – Grenoble

Juillet 2010

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et de l'enseignement supérieur

Section des Unités de recherche

Rapport de l'AERES sur l'unité :

Laboratoire National des Champs Magnétiques Intenses (LNCMI) – UPR 3228

Sous tutelle des établissements et organismes

CNRS

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Le Président de l'AERES	Section des unités de recherche
	Le Directeur
Jean-François Dhainaut	**Pierre Glorieux**

Juillet 2010

Unit

Name of the unit : Laboratoire National des Champs Magnétiques Intenses

Requested label : UPR

No. in case of renewal : 3228

Unit director : Mr Gerardus RIKKEN

Members of the expert committee

Chairperson :

Mr Jean-Yves MARZIN, LPN, CNRS, Marcoussis

Reviewers :

Mr Jean-Paul AMOUREUX, Université des Sciences et Technologies de Lille

Mr Marc BIRD, National High Magnetic Field Laboratory, Tallahassee, USA

Mr Jérôme LESUEUR, CNRS, Ecole Supérieure de Physique et Chimie Industrielles de la ville de Paris

Mr Noboru MIURA, National Institute for Materials Science, Tsukuba, Japan

Mr Eric PALM, National High Magnetic Field Laboratory, Tallahassee, USA

Reviewer(s) nominated by the staff evaluation committees (CNU, CoNRS, CSS INSERM ...) :

Mr Guy LE LAY, CNU

Mrs Olena POPOVA, CoNRS

Representatives present during the visit

Scientific delegate representing AERES :

Mr Claude LECOMTE

Research organization representatives :

Mr Charles SIMON, CNRS, Institut de Physique

Invited representatives :

Mrs Pascale BUKHARI DR11/CNRS, Grenoble

Mr Laurent DAUDEVILLE, Université Joseph Fourier, Grenoble 1

Mr Raoul FRANCOIS, INSA, Université Toulouse 3

Mr Alain MILON, Université Paul Sabatier, Toulouse 3

Report

1 • Introduction

- Date and conduct of the visit :

The evaluation relies upon the documents provided and a visit of the Grenoble site of LNCMI which took place on March 8 and 9 2010. The first day was devoted to a general description of LNCMI by the direction, a virtual visit of the Toulouse facilities and a real one of those of Grenoble, a discussion with the LNCMI operators and with the personnel, and to seven scientific presentations of the activities. On the second day, five other presentations focused on scientific and technical aspects and the future plans were outlined by the laboratory director.

The prepared material and organization of the visit itself were of high quality thanks to the LNCMI direction as well as all contributors from Toulouse and Grenoble.

- History and geographical location of the unit and brief description of its field of study and activities :

LNCMI results from the merger, in January 2009, of the Grenoble High Magnetic Field Laboratory (LNCMI) and the Toulouse National Pulsed Magnetic Fields Laboratory (LNCMP). The unit, implanted thus on both sites, is at the same time a national and international facility and a research laboratory. Operated by CNRS, it is associated with the INSA and the University Paul Sabatier of Toulouse and with the University Joseph Fourier of Grenoble. It is active, through in house research and hosted projects, in all fields of science requiring high magnetic fields, as well as in related technical developments.

- Management Team :

The unit director is Mr G. Rikken, with two deputy directors: Mr C. Berthier and Mr O. Portugall.

- Staff: (according to the dossier submitted to AERES) :

	In the project
N1: Number of professors (see Form 2.1 of the unit's dossier)	11
N2: Number of EPST, (Public scientific and technological institution) or EPIC, (Public industrial and commercial institution) researchers (see Form 2.3 of the unit's dossier)	15
N3: Number of other professors and researchers (see Form 2.2 and 2.4 of the unit's dossier)	3
N4: Number of engineers, technicians and tenured administrative staff members (see Form 2.5 of the unit's dossier)	52
N5: Number of engineers, technicians and non-tenured administrative staff members (see Form 2.6 of the unit's dossier)	2
N6: Number of doctoral students (see Form 2.8 of the unit's report dossier and 2.7 of the unit's project dossier)	13
N7: Number of persons accredited to supervise research and similar	14

2 • Assessment of the unit

- Overall opinion :

The high magnetic field laboratories in Toulouse and Grenoble both have long tradition and history since 1960's or early 1970's, and have made steady progress for many years. Both institutions have been well known as representative high field facilities of France, for pulsed and steady fields, respectively. Recently, the visibility of the two laboratories has become very prominent, and especially after their merger in 2009 as LNCMI. This tendency was accelerated by many excellent achievements which have been made by in-house staff and outside users, from both France and abroad, in various fields of science. The high quality of the research accomplishments is confirmed by the number of outstanding papers in journals with high impact factors. This fact demonstrates that the facility (the largest in Europe) has now matured to a real national and international centre of the high magnetic field research. As outlined by the LNCMI direction, the laboratory (and Europe in this field) is nevertheless at a crossroads, where the choice is either to invest and grow, to remain competitive with similar centers in the US, Japan and China, or accept to rely upon the access to these facilities.

- Strengths and opportunities :

The most important factor as a national research center is to provide unique and user-friendly facilities for the community. At the same time, the activity of the in-house staff is also essentially important, since for the joint use of the facilities, the cooperation with the staff is essential. In these respects, the strength and opportunities of LNCMI are considered to be at quite a high level: the high field installations can produce world-class magnetic fields both in steady and pulsed forms, they seem to be reasonably user-friendly, and the scientific level and skills of the in-house staff are also very high.

Another big advantage of the LNCMI is the vicinity, in Grenoble, of ILL and ESRF where strong beams of neutrons and synchrotron radiations are exploited. This proximity to ESRF and ILL, a strong materials development program and a larger dc power supply than labs in Nijmegen and Hefei will be critical advantages over the next few decades. When complete, the 42.5 T hybrid magnet will be the highest dc field in Europe and might rival the one in Tallahassee. There are also many other laboratories in France where the scientists need high magnetic fields. Collaborating with these institutions and researchers, as well as those in other nearby countries in Europe, the LNCMI would be able to produce many excellent results in future as long as the technology is regularly updated in due time. The hiring of new researchers in the chemistry or biology should further enlarge the community of users.

The creation of the European Magnetic Field Laboratory (EMFL), which is now included on the ESFRI roadmap, is a key point for the future of the LNCMI, if it could secure the necessary funding for upgrades and developments.

- Weaknesses and threats :

The main problem of the LNCMI is that some of the equipment including the field generators are becoming rather old since they were built in the early 1990's. In the meanwhile, the other European facility in Nijmegen and Dresden are either new or much younger. Whereas three quarters of the projects executed in the European facilities are hosted in LNCMI, the lack of support is a real threat. For example, the capacitor bank of 14 MJ in Toulouse is now 15 years old, and the protection chambers for the pulse magnets which were built when the laboratory started do not look sufficiently robust for routinely generating higher fields safely at present. Renewal of some facilities would certainly be necessary.

Another point is the relatively low number of tenured researchers and professors attached to LNCMI, as compared to similar facilities. Although the CNRS and the associated universities consider it a priority to maintain the personnel at the present level, LNCMI did not yet recover the staff number it had when the LNCMI was associated with the Max Planck Institute for Solid state physics.

A third weak point (linked to the previous one) is that there seem to be not so many students in the two laboratories at Grenoble and Toulouse. Though the number relative to that of tenured researchers is reasonable, the absolute number is low. It would be desirable to increase the number, especially in such excellent and unique facilities with many constituents, for further increasing the activity of the laboratories and to foster young scientists in the research field in the next generation.

The main threat is a possible lack of competitiveness in the future, if necessary investments in human and financial resources are not made in time.

- Recommendations for the unit director :

It is a very good point that the merger of the two high magnetic field facilities in France has so far been very successful to enhance the activity of the entire LNCMI. It is now a good opportunity to implement various new projects based on the excellent achievements so far acquired. The proposed plan looks very appropriate, though the committee recommends setting up priorities among the planned projects. Needless to say, the safety is the most important issue for such laboratories as high field facilities: the programs related to the safety guard (e.g. fail-safe site in Toulouse) should be given first priority, as well as the completion of the hybrid project, which is clearly a very high priority.

As far as the advertising on the lab activity is concerned, it would be useful, to fix a scientific reference frame (common to Grenoble and Toulouse) and stick to it, accelerate the effectiveness of the Toulouse/Grenoble merger by defining common scientific and technical projects, and identify more clearly the in-house and externally driven research.

On the medium term, the implication of LNCMI in ESRF and ILL high field projects and set-up of EMFL are strategic issues which need to be clarified and prioritized.

- Data on work produced :

A1: Number of *produisants* (professors and researchers whose names appear in a minimum number of "publications" over a 4-year period) listed in N1 and N2 in the project column	26
A2: Number of *produisants* among the other staff listed in N3, N4 and N5 in the project column	
A3: Proportion of *produisants* in the unit [A1/(N1+N2)]	100%
Number of theses for accreditation to supervise research defended	3
Number of theses defended	15
Any other data relevant for the field (please specify)	

3 • Detailed assessments

- Assessment of work produced and scientific quality :

  - Relevance and originality of the research conducted, quality and impact of the results :

The research conducted in LNCMI reflects in a large part the research conducted by the community of researchers using high magnetic fields: it is thus diverse and ranges from solid state physics to the experiments to evidence the magnetic birefringence of vacuum. It would thus be somewhat unfair to evaluate it as if disconnected from its community of users. This being said, the quality of this research is indeed excellent, with several important breakthroughs in the 2005-2008 period.

It is also worth noting that: (i) the LNCMI, as a facility, is also evaluated on a yearly basis by an international scientific committee which shares the present committee opinion on the scientific quality, (ii) that all the research projects executed have to go through an international program committee (common to the 3 European facilities through the European network EuroMagNETII) to get magnet time. Often, these projects are jointly set up by in house researchers and external users, the whole procedure ensuring an optimal use of the facility.

  - Quantity and quality of publications, papers, theses and other work :

The number of publications is of the order of 130 per year, among which about one fifth in letters, and 40 contributions to international conferences with proceedings + 20 invited talks in international events. These figures, much higher than in "normal" solid state physics laboratory and the journals where the results are published attest both the quality of the research held at LNCMI and the impact it has as a facility. 15 PhD theses were defended from 2005 to 2008. The visibility of LNCMI researchers is globally very good, with a high number of invited talks in conferences.

  - Quality and solidity of contractual relations over time :

LNCMI has a long tradition in supporting external research teams (national or not) needing access to high magnetic fields. The laboratory staff is involved in preparing the projects to be submitted to the program committee, thus increasing the success rate (some 85 %). As far as the relationship with partner organizations is concerned, the associated universities did and do support LNCMI, which proves a long term fruitful partnership.

- Ability to recruit top-level researchers, post-doctoral and other students, especially foreigners :

LNCMI was well supported in the recent years and can benefit from the hiring of very good researchers. It suffers nevertheless from the low number of students in physics for attracting PhD students. This is made worse by the low number of faculties; mainly in Grenoble (being researcher, professor and local point contact does not provide an easy life). Other French laboratories, which have been taking benefit from the facility should be strongly encouraged (by the program committee) to share PhD students with LNCMI, in order to ensure a sufficient breeding ground for future recruitments.

- Ability to obtain external financing, to respond to or launch calls for tenders and to participate in the activities of competitiveness clusters :

The LNCMI has been and is very active in European projects as well as for national calls of the ANR. The ANR funding (500 k€/year) is at an excellent level, which will be difficult to increase further.

- Participation in international or national programs, existence of important collaborations with foreign laboratories :

Several international conferences were organized or co-organized by LNCMI in the report period. The international collaborations are obviously at a high level (80% of the projects come from abroad).

- Valuation of research and socio-economic or cultural relations :

One patent was issued in 2007: this number is rather low, if one refers to the number of technical staff and to the field covered (this may be due to the specificity of the technical innovations).

- Assessment of the strategy, governance and life of the unit :

  - Relevance of the unit's organization, quality of its governance and internal and external communication :

The LNCMI, despite its peculiar configuration, is running smoothly, and the personnel appreciates the way it is governed. Although they have the difficult task to do their own research and serve as local contacts, and for some of them also to teach, the LNCMI researchers are dynamic and productive. A special mention should be given to the PhD students (half of them from abroad) who are enthusiastic about their work and conditions.

It should also be noted that the direction makes a large effort to increase the opportunity for the staff and workers in both sites of Grenoble and Toulouse to meet each other in order to enhance the good cooperation and communication. Actually, it should be very important to speed up the lab consolidation.

Despite the complicated institutional and international landscape, the LNCMI direction has succeeded in building a very positive atmosphere inside the lab.

- Project assessment :

  - Existence, relevance and feasibility of a medium- or long-term scientific project :

The projects of LNCMI on the medium term are both in the scientific domain as well as for magnet technology. On the first one, the committee approves the will to enlarge the community of users, beyond its traditional solid-state basis, in the fields of chemistry, fundamental and plasma physics, and to magneto-science. The LNCMI indeed prepares already adequately this broadening by having attracted in-house researchers who will accompany this growth.

Concerning the magnet developments, the projects are considered as positive by the committee, both for pulsed and DC fields. In particular, the choice of 1 and 6 MJ banks for pulsed fields are adequate in the context of portability and user-oriented policy, as well as the future projects of hybrid 35T/12 MW and high T_c superconductors based magnets for the DC fields. Given the cost of developing new high field installation, one has also to pay attention to the proper development of state to the art instrumentation, and even new ones like NMR, EPR, ultrasound, thermoelectric probes, etc. The recent outstanding results in cuprates for instance, are directly related to the gain in signal/noise ratio in the measurements. It is important to keep investing in instrumentation on both sites.

- Originality and risk-taking :

The past and future scientific projects (which are again also those of the community, and selected by an international committee to check their relevance) are indeed original and some of them risky (e.g. vacuum birefrigence).

On the technical side, the LNCMI is developing an original hybrid magnet system that has high visibility (and high cost). Risks are being managed well. The lab is playing a leading role in the new field of combining pulsed magnets with x-ray scattering and in trying to install dc magnets at both x-ray and neutrons sources: this is a clear originality with respect to similar facilities.

4 • Team-by-team and/or project-by-project analysis

4 • 1 Metals and Superconductors

- 5 chargés de Recherche CNRS
- 2 maîtres de Conférences

The physics of metals and superconductors is studied on both sites through transport and spectroscopic measurements. The most important subjects of interest for the scientific community nowadays that are addressed are: strongly correlated systems, heavy fermions and organic materials. The overall quality is very good, with some exceptional contributions for example in the physics of cuprates in Toulouse or the study of the superconducting-ferromagnet URhGe in Grenoble, and some very detailed work on the fermiology of organic conductors. The magnetic field is a powerful tool to probe new and exotic electronic states in matter, providing an appropriate instrumentation is used. Such an effort has been made on both sites, where accurate measurements of magneto-resistance, Shubnikov de Haas (SdH), de Haas van Alphen (dHvA), Nernst, ultra-sound, NMR... in very high field and often very low temperatures can be made. This appears to be decisive to compete at the highest international level.

Through very efficient collaborations worldwide, this activity generated high level scientific contributions, published in high impact factor journals (3 Nature, 2 Science, 27 PRL).

The most striking results are related to superconductivity. For the first time, the topology of the Fermi surface of cuprates has been determined by quantum oscillation measurements (SdH, dHvA) for different doping levels in the phase diagram, and electron pockets have been surprisingly discovered in these hole doped materials. A Fermi surface reconstruction therefore must occur, whose nature is under strong debate in the community. This LNCMI work is a real breakthrough in the field. Another surprising and important result is the discovery of a ferromagnet at 9.5 K being a superconductor at 250 mK, namely the heavy fermion compound URhGe. Moreover, a field induced superconducting pocket has been found related to a quantum critical point. A detailed magnetic phase diagram has been obtained, where the orientation of the field with respect to the crystallographic axis plays a major role. Another field induced superconducting state has been observed in an organic conductor □-(BETS)2FeCl4. The competition between superconductivity and magnetism is also addressed in heavy fermion compounds and in organic conductors, where hints of the FFLO* state have been observed by NMR in CeCoIn5 and magnetometry and torque measurements in □-(BEDT-TTF)2Cu(NCS)2.

Other interesting results on the properties of exotic electronic phases has been obtained thanks to high magnetic fields, like the “hidden order” in heavy fermions like URu2Si2, the Luttinger physics in the organic CuBr4(C5H12N)2, or the determination of the Fermi surface in the two band superconductor ZrB12 for example.

Beyond metals, the physics of quantum spin systems studied by NMR at LNCMI has a major impact in the community. In antiferromagnetic Heisenberg systems of coupled ½ spin dimers, quantum transitions occur under strong magnetic fields, where the Dzyaloshinsky-Moriya interaction has been found to play a key role, like in the ladder system Cu2(C5H12N2)2Cl4. The possible Bose-Einstein Condensation of triplets on the background of the commensurate spin superlattice has been explored in SrCu2(BO3)2 and in BaCuSi2O6.

The above mentioned activities have their own strong dynamics, and there is no doubt that they will be fruitful in the future. They have to be strongly supported. The NMR group will be reinforced by two permanent researchers, which is a very good perspective.

4 • 2 Nano & Meso

- 4 professeurs
- 2 directeurs de recherche
- 4 chargés de recherche
- 1 maître de Conférences

The scientific contributions in this area are based, on the one hand on semiconductor physics, comprising low dimensional structures: basically, two-dimensional electron gas (2DEG), quantum wells and quantum dots, and, on the other hand, on the study of graphite, graphene and carbon nanotubes.

11 researchers (2 DR + 2 CR + 1 Pr from Grenoble and 4 PR + IR +1 CR+ 1 MCF from Toulouse, as of 01/01/2010) work in this area together with 6 students (on a total of 13), i.e., a large proportion.

The production is largely superior to the usual standards in this field and of high quality. Just for the year 2009, it includes 14 in-house projects (11 on graphene, one on graphite, 3 on semiconductors) on a total of 39, 53 articles, among which 15 are related to carbon allotropes (comprising 7 Phys. Rev. Lett. : 3 on graphite, 3 on graphene, 1 on carbon nanotubes).

Typically, the last theme of carbon-based nanostructures regroups in a very fruitful synergetic collaboration researchers from both previous laboratories, i.e., the LNCMI in Grenoble and the LNCMP in Toulouse. Samples are prepared in house and studied in static and pulsed fields both in Grenoble and Toulouse.

Some highlights concern the study of the Aharonov-Bohm effect in ballistic multi-wall carbon nanotubes and the Landau level spectroscopy of graphene-based structures.

Other highlights in semiconductor physics concern:

- The study of electron-electron interactions; e.g., in strongly interacting 2D electron systems, the Stoner transition which drives a 2DEG into a ferromagnetic state; their role affecting electronic transport in a 2DEG via plasmon excitations; their role in determining the spin and charge state of optically probed single quantum dots.
- The “ratchet effect”: anisotropic transport induced by microwave excitations in a 2DEG with intentional anisotropic disorder.
- The study of magnetic semiconductors.

The points to develop concern the relationship with the Universities, the Polytechnic Institute.

4 • 3 Magnetic Resonance

- 1 professeur,
- 2 directeurs de recherche
- 1 chargé de recherche
- 2 ingénieurs de recherche

The scientific contributions in this area are mainly in solid-state Physics (broad-band NMR) at very large variable magnetic fields (up to 34 T) and low temperature (a few tens of mK). They are also based on high-resolution NMR for material science at room temperature and 30 T; however, this is a starting new project.

Five permanent positions of researchers, three postdocs and two students work in this area. This is a small group, which nevertheless attracts several (6) regular visitors.

The production is very good and quite superior to usual standards.

The themes which have been developed for solid-state Physics concern: (1) High T_C superconductors Cobaltates and Pnictides; (2) Exotic superconductivity: FFLO phase in $CeCoIn_5$ and Jaccarino-Peter mechanism in λ-$(BETS)_2FeCl_4$; (3) Quantum anti-ferro-magnets: (i) Luttinger-liquid behavior in the spin ladder $CuBr_4(C_5H_{12}N)_2$, (ii) Wigner crystallization of bosons: magnetization plateaus in $SrCu_2(BO_3)_2$, (iii) Bose-Einstein Condensation of triplets/bosons in Han purple $BaCuSi_2O_6$.

The second topic, which concerns 'classical' NMR, has only started very recently by analyzing at 30 T, on a static ZrF_4 powder sample, the ^{91}Zr spectrum.

Concerning the projects, which concern solid-state Physics, there are related to :

- Quantum spins: Ising chain of BaCo2V2O8, NiCl2·4SC(NH2)2 compound (DTN), High-field phase transition in Volborthite.
- High Tc's, cobaltates and pnictides.
- Field-induced super-conductivity.

However, the main new project of this group concerns the application of very high-field NMR to 'classical' NMR. This project should be encouraged. Indeed, there is another TGE (based on the Federation 3050), which is devoted to 'classical' NMR. At least ¾ of its proposals are based on quadrupolar low-gamma nuclei, which can only be recorded with very large field NMR spectrometers. The two largest fields presently available for this purpose are 21.1 T (Lille) and 20 T (Orléans). Indeed, the 23.5 T magnet of Lyon is reserved for biology, which means $^{1}H/^{13}C/^{15}N$ nuclei, all spin-1/2 nuclei. Even at 21.1 T, the 1D spectra of low-gamma nuclei remain very broad with all resonances overlapping. For such broad spectra, the resolution of c.a. 1 ppm accessible at Grenoble is quite sufficient. The resolution of such nuclei is proportional to the square of the magnetic field, and thus spectra recorded at 30 T are 2.25 more resolved than those recorded at 20 T.

It should thus be fine for the two TGEs (LNCMI and Lille-Orléans) to work together on such project of low-gamma quadrupolar nuclei. This new topic would create links between LNCMI and the large community of people working in the field of material science. In order to do so, it means for LNCMI to develop double-resonance (^{1}H-^{19}F/X low-gamma) MAS probes, with the shortest as possible dead-time. There are several very recent 'tricks' that can be used to improve such a development. This can thus be done in collaboration with the two groups (Lille and Orléans) of 'classical' NMR.

4.4 Molecular Magnetism

- 1 professeur
- 1 directeur de recherche
- 1 ingénieur de recherche

Besides a nice NMR experiment on CsFe8, which displays a field-induced phase transition, most of the research on molecular magnetism is made within the High-Field EPR group. The recent arrival of a chemist researcher will boost that already well known activity on molecular magnets and will be the opportunity to develop a new activity on new materials presenting ferroelectric or even multiferroic properties.

The main results to date refer to S>1 systems, where the multifrequency operation mode of the HF-EPR system is particularly suitable. For example, double Ni(II), Mn(II) or Fe(III) complexes have been studied, and their molecular configuration explored, and compared with models. These results are important in order to be able to build new molecular magnets. Biological systems have been also investigated, namely proteins with Fe-4S tetrahedra. The structure of Single Molecular Magnets which present quantum properties at low temperature has been studied.

In the future, study of P and T violation in chiral molecule will be studied, in collaboration with the magneto-optic group, which is a very appealing perspective. Complex materials like ferroelectrics and multiferroics will be also investigated. Single-chain Magnets may be an alternative to single molecule one, with higher blocking temperature. An important research program is proposed in that perspective based on verdazyl chemistry.

The development of a pulsed HF-EPR spectrometer up to almost 300 GHz will allows dynamical studies of these compounds like the magnetic relaxation for instance.

Whereas the spectroscopic group "EPR & NMR" is on the same site, the committee wonders whether this is just a cosmetic label "spectroscopy", or if one can imagine interactions? This should be possible on molecular magnetism for instance ... The committee does not see clear projects in that direction.

4.5 Magneto-Optics, Neutrons and X-Rays

- 1 professeur
- 1 directeur de recherche
- 1 chargé de recherche
- 1 maître de conférences

Another highlight is the magneto-spectroscopy of carbon nano-tubes and graphene. In carbon nano-tubes, a remarkable achievement is that the evidence of Aharonov-Bohm effect was observed in both optical and transport experiments in pulsed high magnetic fields. In graphene, magneto-optical transitions between Landau levels were observed, and most of the peculiar Landau level structures arising from the mass-less Dirac carriers were clarified. At present, the subject has become very popular and many experiments are going on competitively. At LNCMI, these results have been obtained at a rather early stage, so that LNCMI has been playing a leading role in this research field, and has given a large impact.

One of the great advantages of the LNCMI is that the Grenoble lab. is located very close to the neutron scattering facilities of ILL and the synchrotron radiation facilities of ESRF. Both machines provide extremely powerful techniques for condensed matter sciences. Neutron scattering is particularly useful for magnetism, and the synchrotron radiation is very useful as an intense radiation in the X-ray range. The combination of high magnetic fields with these facilities would open up many new possibilities, such as the investigation of magnetic phase transitions or exploration of new magnetic and crystal structures, magneto-optical processes, etc. The effort of the LNCMI towards this direction is highly evaluated. Various special types of magnets have been developed. Both for steady fields and pulsed fields, coils with a conical access or split coils were designed and are being developed. For pulsed fields, a 1 MJ portable capacitor bank was built to install on the beam lines.

In collaboration with the group of Tohoku University, Japan, magnetic structures of the plateau phases were investigated in $CdCr_2O_4$ and TbB_4. The lattice deformation with temperature and magnetic fields was measured in NdFeAsO using the beam at ESRF. These nice results obtained in these experiments demonstrated a promising future, and hence the demand of high magnetic fields for these beam experiments will increase significantly from now on.

4.6 Magnets / Instrumentation

- 10 ingénieurs de recherche

Pulsed-field

- Assessment of work produced and scientific quality :

On the basis of the long-standing tradition of the pulsed magnet technology in Toulouse and the European "ARMS" project in which the Toulouse laboratory was intensively involved, high field pulse magnets have been successfully built. The magnet construction was made basically following the fibre reinforcement technique which has now become one of the standard techniques for the pulsed magnets, and wet winding method. Furthermore, the team leader introduced his technique developed at Amsterdam. The quality of these magnets is quite good in the sense that they are reliable and have reasonably long life.

A unique point of the LNCMI magnet technology group is that they are developing strong wires by themselves in the lab. It would be marvellous if these wires become really available for practical use, but it would take some more time to solve all the technically difficult problems which still exist. With the recent merger of the Toulouse and Grenoble labs, this expertise is now being applied to development of materials suitable for high-field dc magnets as well, which is a good point.

Also, the polyhelix magnet technology that was developed in Grenoble for dc magnets is being transferred to the Toulouse facility for application in pulsed magnets. This shows potential for reducing the cool-down time of the pulsed magnets which should allow the lab to combine long pulses with short cool-down times, a formidable combination which could propel the lab to the international forefront of the pulsed magnet community. The scientific productivity of the pulsed-field facility is already competing with much larger labs worldwide, including Los Alamos. Such a development might allow Toulouse to be recognized as the international leader in this field.

Concerning the power supply, the plan to build a new 6 MJ bank is a sensible decision, because it would be very useful for generating most of the necessary pulsed fields by itself, and also it can be used for generating really very high fields with a two-coil structure, by combining with the 14 MJ bank. The committee also places a high value on their good success in building a 1 MJ portable capacitor bank for X-rays and neutron experiments, since nice results have been obtained with it.

Another notable recent progress is seen in the single turn coil system. The entire system was moved from Berlin to Toulouse, and it is now in operation. The technique is very useful as very high pulsed fields well above 100 T (up to 300 T) can be generated rather easily without spending so much energy in the capacitor bank. Although it is a destructive method ("semi-destructive" in the sense that the samples are not destroyed), and pulse duration is very short, a lot of interesting experiments can be performed as demonstrated in Tokyo and Berlin. The system will provide useful means for obtaining high fields and will become one of the attractive facilities of LNCMI for users.

- Quantity and quality of publications, papers, theses and other work :

Besides the publication on the science in high fields, reasonable amount of the pulsed magnetic field technology of Toulouse has also been published and is well accepted internationally.

- Assessment of the influence, appeal and integration of the team or the project in its environment :

  - Number and reputation of the prizes and distinctions awarded to the unit members, including invitations to international events :

Several series of international conferences are held periodically on high magnetic fields and related science, and LNCMI always plays principal roles including invited talks. It also has hosted some of these conferences.

  - Ability to recruit top-level researchers, post-doctoral and other students, especially foreigners :

Considering the attractive research environment and very high reputation at present, it will not be so difficult to obtain very good researchers, post-docs, or students, if there are available positions created in LNCMI with reasonable salaries.

- Assessment of the strategy, governance and life of the team or project :

Some staffs in the lab are professors of universities and there are students in their groups. However, the number of students is relatively small.

DC fields

- Assessment of work produced and scientific quality :

The largest project presently underway in magnet technology is the development of a 42.5 T hybrid magnet. This is a very ambitious and original activity. There have been only 15 hybrid magnets built worldwide. This compares with thousands each of NMR, MRI and accelerator magnets. The project includes a collaboration with a highly respected magnet development group at CEA. The lab has taken a conservative approach in the design of the superconducting outsert by avoiding a high-field, small-bore Nb_3Sn approach and building a relatively low-field, large-bore NbTi magnet. The conductor design for the outsert shows a good balance of relying on proven concepts (Rutherford cable w/ additional stabilizer, superfluid helium ventilated windings) while still incorporating new features to optimize the conductor for this application. This magnet shows great promise of being successful and, when successful, will be the highest field dc magnet in Europe. There is also some possibility of upgrading the resistive insert to allow the system to rival the 45 T system in the USA (Tallahassee).

The dc resistive magnets in Grenoble have for many years attained lower fields than those at other labs worldwide, but recently a series of upgrades have been successfully completed, with more expected soon. Grenoble now has the highest dc fields in Europe and is starting to challenge those provided in Tallahassee. This is a most welcome development; the new director is to be praised for it. The LNCMI is starting to organize collaborations in Grenoble and elsewhere in France focused on high-temperature (or high-field) superconductors. The US is well organized in this regard, with the Applied Superconductivity Center in Tallahassee playing a lead role. It is commendable that the LNCMI-G is trying to organize the development of these materials that show so much promise for the future.

- Quantity and quality of publications, papers, theses and other work :

The LNCMI publishes extensively on pulsed magnet technology and materials development. The hybrid project is a large construction project, where one wants to minimize risk, hence it relies more on proven technology and little of the work is publishable in the scientific literature. The new conductor technology has been presented at the recent 21st International Conference on Magnet Technology in Hefei, China where it was well-received. They have started to publish in their new initiative in high-field superconductors.

- Quality and solidity of contractual relations over time :

The LNCMI did enter into an inappropriate contract with Oxford Instruments many years ago, however it was a guaranteed-performance contract and when OI failed to deliver, the money was returned. It appears that presently the labs contractual relations are robust.

- Ability to recruit top-level researchers, post-doctoral and other students, especially foreigners :

The magnet technology group in Grenoble recently recruited a researcher from CERN to play a leading role in the design and construction of the new hybrid magnet. This new staff has a strong track record spanning more than 10 years in superconducting magnet system development. He is a most welcome addition to the team and should be able to play a leading role in magnet development in both Grenoble and Toulouse as senior colleagues retire.

- Ability to obtain external financing, to respond to or launch calls for tenders and to participate in the activities of competitiveness clusters :

LNCMI has been quite successful in securing additional funds for the hybrid magnet project and shows great potential for securing funding for other new initiatives, particularly the development of magnets for neutron and x-ray scattering.

- Participation in international or national programs, existence of important collaborations with foreign teams :

LNCMI is leading the EuroMagNET II, collaboration between the European high-field facilities in Nijmegen, Dresden, Grenoble and Toulose. This collaboration shows potential to allow the European labs to jointly rival the US lab. The lab also is developing collaborations with ILL & ESRF, both of which are international labs. This collaboration also shows great potential to lead transformational science. The Toulouse branch of the lab has a long-standing collaboration with Oxford University on development of high-strength, high-conductivity materials for use in pulsed magnets. At the national level, LNCMI has a major collaboration with CEA on the development of the hybrid outsert for Grenoble. The new initiative in high-field superconductors is an international collaboration that shows great potential.

- Relevance of its organization, quality of its governance and internal and external communication :

The magnet development activities in Grenoble have been recently re-organized with the arrival of the new director. Since then, external communications have improved with more visibility at international conferences. The lab is communicating very well with its immediate neighbors developing collaborations in superconductivity as well as high-field magnets for x-ray and neutron scattering.

- Relevance of initiatives aimed at scientific coordination and the emergence and taking of risks :

The new initiatives with ILL & ESRF are focused on an emerging set of possibilities and that various organizations and nations (Japan, US, Germany) have been pursuing. LNCMI is one of the leaders in this field and shows great potential for the future, given the success to date with pulsed field at ESRF and ILL and the proximity of the Grenoble branch to ESRF & ILL. The collaboration with CEA on the hybrid project should greatly reduce the risk associated with the development of a hybrid magnet. The collaboration with Nijmegen and Dresden is a much-needed step to allow the European labs to compete with the American one. The collaboration on high-field superconductors is much needed to pull together the European efforts. These materials show great potential not only for higher-field, more economical magnets, but also in revolutionizing power transmission and production, which is an increasingly important issue in coming years.

- Involvement of the members in teaching activities and in organising research in the region :

The magnet development team is very active in organizing research combining high fields with neutrons and x-rays and research in high-field superconductors in the city of Grenoble. The Toulouse and Grenoble branches of the lab are now leading the research at high fields in southern France.

- Project assessment :

Existence, relevance and feasibility of a medium- or long-term scientific project:

The hybrid magnet project will take a few years to complete (2013) and will result in the highest field dc magnet in Europe, possibly rivaling the 45 T system in the US (Tallahassee). This magnet seems feasible as it uses a relatively low-risk technology (NbTi 8.5 T, large bore outset).

Existence and relevance of a resource allocation policy: The lab has been successful in undertaking a hybrid project along with resistive magnet upgrades, design of split magnets for neutron and x-ray scattering and continuing to push the limits of pulsed-field facilities with a relatively small staff and budget. It seems that resources are being allocated very well.

To conclude on this part, the Toulouse and Grenoble magnet labs have been very prominent in the international magnet development communities for decades. In recent years both labs have taken on major new initiatives that show great promise of coming to successful fruition. The future looks very promising!

Note de l'unité	Qualité scientifique et production	Rayonnement et attractivité, intégration dans l'environnement	Stratégie, gouvernance et vie du laboratoire	Appréciation du projet
A+	A+	A+	A	A+

LNCMI

Laboratoire National des Champs Magnétiques Intenses UPR3228
Grenoble - Toulouse

AERES - LNCMI Evaluation committee

Grenoble & Toulouse, april 16th 2010

The directors and the Conseil de Laboratoire have studied the preliminary version of the report of the AERES evaluation committee on the LNCMI. We would like to thank the committee members for their work, praise and encouragement. Detailed linguistic corrections will be communicated in a separate document. Although we largely agree with the committee's conclusions and recommendations, we would like to submit the following comments for consideration:

p.5 'Recommendations for the unit director'
prioritizing the EMFL and ESRF/ILL initiatives; we fully agree with the committee that such a prioritization is important, but would like to stress that these initiatives are subject to high level international political aleas that surpass the control of the LNMCI and that of its operators.

Identifying clearly the inhouse and outside driven research; we feel that it would not be very useful to introduce such a distinction. Almost all experiments performed at the LNCMI are close collaborations between LNCMI staff and external researchers: The LNCMI has no sample growth or preparation facilities and relies entirely on outside sample sources, and all experiments are performed using dedicated instrumentation developed by inhouse staff. One might base such identification on the principal investigator who submits the magnet time request, but in practice this is mostly dictated by administrative considerations.

the absolute number of students is low, as the committee pointed out, this is related to the relatively small scientific staff, but in particular to the low number of university scientists at the LNCMI-G, which furthermore is surrounded by laboratories that offer higher salaries to their PhD students (CEA, ILL, ESRF), something which is not possible for a CNRS unit.

Accelerating the merger between Grenoble and Toulouse, currently all financial and human resources are tied up in the realization of long standing projects at the two sites (hybrid project, generator upgrade etc) and the everyday operation of the two installations. In the absence of supplementary resources, starting major common projects, which is certainly technically and scientifically very promising, can only be done when the ongoing ones have been completed. In the mean time, the technical and scientific staff is strongly encouraged to strengthen the synergy between the two sites, which is resulting in increasing interactions and collaborations.

p. 7 'Valuation of research'; *the number of patents is rather low*. Although true, this is not an indication of the level of technical innovations. It simply reflects that the specificity of the innovations produced by the LNMCI technical staff are in an area where no industrial activity exists, and that therefore the costs of filing a patent can never be recovered through licensing.

p. 9 'Nano & meso'; *the relationship with Universities, the Polytechnic Institute*; we do not quite see what the committee is trying to say with this remark.

p.11 'Molecular magnetism': we feel that the current text does not entirely justice to the past activities in this domain. We would therefore like to propose a slightly modified text (changes marked in red)

"The main results to date refer to S>1 systems, where the multifrequency operation mode of the HF-EPR system is particularly suitable. For example, mononuclear Ni(II), Mn(II) or Fe(III) complexes have been studied, and their electronic configuration explored, and compared with theoretical calculation obtained from Angular Overlap Model or DFT. These results are important in order to be able to build new molecular magnets. Biological systems with ferrous iron have been also investigated, namely proteins with Fe-4S tetrahedras. The structure of Single Molecular Magnets which present quantum properties at low temperature has been studied, allowing for the first time unravelling the origin of their magnetic anisotropy.

In the future, study of P and T violation in chiral molecule will be studied, in collaboration with the magnetooptic group, which is a very appealing perspective. Complex materials like ferroelectrics and multiferroics will be also investigated. Single-chain Magnets may be an alternative to single molecule one, with higher blocking temperature. An important research program is proposed in that perspective based on verdazyl chemistry.

The development of a pulsed HF-EPR spectrometer up to almost 300 GHz will allows dynamical studies of these compounds like the magnetic relaxation for instance.

The two groups 'Molecular magnetism' and 'Magnetic resonance' are on the same site but have different main field of interests. Whereas the NMR group is more involved in solid state physics studies, the research in the molecular magnetism group appears at the interface between physics and chemistry. The committee wonders whether one can imagine interactions between the two groups, on SMM for instance. "

p. 12 'power supply' , the planned 6 MJ power supply will also be mobile, and will, apart from what is highlighted by the committee, also serve at other facilities, like ILL and ESRF. The 1 MJ mobile bank has not only generated interesting results with X ray and neutron scattering, but in combination with the original LNCMI X-coil technology, has produced important results at the high power laser facility LULI. (C. Robillard et al, Phys. Rev. Lett. **99**, 190403 (2007))

p. 13 'Assessment of work', the recent increases in field strength at the LNCMI-G are the result of a collective and concerted effort. We would feel it to be more correct if the appreciation of the committee would be expressed in this spirit, e.g. 'the new director and technical staff are to be praised for it'.

G. Rikken, director LNCMI

LNCMI / CNRS
25 rue des Martyrs - B.P. 166
38042 GRENOBLE CEDEX 9 France
Tél. : +33 (0)4 76 88 10 48
Fax : +33 (0)4 76 88 10 01
http://ghmfl.grenoble.cnrs.fr/

143 avenue de Rangueil
31400 TOULOUSE - France
Tél. : +33 (0)5 62 17 28 60
Fax : +33 (0)5 62 17 28 16
http://www.lncmp.org/