Director's Introduction

The "Laboratoire Léon Brillouin" is a Mixed Research Unit (UMR12) shared and funded jointly by the "Commissariat à l'Energie Atomique" (CEA) and the "Centre National de la Recherche Scientifique" (CNRS) . It uses the neutrons produced by the Research Reactor ORPHEE.

The recent confirmation of the LLB as the national French neutron source occurs in a changing European landscape. Several small facilities are closing whereas medium and world-class ones have either been recently commissioned (FRMII, SINQ) or are benefiting from major upgrades (ILL, HMI, ISIS). The near future will see the opening of several new megawatt spallation sources: SNS in the United States, JPARC in Japan and probably later ESS in Europe.

Neutron scattering is undoubtedly in a phase of expansion, and the demand for measurement time is increasing. In a complex world which is facing critical challenges in health, environment, energy, transport, communication and food, neutron scattering is a unique tool which can answer many questions in condensed matter science that no other technique can address.

Because efficient use of this technique requires a significant commitment of resources and time, a tiered structure of the neutron facilities and the scientific community is necessary. In addition, there is no way to perform neutron scattering in a standard laboratory as neutrons are only available at medium- and large-scale facilities. The European network is well organized with the ILL as the European Source and national sources located in the main countries. NMI3* is a very efficient structure, and the Heads of the European facilities meet regularly to share information. LLB is one of its cornerstones. It serves as a base for the French neutron community and provides access to many European users who are supported by the European Access program. It also fosters the education of PhD students and supports instrument and method development.

LLB is a laboratory in which teams have the mission to carryout their own research programs. For this reason each team member is involved in the national and international scientific community in order to enrich the community with results obtained from neutron techniques, attract new users and provide a link between the laboratories and the professionals who use neutron methods.

The work described in this report is that performed and/or initiated by the researchers of LLB and that of close users. The results of experiments led by the other external users, often with the help and the expertise of LLB scientists, are beyond the scope of this report. These efforts are evidenced by the many publications in which the contribution of the LLB is acknowledged. The statistics for these external studies may be found in the last section of this report.

In order to provide users with special expertise that spans the broad spectrum of topics accessible using neutron methods, the research groups are rather small and tackle very different problems. The report is presented in seven sections: Structure and Phase Transitions, Superconductivity and Magnetism, Materials Science and Applications, Soft Matter, Life Science, Instrumentation and Theory. Each section is introduced by an overview of the work accomplished and a discussion of future prospects. The details of the experiments are described in subsequent highlights (referred to as H*n*) or short clips (referred to as C*n*).

SUPERCONDUCTIVITY AND MAGNETISM

The LLB team is recognized as a leader in the physics of strongly-correlated electron systems whose properties include unconventional superconductivity as well as the unusual magnetic behaviour of manganites and ruthenates. Significant progress has recently been achieved with the detection of magnetic moments, probably due to orbital current, in the pseudo-gap region of YBaCuO. Beyond the particulars of each system, the aim of this research is to elucidate more general parameters that govern their behaviour: inhomogeneities, quantum critical points, orbital degrees of freedom, etc. The other research topics of the group are frustrated magnetism, surface magnetism and photomagnetism.

STRUCTURE AND PHASE TRANSITIONS

Smart materials are solving engineering problems and providing opportunities for new innovative products. Since their properties are linked to structural details, it is essential to carefully determine their structure and control their phase transitions. This drive has stimulated strong activity by the LLB team, which takes advantage of the unique properties of the neutron to see light atoms and resolve magnetic structures. The activity is further enriched by strong interactions with the French community of chemistry of solids.

The main research on phase transitions concerns confined mediums, pressure effects, effects of magnetic frustration, and transitions in electrolytic medium. The structure studies are focused on new materials such as nanotubes, hydrides, manganites and biomaterials and on materials under combined, extreme conditions of pressure and/or field and/or temperature.

The tools developed at the LLB (improved diffractometers, world-class sample environments and new methods for structure analysis) and the emergence of new functional and multifunctional materials foretells a bright future for this research activity.

MATERIALS SCIENCE AND APPLICATIONS

While a much of neutron activity is still devoted to the study of model systems, there is a simultaneous move towards the resolution of technological problems. Extensive research focused on energy problems, information technology and structural materials has been developed at the LLB during the last two years. The diversity of the research on key elements of energy systems is quite impressive and it includes the dynamics of water in Nafion membranes, structure and dynamics in solid oxide fuel cells, relaxation processes in polymer electrolytes for Li-batteries, porous alumina membranes, water-oil macroemulsions for heavy oil extraction, advanced materials for the nuclear industry.

The scientific activity in the field of metallurgy is focused on the development of new alloys and on the microstructural evolution of materials submitted to external loadings. These fields involve much industrial collaboration, and efforts are underway to improve the diffractometers devoted to texture and strains.

The study of the magnetism of surfaces and of thin layers is a key part of the research program at LLB and is driven by the spintronics and recording media technology.

* NMI3 : Integrated Infrastructure Initiative for Neutron Scattering and Muon Spectroscopy of the European Union 6th Framework Programme.

SOFT MATTER

LLB has a long history in soft matter. Some of the currently accepted models of polymers were confirmed at LLB, in large part because the interaction between the internal team and the external user community is strong and very professional. This example typifies the proliferation within the national community of a strong research activity that was established at the LLB. The group has many ongoing activities including determination of the structure and behaviour of new polymers, study of systems under constraints (mechanic, magnetic etc...), investigation of the effects of confinement, and study of complex ternary mixed systems. This research takes advantage of small angle scattering, reflectivity and quasi-elastic neutron scattering techniques as well as of contrast matching from selective deuteration, which allows one to independently highlight different parts of a complex system.
The research in the area of soft matter is very rich and encompasses a diverse set of systems. It is driven by the underlying applications that include mechanic reinforcement, pharmacology, food, oil, transportation etc.

LIFE SCIENCE

Water is the major constituent of living matter, and it obviously plays a key role in the dynamics of proteins. In this research area, the vast, specialized experience of the LLB team is fully exploited. The research at LLB is directed towards the shape and dynamics of the proteins and their correlation with biological functions. Special attention is focused on the folding and unfolding mechanism of the proteins, on the translocation process and on the dynamics of photo-excited proteins.
In life science, probably more than in any other systems, the objects (such as proteins in the cells) interact, form and move in crowded environments. Measurements of samples in similar environments have been initiated, and it is a new step forward for the biology community and food industry which are confronted by such complex situations. Also here, small angle neutron scattering and quasi-elastic scattering are well-adapted tools for such studies. The implementation of the deuteration laboratory on the ILL-ESRF site should give a new boost to life science research at LLB as well.

THEORY

A small group of theoreticians support the experimental activities, especially in the areas of superconductivity and biology.
For superconductivity, they have provided theoretical support for the asymmetry between the hole-doped and electron-doped cuprates, and performed calculations on the mechanism responsible for superconductivity based on spectra obtained with neutron scattering. They recently reproduced quantitatively the parameters of supraconductivity.
In biology the activity is focused on the calculation of Brownian and fractional Brownian dynamics of proteins in relation to quasi-elastic neutron scattering.

INSTRUMENTATION

In the changing landscape of neutron scattering, the LLB faces a serious challenge of instrumentation maintenance and upgrades in order to maintain the high standards of a national source. The current effort is insufficient for the LLB to retain its current status as a medium source competitive with “sister facilities” such as FRMII in Munich or NIST in the United States. The ongoing CAP 2010 program must only be viewed as a first step to provide momentum for a more complete renewal of the instrumentation. It is now urgent to adopt an ambitious policy for instrumentation improvements and upgrades which involves increased funding as well as increased manpower devoted to this mission. It is only under these conditions that the best scientists will be attracted to the LLB, the brightest students will choose our laboratory to prepare their PhD, the users will continue to submit proposals to LLB, and the French community will be strong enough to put effort into the emerging new facilities. The Board of Directors wishes to make this message very clear.

OTHER ACTIVITIES OF ORPHEE

The commercial activities of neutron radiography and silicon doping are run by DEN (Direction of Nuclear Energy of CEA), and activation analysis is performed by LPS (Pierre Sue Laboratory). While these are important activities of ORPHEE, they are beyond the scope of this report which is devoted to LLB.
With its triple mission of (1) offering neutron instrumentation, technical support and expertise to the users, (2) teaching the neutron technique to young scientists and new users, (3) carrying out its own research, the LLB is at the heart of many research efforts and is active in the specific research communities working on subjects developed in the laboratory.
Each year, LLB organises a tutorial “les FAN du LLB” based on practical training and hosts the students of The European HERCULES training program. LLB also participates in and contributes to the thematic school of the “French Neutron Society” (SFN), and LLB team members teach in doctoral schools in several French universities via the “itinerant chair” of the SFN.
In 2006 LLB hosted two thematic (GDR) meetings. It is involved in national and international research networks as the RTRA *“triangle de la physique” (Triangle of Physics) on the (“plateau de Saclay”); C-Nano or the European Network of Excellence: Functionalized Advance Materials and Engineering Hybrids and Ceramics (FAME).
With the synchrotron SOLEIL at walking distance from LLB, new horizons are opening. Saint Aubin LLB/SOLEIL meetings (the next one scheduled in March 2007) and their joint organization of the tenth International Conference on Surface X-ray and Neutron Scattering (SXNS10) in 2008 are the witness to a fruitful scientific collaboration. We also expect to share technical support and some infrastructure.

The immersion of LLB in scientific communities, the professionalism of its members, and the number and quality of the users are ingredients for a strong neutron community that utilizes the best current and emerging neutron sources to tackle scientific problems which will address the challenges of the 21st century.

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