

Overview of User Facilities for Basic Research in the Field of Materials Under Irradiation

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Foreword

Under the auspices of the Nuclear Energy Agency (NEA) Nuclear Science Committee (NSC), the Working Party on the Scientific Issues of the Fuel Cycle (WPFC) has been established to co-ordinate scientific activities regarding various existing and advanced nuclear fuel cycles, including advanced reactor systems, associated chemistry and flowsheets, development and performance of fuels and materials, accelerators and spallation targets. Various expert groups were established to cover the above-mentioned topics.

The Expert Group on Innovative Structural Materials (EGISM) was created in 2008 to conduct joint and comparative studies to support the development, selection and characterisation of innovative structural materials that can be implemented in advanced nuclear fuel cycles under extreme conditions such as high-temperature, high-dose rate, corrosive chemical environment and long-service lifetime. The objectives of the expert group are:

- to provide a state-of-the-art assessment of specific areas so as to identify priority areas of research;
- to determine areas where experimental protocols and standards are needed and where the sharing of available experimental installations could be possible;
- to identify existing databases;
- to organise a series of workshops on structural materials for innovative nuclear systems (SMINS).

To address the EGISM's objective related to sharing available experimental installations, this report considers the existing facilities, also defined as "user facilities" that may support basic research for the development of materials for innovative nuclear systems. The report lists existing facilities offering an access to researchers in the field of materials under irradiation. In addition, some key testing facilities, mainly utilised by the applied research community, are cited.

The general concept of a user facility, supporting basic research in the field of materials under irradiation, is described, as is the value that user facilities, such as sources of neutron and ion irradiation, can bring. Examples are given on how some international and national user facilities have been used in basic research to support the development of structural materials for nuclear energy, with recommendations on how user facilities may be effective. Descriptions are then provided of the user facilities that are currently available in the NEA member countries, and the procedures that should be followed to access them.

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A list of contributors can be found in Appendix C.

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List of abbreviations and acronyms

ANAFIRE	ANALyses et Faisceaux d'Ions pour la Radiobiologie et l'Environnement (France)
AHL	Hot laboratory at PSI (Switzerland)
AL	Analytical laboratory
ANM	Advanced Nuclear Materials
ANMT	Advanced nuclear materials testing facility
APS	Advanced photon source
APSUO	Advanced photon source users organisation
APT	Atom probe tomography
ARRONAX	Accélérateur pour la Recherche en Radiochimie et Oncologie à Nantes Atlantique (France)
ATR	Advanced test reactor
BAG	Block allocation groups
BIO-REF	BIO neutron reflectometer
BNL	Brookhaven National Laboratory (United States)
BR2	Belgian Reactor No. 2
BRIF	Beijing Radioactive Ion beam Facilities
BSRF	Beijing Synchrotron Radiation Facility
BUG	GANIL User Board
BWR	Boiling water reactor
CAES	Centre for advanced energy studies (United States)
CALIPSO	Core Advanced Loop for Irradiation in Potassium Sodium
CARR	China Advanced Research Reactor
CCFE	Culham Centre for Fusion Energy (United Kingdom)
CCL	Carbon characterisation laboratory
CEA	Commissariat à l'énergie atomique et aux énergies renouvelables (France)
CELLS	Construction Equipping and Exploitation of the Synchrotron Light Source
CEMHTI	Conditions extrêmes et matériaux: Haute température et irradiation (France)

CIAE	China Institute of Atomic Energy
CIMAP	Centre de Recherche sur les Ions, les Matériaux et la Photonique (France)
CMAM	Centro de Microanálisis de Materiales (Spain)
CIME	Cyclotron pour Ions de Moyenne Energie (France)
CNA	Centro Nacional de Aceleradores (Spain)
CNI	Cold neutron imaging
CNME	Centro Nacional de Microscopía Electrónica (Spain)
CNMS	Centre for Nanophase Materials Sciences (United States)
CNMSUG	Centre for Nanophase Materials Sciences User Group
CNRS	Centre National de la Recherche Scientifique (France)
CSNSM	Centre de Spectrométrie Nucléaire et de Spectrométrie de Masse (France)
Cold-TAS	Cold triple axis spectrometer
CRGs	Collaborating research groups
DCF	Dalton Cumbrian Facility (United Kingdom)
DDT	Director's discretion time
DSM	Direction des sciences de la matière (France)
EBSA	Electron backscatter diffraction
EDAX	Energy dispersive x-ray analysis
EDF	Electricité de France
EDS	Energy dispersive x-ray spectrometry
EDX	Energy dispersive x-ray spectrometry
EMC	Electron microscopy centre
EMF	Electron microscopy facility
EMIR	Réseau national d'accélérateurs pour les études des matériaux sous irradiation (French national network for the study of materials under irradiation)
EML	Electron microscopy laboratory
ENF	Ex-core neutron irradiation facility
ERDA	Elastic recoil detection analysis
ESRF	European synchrotron radiation facility
EPSRC	Engineering and Physical Sciences Research Council
EUC	EMC Users Committee
FCD	Four-circle neutron diffractometer
FEDER	Fonds européen de développement régional (European Union)

FEGTEM	Field emission gun – Transmission electron microscope
FIB	Focused ion beam
FTL	Fuel test loop
GANIL	Grand accélérateur national d'ions lourds (France)
GeV	Giga electron Volt
GIXRD	Grazing incidence X-ray diffraction
HANARO	High-flux Advanced Neutron Application Reactor (Korea)
HFEF	Hot fuel examination facility
HFETR	High-flux engineering test reactor
HFR	High-flux reactor
HFIR	High-flux isotope reactor
HIPD	High-intensity powder diffractometer
HIRFL:	Heavy Ion Research Facility in Lanzhou (China)
HRPD	High-resolution powder diffractometer
HR-SANS	High-resolution small-angle neutron spectrometer
HVEC	High-voltage engineering corporation
IAD	Industrial application diffractometer
IAEA	International Atomic Energy Agency
ICERR	International Centre of Excellence operating a Research Reactor
ICTS	Spanish singular scientific and technical infrastructures
ILL	Institut Laue-Langevin (France)
IMEF	Irradiated Material Examinations Facility
IMP	Institute of Modern Physics (China)
INFCIS	Integrated nuclear fuel cycle information system
INL	Idaho National Laboratory (United States)
INP	Institute of Nuclear Physics (France)
IPPE	Institute for Physics and Power Engineering (Russia)
JHR	Jules Horowitz Reactor (France)
IMCL	Irradiated materials characterisation laboratory (United States)
INC	Instituto de Ciencia de Materiales Nicolás Cabrera (Spain)
IRAMIS	Saclay Institute of Matter and Radiation (France)
ISOL	Isotope separator online
KBSI	Korea Basic Science Institute
KAERI	Korea Atomic Energy Research Institute
LANSCE	Los Alamos Neutron Science Centre (United States)

LBE	Lead-bismuth eutectic
LHMA	Laboratory for high and medium activity
LIGA	Lithographie, Galvanoformung, Abformung (Lithography, Electroplating and Molding)
LINAC	Linear accelerator
LMA	Advanced Microscopy Laboratory (Ireland)
LNS	Laboratory for Neutron Scattering and Imaging (Switzerland)
LOCA	Loss of coolant accident
LSI	Laboratoire des solides irradiés (France)
LTP	Long-term proposal
LUG	LANSCE user group
LWR	Light water reactor
MACS	Multi-axis crystal spectrometer
MARS	Multi analyses on radioactive samples
MCF	Materials and fuels complex
meV	Millielectronvolts
MeV	Megaelectronvolts
MICA	Material irradiation capsule
MIR	Multi loop reactor
MJTR	Min Jiang Test Reactor (China)
MRF	Materials research facility
MTR	Materials test reactor
MTS	Materials test station
MW	Megawatt
MWth	Megawatt thermal
MYRRHA	Multipurpose hybrid research reactor for high-tech applications
NAA	Neutron activation analysis
NDA	Non-destructive analysis
NECV	National electrostatics corporation (United States)
NNL	National Nuclear Laboratory (United Kingdom)
NNUF	National Nuclear User Facility (United Kingdom)
NPP	Nuclear power plant
NRA	Nuclear reaction analysis
NRF	Neutron Radiography Facility (United States)
NSLC	National synchrotron light source (United States)

NSRL	National Synchrotron Radiation Laboratory (China)
NSUF	Nuclear Science User Facility (United States)
NTD	Neutron Transmutation Doping of Silicon (United States)
OCCITANE	Out-of-Core Capsule for Irradiation Testing of Ageing by Neutrons
ODS	Oxide dispersion strengthened
ORNL	Oak Ridge National Laboratory (United States)
PAC	Programme Advisory Committee
PET	Positron emission tomography
PIE	Post-irradiation examination
PIEF	Post-Irradiation Examination Facility (United States)
PLS	Pohang light source
PGAA	Prompt gamma thermal neutron activation analysis
PNNL	Pacific Northwest National Laboratory (United States)
pRad	Proton radiography
PSI	Paul Scherrer Institute (Switzerland)
PWC	Pressurised water capsule
PWR	Pressurised water reactor
R&D	Research and development
RD&I	Research, development and innovation
REC	Research and education campus
REF-H	Horizontal neutron reflectometer
REF-V	Vertical neutron reflectometer
RF	Radio-frequency
RI	Radioisotope
RIAR	Research Institute of Atomic Reactors (Russia)
RR	Research reactor
RSI	Residual stress instrument
RW	Radioactive waste
SANS	Small-angle neutron spectrometer
SAXS	Small-angle X-ray scattering
SEM	Scanning electron microscopy
SHUG	SNS-HFIR User Group (United States)
SINQ	Swiss spallation neutron source
SKLNPT	State Key Laboratory of Nuclear Physics and Technology (China)
SLS	Swiss light source

SNS	Spallation neutron source
SNICS	Source of negative ions by cesium sputtering
SPL	Sample irradiation laboratory
SPM	Scanning probe microscopy
S&T	Science and Technology
SMR	Small modular reactors
SSRF	Shanghai Synchrotron Radiation Facility (China)
SSRT	Slow strain rate test
TD	Texture diffractometer
TEM	Transmission electron microscopy
Thermal-TAS	Thermal triple axis spectrometer
TNI	Thermal neutron imaging
TREAT	Transient reactor experiment and test
UAB	Universitat Autònoma de Barcelona
UAM	Universidad Autónoma de Madrid
UCM	Universidad Complutense de Madrid
UCN	Ultra-cold neutrons
UPM	Universidad Politécnica de Madrid
U-SAXS	Ultra small-angle X-ray scattering
USTC	University of Science and Technology of China
UV	Ultraviolet
WNR	Weapons Neutron Research Facility (United States)
WPFC	Working Party on Scientific Issues of the fuel Cycle (NEA)
XAFS	X-ray absorption fine structure spectroscopy
XAS	X-ray absorption spectroscopy
XIL	X-ray interference lithography
XRF	X-ray fluorescence

1. Introduction

Historically, the Nuclear Energy Agency (NEA), with the participation of the Nuclear Science Committee (NSC) and the Committee on the Safety of Nuclear Installations (CSNI), has engaged substantive efforts to provide overviews of the availability of nuclear research infrastructure, in particular in the context of existing needs, in order to give decision makers balanced and comprehensive resources (NEA, 2001; NEA, 2007; NEA, 2003; NEA, 2009).

In an effort to continue the work started at the NEA, under the auspices of the NSC Working Party of the Scientific Issues of the Fuel Cycle (WPFC), the Expert Group on Innovative Structural Materials (EGISM) has carried out a review of existing user facilities to address basic innovative materials research. This report intends to list the different existing infrastructures in NEA member countries that can provide researchers with state-of-the-art facilities for external use to advance scientific or technical knowledge for fundamental nuclear materials science. The concept of user facilities for basic research use is described in detail in Chapter 2.

In addition to the user facilities, development and qualification of nuclear fuels and materials are performed in the following infrastructures:

- nuclear power plants (NPPs), where advances in fuel design and materials can be addressed at normal operating conditions, either in normal fuel assemblies or in so-called lead test fuel rods/assemblies;
- research reactors (RRs), mainly for irradiation at conditions not achievable in NPPs, such as special water chemistry, high neutron flux, high power and diminished cooling, transient conditions, irradiation conditions leading to fuel integrity limits/fuel degradation for the safety margins assessment. Tests with instrumented fuel rods or material specimens are also done in RRs. The hot cells are used for post-irradiation examination (PIE) and testing, as well as for the preparation of fuel/material specimens suitable for further testing in RRs. Many of these infrastructures are offering access to the international community.¹

Even if it is not the main focus of this report, some RRs and PIE facilities are presented in this document in their capacities to welcome basic research activities. Some other infrastructures are utilised extensively by the community to develop basic research to support the science of materials under irradiation. The present report focuses on these facilities, which are quite important in the early stage of any material development and to improve the understanding of the key single-effect mechanisms involved in the science of materials under irradiation.

¹ In the aftermath of the Halden reactor shutdown, the NEA is currently establishing a multinational co-ordination of applied-research experimental programmes to optimise the utilisation of existing infrastructures by the industry and the safety bodies.

2. The user facility concept

Many modern research facilities are large and complex and have capital costs of such magnitude that they cannot be replicated within a sponsoring country. As a result, national research organisations attempt to find methods to provide access to researchers not physically located at the major research facility. Examples of these large facilities would be neutron scattering facilities or synchrotron X-ray facilities. The method of providing access varies between countries or regions. In some cases, funding is provided; researchers can propose specific R&D ideas that are then selected by peer review to provide facility access. In other countries, researchers must obtain funding and then reimburse the major facility for the support provided.

In this document, these major facilities are broadly defined as “user facilities” and their general concept is described below. In the following sections, the value of user facilities to nuclear research is described and then some specific applications of the user facilities in different nations are outlined, which have been used to support the development of materials for innovative nuclear systems. Finally, recommendations for improved use of user facilities are given. In the appendices, more detailed descriptions of major national user facilities are then provided.

The general form of the user facility concept is one that gives researchers access to exceptional and unique resources, in-house staff expertise, state-of-the-art facilities, tools and instruments and infrastructure that allow the best ideas to be proven using the most advanced capabilities. In addition, user facilities should be managed to ease access and to assist scientists in the execution of research. The goal of a user facility is to connect good ideas with capability, regardless of geographic location, national affiliation or organisation.

Typically, allocation of facility capital is managed through a merit-based peer review of submitted research proposals so that there are sufficient resources for users to conduct work safely and efficiently. User facilities may also support a formal user organisation to represent the users and facilitate sharing of information, forming collaboration and organising research efforts among users. In addition to the independent proposal review bodies mentioned above, a user facility should also establish ways to receive advice and input on its activities. A facility typically receives this input from a scientific advisory committee and/or user group. User facilities also play a role in helping educate current or potential users on the issues and tools available to address research questions through conferences, workshops and user meetings.

3. The value of user facilities for basic research in the field of materials under irradiation

The value and key to any successful user facility is to provide users with resources that are critical to their experiments. Another key to success is to offer unique opportunities to work with some of the most advanced technology in the world in a specific location or through a single portal to gain access to a broader set of capabilities. User facilities also assist in educating current or potential users on the issues and tools available to address research questions through conferences, workshops and user meetings. Last of all the value to any scientist is the ability to have a facility that is highly reliable and fosters a productive environment focused on conducting their research.

Traditionally, access for research in the nuclear energy field has been difficult due to associated hazards/risks, lack of infrastructure to handle this kind of work, transportation of materials, security and cost. The main role that user facilities play is to help maximise investments in this field by organising assets in a common place or portal so that researchers may exploit them. By centralising investments, people, assets, risk and infrastructure, the burden on a scientist is reduced so that they can concentrate on the science and not on how to accomplish the research.

User facilities that can irradiate materials are critical to research on innovative reactor systems. These may utilise neutrons or ions and are generally coupled with special facilities that can perform post-irradiation examinations.

- Neutron irradiation

Neutrons generated in research reactors are used to achieve experiments related to the development of nuclear power reactors, for both the understanding of the phenomena involved and the validation and qualification of the solutions retained.

Materials test reactors are designed to investigate the behaviour of structural materials and fuels under irradiation. They are extensively used to qualify the main components of power reactors – i.e. materials and fuels, sensors, etc. – under irradiation conditions representative of those occurring in power reactors. So they have to display high-performing features with respect to flux level and operating capability, for one of their main interests is to allow highly instrumented experiments to be achieved, under continuous monitoring, up to limits that could not be tolerated in a power reactor. These high-flux levels, exceeding those to be met in nuclear power plants, allow thorough studies of materials and components ageing under irradiation to be performed within sufficient time intervals for the best materials and provisions to be determined at the design step for these reactors. Accordingly, powers to be met in materials test reactors range from a few dozen MW to 100/200 MWth, which means a neutron flux of about 10^{13} to 10^{15} n.cm⁻².s⁻¹.

The other main interest of these irradiation reactors lies in that materials and fuels to be experimented can be put under conditions representative of those encountered in power reactors; in addition to neutron flux and according to experiment complexity, these conditions may involve temperature, mechanical stresses, such as pressure, the physicochemical conditions of the environment, etc.

In order to get such representative conditions, materials and fuels are placed in appropriate devices designed so as to be positioned in the reactor core or on its peripheral part according to the flux of

interest and the type of experiment considered. These devices also hold the instrumentation that allows measurements required for real-time follow-up of the irradiation.

Finally, these devices are designed so that their use may not entail any risk for the reactor, under any circumstance, or any radioactive release.

They roughly belong to two types:

- capsules, in which the coolant (gas, NaK*...) is static, as heat exchange for cooling is performed by conduction to the water of the reactor coolant system;
- (water, gas, sodium) loops, that allow for higher representativeness and are endowed with their own pressurisation and temperature control system; these systems are most often placed in shielded cells on the periphery of the reactor, and are connected to the in-pile device itself by flexible pipings.

Materials test reactors typically operate by cycles of 20-30 days of power operation, during which a number of irradiation experiments are loaded in parallel in the reactor. Inter-cycle periods of a few days are used to load and unload experimental devices according to needs. Some specimens under irradiation can then be subjected to non-destructive examinations, such as visual, dimensional, gamma spectrometry and neutron radiography examinations that make it possible to follow their evolution under irradiation. After irradiation, specimens often undergo destructive examinations in hot cells so that the effects of this irradiation may be fully characterised.

Research reactors are also tools for the benefit of basic research and neutrons so generated could have multiple applications outside the so-called nuclear area. Regarding materials, the penetration and interaction properties of neutrons allow matter to be explored at the atomic and molecular scale. These properties have led to develop high-performance specialised reactors that have been implemented to study solid state physics, magnetism, crystalline structures, molecular and macromolecular physico-chemistry, biochemistry and biology.

- Ion irradiation

Ion irradiation is another powerful tool to modify the atomic structure of materials. Generally, disorder or damage is produced in the process, although in some specific cases, useful structural rearrangements can be produced. During an irradiation, energetic particles collide with target atoms, inducing nuclear recoil damage and/or electronic excitations producing local excited states. By different processes, the structure relaxes to atomic defects. By controlling the irradiation parameters (nature, energy and fluence of the incident particles), it is possible to control the creation of damage. Gases can also be simultaneously implanted at the damage peak to emulate gas production through transmutation or fission. It is also possible to follow as a function of the defect population and concentration or the phase transformation, the evolution of mechanical, optical and conductivity properties.

Presently, accelerators are mainly used to simulate the ageing of materials under radiation. In particular, controlling irradiation parameters allows studying the evolution of material properties and, by adjusting the flux of particles, to explore the long-term stability of nuclear materials. Accelerators are involved in the following research areas:

- control of ageing of the nuclear materials and optimisation of nuclear plant lifetime, new materials for the next generation of nuclear plants, materials for nuclear waste management, etc.;
- production of new materials;
- control by irradiation of the nano-structure of the materials.

As mentioned above, ion irradiation infrastructures provide more than valuable contribution to the fundamental study of radiation damage. They should be complemented by larger scale experiments.

4. Survey of the use of user facilities for basic research in the field of materials under irradiation

This chapter gives an overview of the existing facilities for research on nuclear materials at the national and international levels, such as material research reactors, beam lines, synchrotron, etc. Details of each facility are provided in the Appendix (Chapter 6).

4.2. International

- IAEA-INFCI Post-Irradiation Examination Facilities Database

In 2007-2008, following an agreement with the international HOTLAB working group, the IAEA PIE Database integrated the HOTLAB PIE Catalogue. The merged data are kept at the IAEA INFCIS website, which is jointly managed by the IAEA and HOTLAB. This database represents the only publicly accessible worldwide source of the subject information.

As described on the IAEA website, located at <https://infcis.iaea.org/>, the database consists of five main areas describing PIE facilities (i.e. acceptance criteria for irradiated components, cell characteristics, PIE techniques, re-fabrication/instrumentation capabilities and storage and conditioning capabilities) as well as major technical and licensing data of casks. The PIE facility list can be found on link to the IAEA INFCIS site or by going to <https://infcis.iaea.org/PIE/PIEMain.asp>.

The content of the database represents the status of the participating organisations and helps interested users select the most appropriate facilities, casks and examination techniques. The database can also be used to compare the PIE capabilities worldwide with current and future requirements, as well as to provide development incentives for laboratories with limited PIE techniques.

- Jules Horowitz Reactor (JHR)

The Jules Horowitz Reactor (JHR) is a new materials test reactor currently under construction at the CEA Cadarache research centre (France). The JHR is being built under the framework of an international consortium of research institutes from Belgium, the Czech Republic, Finland, France, Spain, Sweden, the United Kingdom and the European Commission and major companies such as EDF and Areva. The reactor will support research and development programmes for the optimisation of the present generation of nuclear power plants, support the development of the next generation of plants and also offer irradiation capacities for future reactors. The reactor will also enable medical isotopes production.

The JHR is a pool-type reactor using water as coolant and moderator and has been designed to allow irradiation with the large thermal and fast neutron fluxes required to support Generation II and III reactors and also to develop Generation IV technologies in the longer term. As such, the irradiation conditions that can be achieved are up to 5.5×10^{14} neutrons per cm^2 per second at energies >1 MeV (i.e. including high-energy or fast neutrons) and up to 10^{15} n/ cm^2/s at energies $E > 0.1$ MeV (i.e. lower

energy or thermal neutrons). To put this into context, the lifetime thermal dose at the reactor pressure vessel in current Generation II/III plant is of the order of 10^{19} n/cm².

The JHR reactor has numerous positions in the core to accommodate irradiation experiments and there have been several long-term programmes in the past decade to select and design the experimental rigs to use these, using experience of such rigs in other test reactors such as the French experimental reactor OSIRIS. In addition to the rigs described below, it is likely that other devices may become available in due course, such as CEDRIC (Creep Experimental Device for Research on Innovative Ceramics), which was developed at CEA OSIRIS test reactor for testing the effects of stress on irradiated ceramic composites (600-1 000°C) in He gas.

- CALIPSO (Core Advanced Loop for Irradiation in Potassium Sodium) is a NaK loop with forced circulation that can maintain sample temperatures under irradiation at between 250°C to 450°C.
- MICA (Material Irradiation CAPsule) is complementary to CALIPSO and will also be available at temperatures between 250°C and 450°C. It is designed to be able to hold about ten samples for simultaneous irradiation, with a fast neutron flux of approximately 3×10^{14} n/cm²/s. An instrumented MICA will have one sample, with in situ loading and measurement of dimensional changes. A high-temperature version (HT-MICA) is planned and will allow irradiations at temperatures in excess of 1 000°C in helium gas.
- CLOE (a corrosion loop) is designed to have accurate water chemistry monitoring for pressurised water reactor (PWR) or boiling water reactor (BWR) requirements.
- OCCITANE (Out-of-Core Capsule for Irradiation Testing of Ageing by NEutrons) is designed for pressure vessel material testing, with samples in inert He gas at temperatures between 230-300°C and dose rates of around 100 mdpa/year.
- MADISON, ADELINe and LORELEI: These rigs are for fuel and fuel component studies: MADISON is designed to investigate the behaviour of LWR fuel rods (both PWR/VVER and BWR conditions) in normal operating situations. ADELINe is designed to test a single experimental instrumented LWR fuel rod in “off-normal” conditions for PWR or BWR.
- LORELEI will produce conditions representative for ballooning and burst of fuel cladding and will allow studies of corrosion at high temperatures and the main phenomena involved during a LOCA transient (Loss of Coolant Accident).

4.3. Belgium

The Belgian Reactor No. 2 (BR2) is the Material Testing Reactor (MTR) currently offering the highest neutron flux in Europe and ranking among the most powerful and flexible research reactors in the world. The pressurised water cooled and beryllium (Be) moderated tank-in-pool reactor was first started in 1962. It initially provided a test bed for the development of fast reactor fuels, claddings and structural materials until the mid-eighties, operating a large variety of test loops including sodium and gas filled fast flux facilities. For the last decades, the reactor has operated 5-6 cycles per year at 50-75 MW power (power can be adjusted to fit experimental requirements up to 100 MW), mainly in support of the Generation II/III community, the MTR LEU fuel development and for radioisotope production (25% of the world need for ⁹⁹Mo on an annual basis). As part of its decennial safety review and licence renewal, the BR2 has undergone a thorough maintenance and modernisation operation in 2015-2016, including a full replacement of its Be matrix. To guarantee a safe and efficient operation, various systems and components have been replaced as a precaution. This renovation and rejuvenation operation has prepared the reactor for at least another 10 years of service to the nuclear community under its current licence and likely even longer.

The BR2 reactor offers a wide variety of irradiation conditions which can be adjusted to fit the needs of the experiments. Thanks to the well-tuned thermal (7×10^{13} to 1×10^{15} n/cm²s) and fast (1×10^{13} to 6×10^{14} n/cm²s at $E > 1$ MeV) fluxes that can be made available in different volumes in the core and a wide variety of available irradiation rigs, BR2 is used to irradiate all kinds of nuclear fuels and materials for different reactor types (GenII/III and GenIV, SMRs and research reactors) and the European nuclear fusion programme. The operating licence of the BR2 reactor allows the use of several kg of sodium or sodium-potassium in the core, providing a direct opportunity to perform irradiations related to the Generation IV SFR or Na-cooled SMR types. The BR2 reactor also has experience with irradiations in lead-bismuth eutectic for supporting the development of LFR-type Generation IV reactors and the SCK•CEN MYRRHA project.

Some of the irradiation devices available for direct use:

- **BAMI:** The BAMI capsules are un-instrumented capsules that can be loaded in irradiation positions inside the central channel of the tubular BR2 fuel elements or in standard channels, replacing a fuel element. Up to eight capsules are loaded in one irradiation position. The capsules can be loaded in the primary water flow (entire cycle irradiation) or in a thimble tube device (flexible irradiation time). The capsules can be open to the water (irradiation temperature $< 100^\circ\text{C}$) or can be gas filled, in which case the irradiation temperature is determined by the irradiation position, the mass and composition of the samples, the composition of the gas (typically He) and the spacing between the samples and the cold wall of the capsule. The BAMI capsules offer the lowest cost and lead time for irradiating structural material samples.
- **ROBIN:** The ROBIN device is loaded in a thimble tube, inserted in a standard channel (flexible irradiation time). The specimens are encapsulated in closed pins (9 pins of diameter 11 mm). The irradiation temperature is determined by the design of the pins and is controlled by adjusting the water flow in the thimble. In order to avoid boiling, the positioning of the experiment is limited to relatively low flux positions. The temperature in the samples is monitored by adding an instrumented dummy capsule with identical design as the specimen pins.
- **LIBERTY:** The LIBERTY device is also loaded inside a thimble tube in a standard channel (flexible irradiation time). Compared to the ROBIN device, there can be only five sample pins, but the pins are larger in diameter (16 mm inside) and can be equipped with active temperature control by integrated electrical heating and temperature measurement. In this way, specimens can be preheated before the start of irradiation. The fluxes in LIBERTY are similar to the ones in ROBIN.
- **MISTRAL:** The MISTRAL device is inserted in the central channel of a fuel element and offers active temperature control in a boiling water environment. The MISTRAL device is designed to irradiate a large number (87) of miniature specimens (5 mm diameter or 3×4 mm² cross-section and length of 27 mm) in stable temperature conditions (160°C - 350°C) with medium to high fast flux level (up to 2.5×10^{14} n/cm²s, $E > 1$ MeV). The rig can be reloaded, so lead times for experiments are limited as well as the rig costs. Of the 87 specimens, 26 are located in the zone having over 90% of the maximum flux in the rig. The irradiation temperature is monitored by measurement inside dummy specimens and the irradiation temperature is actively controlled by electrical heating if the nuclear heating is insufficient (during startup and shut down of the reactor).
- **HTHF:** The HTHF rig is a gas filled capsule for irradiating materials at maximum fast flux (2.8×10^{14} n/cm²s, $E > 1$ MeV) in the central channel of a standard fuel element and at an actively controlled temperature up to $1\ 000^\circ\text{C}$. This capsule is constructed of graphite, allowing high-temperature stability and heat evacuation under the highest fluxes available in

the BR2 reactor. The design is adjusted according to the experimental needs (specimen number and geometry, temperature range) and the capsules are single use. However, capsule cost and experiment lead time are controlled by the generic design and the reuse of the out-of-pile control equipment. Several driver fuel elements with comparable neutronic conditions are available, which allows for the simultaneous irradiation of multiple HTHF devices, for example to compare different materials or generate data at different irradiation temperatures.

- **RECALL:** The RECALL device is a pressurised water capsule device with small flow rate, loaded in a standard channel. The device allows accurate active temperature control in the range from 250 to 320°C, before as well as during and after irradiation. The device is loaded for the entire reactor cycle and allows to irradiate 24 standard Charpy V specimens within a homogeneous flux zone (+/-15% axial deviation). The positioning of the device is flexible in order to achieve between 0.05 and 0.15 dpa in steel in one reactor cycle. The device is reusable, offering very short lead times for experiments.
- **PWC/CD:** The pressurised water capsule (PWC-CD) for fuel pin irradiation is an instrumented capsule that can be used for base irradiation of fuel pins up to 1 metre long, with online power monitoring and control of the cladding temperature by setting the water pressure in the capsule. The device can also be used for transient testing, either by loading a mobile absorber in the vicinity (multiple transients with small amplitude) or by varying the overall reactor power (large single transients). The setup of the device is such that fuel pin failure can be tolerated. Eventually, a fuel pin with instrumentation can also be loaded in the device.
- **FUTURE:** Material test reactor fuel plates can be irradiated in the primary water of the BR2 reactor in different ways. The most straightforward way for flat plate irradiations is the use of the so-called FUTURE basket. Up to four flat fuel plates can be loaded in this basket, replacing a standard fuel element of the reactor. Fuel plate failure can be tolerated up to the contamination limit of the primary water. The environment of the basket is adapted in order to achieve the desired power level in the basket.
- **Custom rigs:** SCK•CEN has its own team of irradiation rig designers and engineers, which permits the construction of dedicated irradiation rigs for the purpose of specific experiments. Rigs for in situ creep, fatigue or tensile testing, sodium or NaK filled rigs for fast reactor fuel irradiations, severe accident testing in dedicated rigs for fuel rod failure or melting, coolant flow booster rigs for simulating thermo-hydraulic conditions in other research reactors, etc. have all been constructed and used in the past and an invaluable database of historic safety studies and rig designs is available as a basis for modern experiments. Also the use of irradiation rigs designed and constructed by users from outside of SCK•CEN is accepted through the general safety review process (3-phase CEE-process).

Transports from the BR2 reactor to the LHMA hot lab facilities are on-site and can be performed even between cycles with non-destructive hot cell measurements on fuel rods possible before returning the rods to the reactor for continued irradiation. The rapid turnaround the proximity of the reactor and the hotlab offers is demonstrated in particular when confronted with requests from the safety authorities or urgent requests from users. BR2 and LHMA have shown to be capable of designing an irradiation, preparing the specimens, loading the rig, irradiating, dismantling and transporting it, performing the mechanical testing on the specimens and reporting within the span of 3 months. The LHMA hotlab offers a wide variety of post-irradiation examination capabilities in hot cell, including a full range of mechanical testing (tensile, impact, bend testing, ...), corrosion testing (SSRT in autoclave in hot cell), non-destructive fuel analyses (metrology, gamma spectrometry, integrity analyses, etc.), microscopy and spectroscopy tools (optical, SEM, EPMA, FIB, TEM, XRD, etc.) with their associated sample preparation suites.

4.4. China

There are many user facilities in China dedicated to research on nuclear reactor materials under irradiation, for example High-flux engineering test reactor (HFETR), synchrotron light sources (*SSRF*, *BSRF*), research reactors (*CARR*) and ion beams (*ANMT*, *NPTSCL*). However, only a few of these facilities are available for the study of radioactive materials due to the unique hazards and risks relative to equipment contamination. Although HFETR could be used for material testing, at this stage, the user facilities for irradiation experiments in China are mainly ion beams, with energies ranging from tens of keV to GeV and dual-beam even triple-beam facilities are in construction. In addition, many useful state-of-the art facilities, such as TEM, SEM, XRD, AFM, FIB, are distributed in many non-nuclear applications.

- High-flux engineering test reactor (HFETR)

The HFETR is a vessel-type reactor by using light water as coolant and moderator and has been designed with power of 125 MW. It has operated for last 35 years in support of R&D for Generation II and III reactors in China. Supported by its excellent capability, such as, during normal operation condition, the maximum fast neutron flux is up to 1.7×10^{15} n/cm²/s, maximum thermal neutron flux is up to 6.2×10^{14} n/cm²/s, 9 large sized vertical channels (diameter up to 220 mm) are located in core for engineering testing and material experiment, HFETR had been involved in the development of Generation IV technologies. HFETR will play an important role in the next generation reactor R&D in the near future.

In order to develop a multiply range of neutron flux for the new reactor material and elements testing, Min Jiang test reactor (MJTR) was built as another test reactor providing slight lower neutron flux with the operational power ~5 MW. Relying on these test reactors operated in last decades, the large complex including the hot cells and affiliated facilities, had been gradually formed. It accomplished all the examination and testing missions downstream the test reactors both in engineering testing and fundamental experiments.

4.5. France

In France, the main Materials Test Reactor has been the OSIRIS reactor, which stopped operation at the end of 2015. The future JHR is currently under construction, and was described above.

The High-Flux Reactor at Grenoble, operated by the Laue-Langevin Institute within the framework of a multinational partnership, stands as the most performing continuous neutron source in the world. In addition, in Europe, the huge needs of the scientific community has led to the setting up of several neutron domestic sources, especially the ORPHEE/LLB facility at Saclay (14 MW, 1980), and more recently, FRM-II in Germany (TUM, 20 MW, 2004).

Each of these facilities is coupled with a beam research reactor, which is operated as a neutron source and an experimentation team in charge of developing and operating the spectrometers of the experimental areas. In the case of ORPHEE/LLB, reactor operation is assumed by the Nuclear Energy Division, and the experimental part by a CEA/CNRS joint unit, the Leon Brillouin Laboratory (a unit integrated in the CEA Fundamental Research Division).

In France, the CNRS and the CEA, in agreement with the French Ministry of Higher Education and Research, have set up a national network of accelerators dedicated to materials irradiation. This network consists of five platforms with unique equipment and specific expertise:

- JANNuS-Saclay facility at CEA Université Paris-Saclay (triple-beam facility with capability for high-dose rate);
- JANNuS-Orsay Facility at CSNSM Université Paris-Saclay (in situ dual beam);

- CEMTHI facility (cyclotron, proton beam, PAS);
- CIMAP facility at GANIL (very-high-energy ions);
- LSI facility (electron beam);
- THT facility at CEA Université Paris-Saclay (in situ electron beam).

Two additional facilities are in operation:

- the ARRONAX (Accélérateur pour la Recherche en Radiochimie et Oncologie à Nantes Atlantique) facility in Nantes (a high-intensity light ion beam);
- the ANAFIRE facility in Lyon are able to perform radiolysis studies on materials.

France also hosts two synchrotron facilities:

- ESRF European Synchrotron Radiation Facility;
- SOLEIL Synchrotron.

Both facilities can be used for materials investigations. In particular, the MARS beam line at SOLEIL Synchrotron is dedicated to study of radioactive materials.

Finally, CEA offers traditional PIE facilities for examination on fuel (Cadarache), on structural and cladding materials (Saclay) and waste management studies (Marcoule). New hot cells capabilities are under investigation at Cadarache adjacent to the JHR reactor. The private nuclear sector also operates hot cells and PIE capabilities.

4.6. Russia

Russian nuclear research facilities offer a large range of possibilities for domestic and foreign investigators, with a large and diverse mix of research reactors that offer a wide range of parameters. They include pool-type research reactors, pressure-tube tank-in-pool reactors, such as MIR, that were designed for in-pile material simultaneous testing for various reactor designs.

The next stage of development is the multipurpose new generation of fast reactor, MBIR. Its experimental capabilities are not only for materials study but also for conducting a whole spectrum of investigations with intensive fast neutron fluxes.

The considerable number of Russian critical assemblies, which are referred to as “zero power reactors”, provided a significant input into reactor materials experimental studies.

- JSC “SSC RF – IPPE” User Facilities

Forty-nine test facilities have been constructed at JSC “SSC RF – IPPE” to perform materials studies. They include five test facilities with lead-bismuth coolant and three with Na and Na-K to perform corrosion and endurance studies of structural materials for liquid-metal cooled reactors.

Sixteen of the test facilities are designed to conduct chemical and technological studies aimed at optimisation of nuclear power plant (NPP) operation conditions, research into high-temperature processes in circulation loops with liquid metal and water coolants.

The experimental facilities of the materials study complex allow implementing mechanical, acoustic, resistance, electron-microscopic, mass-spectrometric, X-ray, optical methods of reactor materials research.

The mechanisms of irradiation-induced swelling of materials and surface erosion are studied at the Tandetron and the EGP-15 accelerators.

Examples of R&D studies include:

- studies of variations of material mechanical properties by the depth of the surface layers after ion irradiations, irradiation-induced segregation;
- ion implantation of the elements into the surface area of crystals;
- variation of hydrogen permeability of the materials using the method of ion implantation doping;
- formation of micro relief on the surface for strengthening electron-physical properties and adhesion;
- build-up of various compositions on the surface using the ion mixing method.

Tandemtron can also be applied in microelectronics, in the study of ion-electron and ion-ion emission of semiconductors and in other areas of science and technology.

Post-radiation studies of fuel, structural, absorbing and moderating materials of nuclear reactors are carried out in the hot cell laboratory that includes 32 hot cells and 7 heavy boxes. They are used for dismantling and studying experimental and standard fuel pins, fuel assemblies, ampoules, units and products, material samples received from research and power reactors.

The hot cell laboratory is equipped with the state-of-the-art remote measurement devices, original NDA systems, a set of special equipment to perform optical and mechanical analyses and a complex of equipment to produce radiopharmaceuticals.

- The JSC “SSC RIAR” User Facilities

The State Scientific Centre of Russian Federation “Research Institute of Atomic Reactors” (RIAR) is a multifunctional nuclear research centre. At present, six research reactors are available at RIAR united in a single complex. There is also an experimental power facility with the VK-50 boiling reactor; Russia’s largest complex for post-irradiation examinations of full-scale components of nuclear reactors and irradiated materials; radiochemical complex for investigation and production of transuranic elements and various radioisotope products; equipment and facilities to perform research work in the field of fuel cycle and facilities for RW handling are available as well.

RIAR carries out research and experimental activities in the following directions:

- reactor testing and post-irradiation examination of materials and components of power and research reactors of different purposes aimed at the improvement of the existing NPP reactors and creation of innovative nuclear facilities;
- development and in-reactor testing of fuel, absorbing and structural materials of nuclear and fusion reactors;
- elaboration of radioisotope production technologies for the industrial and medical purposes and radioisotope production;
- investigations on the closed fuel cycle of nuclear reactors with the use of plutonium, fractioning and transmutation of long-living fission products.

4.7. Spain

The so-called Spanish singular scientific and technical infrastructures (ICTS) are large installations, resources, facilities and services, unique in its kind, that are dedicated to cutting edge and high-quality research and technological development, as well as to promote exchange, transmission and preservation of knowledge, technology transfer and innovation.

Its main objective is provision to national and international scientific, technological and industrial community of essential scientific and technical infrastructure for the development of a scientific and technological research unique or exceptional in its genre, with a very high cost of investment and maintenance and whose importance and strategic nature justifies their availability for the whole RD&I collective.

Therefore, the ICTS are infrastructures of PUBLIC-ownership, are UNIQUE and OPEN to competitive access to users of the whole research community in the public and private sector. The main ICTS facilities devoted to material characterisation are:

- ALBA Synchrotron Light Source;
- National Accelerator Centre;
- Centre for Micro Analysis of Materials;
- Advanced Microscopy Laboratory;
- National Centre for Advanced Microscopy.

4.8. United States

In many universities or other non-nuclear research organisations, state-of-the-art facilities and equipment for conducting materials characterisation studies exist, but it is not common for these facilities to be made available for the study of radioactive materials due to the unique hazards and risks relative to equipment contamination and loss of facility usage compared to the fraction of the customer base that would want to use them for these types studies. Thus, facilities willing and capable of handling radioactive materials are exceedingly valuable as user facilities in order to provide maximum impact to a diffuse user community.

There are a variety of instances where US user facilities have been utilised to advance understanding of nuclear reactor materials behaviour under irradiation. One of the critical stages of development of innovative structural materials for advanced reactor systems is to understand, on a fundamental level, how these materials will behave under irradiation. Synchrotron light sources, such as those available through a variety of user facilities (APS, SLAC, BNL) can provide a range of characterisation capabilities not available through other means. As an example, researchers have studied carbide stability in Mod 9Cr-1Mo ferritic-martensitic (F-M) steel following irradiation using the advanced photon source as a source for brilliant X-rays; conducting X-ray diffraction (XRD) and absorption (XAS) studies to evaluate amorphisation of carbides during irradiation. Similar capabilities have been used previously to study the formation behaviour of oxides on Zr-based alloys exposed in an LWR environment, providing greater insight into corrosion kinetics and degradation processes. The data collected from such studies is frequently used in the development of models that can predict materials degradation behaviour and provide insight into how future materials can be designed to minimise or eliminate deleterious property changes.

In addition to the synchrotron sources, the high-end micro-characterisation facilities such as those made available through several of the user facilities (CNMS, NCEM, ANL) can be invaluable to researchers trying to understand radiation damage in structural materials at the atomistic level. Extensive use of techniques like energy filtered transmission electron microscopy (TEM), aberration-corrected TEM and Atom Probe Tomography have been used to understand angstrom level microstructural and microchemical evolution in irradiated materials. Such techniques have been invaluable in understanding radiation-induced segregation in austenitic stainless steels, stability of oxide particles in ODS alloys and the formation of defect clusters in reactor pressure vessel steels that can lead to ageing embrittlement under irradiation. Most university based researchers do not have access to this type of high-end equipment for even mildly radioactive samples, and thus user facilities

that can handle such materials become invaluable in furthering scientific understanding and advancing innovative materials development for next generation reactor systems.

Traditional PIE capabilities at US DOE laboratories, universities, and in the private sector are widely distributed and lack the state-of-the-art capability necessary to meet the nuclear energy mission need. Current PIE capabilities will continue to be necessary to serve basic needs for fuel examination, material handling and waste disposal but are limited in their ability to function on the micro-, nano- and atomic-scale. The US Department of Energy-Nuclear Energy (DOE-NE) mission will be difficult to achieve without establishing a suitable nuclear facility environment that can accommodate these capabilities for research on highly radioactive fuels and materials. In addition, DOE seeks to make these capabilities available to the broader nuclear energy research community as a user facility concept, similar to DOE-NE's Nuclear Science User Facilities (formerly the Advanced Test Reactor National Scientific User Facility), to enable the United States to effectively harness the intellectual capital of the country to advance US research and development (R&D) goals and objectives.

The NSUF was established in 2007 to provide broader access to unique test reactor and post-irradiation examination facilities (PIE) located primarily at Idaho National Laboratory. Since then, the NSUF has established a network of distributed partnerships with multiple university, national laboratory and industrial PIE, research and test reactor facilities. The NSUF has awarded over 100 research projects utilising this unique distributed user facility approach. In total, this collaborative network has proved instrumental in expanding the scope and impact of a broad range of nuclear fuel and materials research projects.

Idaho National Laboratory (INL) is the United States' only DOE laboratory with a core mission of supporting the development of nuclear energy. INL has a long history of performing PIE to support various DOE programmes and has an existing trained workforce, with considerable expertise in fuels and materials technology. This expertise forms a foundation to build upon as new capabilities are implemented and workload increases.

At INL, the core nuclear and radiological facilities needed to support PIE R&D capabilities already exist:

- Hot Fuel Examination Facility (HFEF) with neutron radiography capability, a large inert environment hot cell facility with the ability to receive and process large material and fuel components;
- Analytical Laboratory (AL), focused on analysis of irradiated and radioactive materials. (c) Electron Microscopy Laboratory (EML), radiological facility containing optical, scanning and analytical microscopes;
- Fuels and Applied Science Building (FASB), used for fuel development, materials characterisation and irradiated materials testing;
- Carbon Characterisation Laboratory (CCL), used to conduct both pre-irradiation and post-irradiation material property measurements of carbon/graphite materials;
- Centre for Advanced Energy Studies (CAES), by design, the CAES research facility operates in the same manner as universities do; in the case of low risk radiological research, this approach provides a cost-effective, innovative, and productive environment for exploring fundamental science questions and executing basic research complementary to research at INL site facilities.

The majority of these facilities exist at INL's Materials and Fuels Complex (MFC) while CCL and CAES are located at INL's Research and Education Campus (REC). INL also has close proximity to irradiation facilities like the advanced test reactor (ATR) and the Transient Reactor Experiment and Test (TREAT) facility. Recently many of these current capabilities, particularly the macroscopic

examination capabilities, have undergone or been scheduled for refurbishment. Collectively, the combined capabilities at INL now provide the most comprehensive capability in the United States.

The reinvigoration of nuclear fuels and materials research is bringing new and different tools to PIE and nuclear and radioactive materials characterisation. These new tools and the research materials examined with them, require unique, reconfigurable, accessible, modularised support facilities that are not presently available at INL.

The rapid evolution of analytical electron microscopes and the advent of high-performance computer interfaces with instruments were not envisioned when many of the existing facilities were constructed at INL. A new laboratory operational model will promote and support continual implementation of state-of-the-art tools and technologies.

To meet the needs of the future, INL is standing up new capabilities that have the sophistication and refinement to house next generation PIE characterisation equipment. The near term capability is the Irradiated Materials Characterisation Laboratory (IMCL); longer term, a second Sample Preparation Laboratory (SPL) will be devoted to advanced high-quality sample preparation for the high-end equipment located in IMCL and throughout the DOE research complex.

The DOE's ability to build a technical foundation to sustain the long-term contribution of nuclear generation to meet US energy needs will be significantly hampered without obtaining a fundamental understanding of irradiation behaviour at the nanoscale and below. All significant advances in nuclear energy technology will rely on the development of improved performance of fuels and more durable materials. Development of improved fuels and materials relies on the fundamental understanding of the effects of irradiation, which, in turn, relies on a programme that couples experimental investigation with modelling and simulation. Current PIE capability does not provide the information required to obtain the fundamental understanding to continue to advance nuclear technology as an economical and sustainable energy source.

For this reason, INL has embarked on a significant effort to expand its already extensive capability to perform PIE through the addition of physical capabilities to the addition of partnerships. These capabilities will be expanding with the installation of state-of-the-art nano- and atomic-scale characterisation equipment and the addition of IMCL and SPL, which will follow a reconfigurable and flexible design plan to ensure compatibility for performing advanced PIE on highly activated fuels and materials along with flexibility for future capabilities.

INL plans to incorporate all the necessary elements for successfully performing PIE and meeting the research needs to enable the advancement of nuclear energy. It allows parties interested in the advancement of scientific knowledge access to the powerful and versatile irradiation capabilities of the ATR and provides them with the diverse equipment and methods needed to analyse their experiment after irradiation. The quality of the programme will only improve with time as INL adds equipment and facilities to what is already available.

5. Recommendations for the use of user facilities for basic research in the field of materials under irradiation

It is recommended that a user facility is best managed for external use to advance scientific or technical knowledge under the following key conditions:

- The facility is open to all interested potential users without regard to nationality or institutional affiliation.
- Allocation of facility resources is determined by merit review of the proposed work.
- User fees are not charged for non-proprietary work if the user intends to publish the research results in the open literature. Full cost recovery is required for proprietary work.
- The facility provides resources sufficient for users to conduct work safely and efficiently.
- The facility supports a formal user organisation to represent the users and facilitate sharing of information, forming collaborations and organising research efforts among users.
- The facility capability does not compete with an available private sector capability.

Experience shows that due to the unique circumstances to conduct nuclear systems work, the following points will improve the operation and efficiency of these kinds of facilities:

- Research on nuclear systems takes much longer than conventional testing. Investigators need to be warned that high hazard nuclear systems work takes much more time than conventional non-radiological testing. When planning to do these types of experiments, users should plan on taking two to three times longer to generate data. Co-location of instruments and resources in strategic locations helps to reduce risk and time and increase efficiency.
- Allocation of internal funds to support research projects needs to be done on a multi-year basis and not on a yearly basis. This is due to the length of time often required to do these kinds of experiments: budgets need to be planned and funds committed on a multi-year basis.
- A successful user facility also needs to have in-house technical experts with knowledge of how to conduct these kinds of experiments and knowledge of the science behind the experiments to support the development of good proposals and research questions.
- Successful user facilities also maintain cross-cutting core capabilities for conducting nuclear systems research that are independent of changes in external research direction.
- User facilities also play a role in helping educate current or potential users on the issues and tools available to address research questions through conferences, workshops and user meetings.
- A successful user facility should support research that is evolutionary but more importantly they should provide a clear and accessible pathway for revolutionary concepts to move forward to testing.

References

NEA (2001), Nuclear Safety Research in OECD Countries. Summary Report of Major Facilities and Programmes at Risk, OECD, Paris

NEA (2003), Research and Development Needs for Current and Future Energy Systems, OECD, Paris

NEA (2007), Support Facilities for Existing and Advanced Reactors (SFEAR), Report of the Senior Group of Experts on Nuclear Safety Research (SESAR), OECD, Paris

NEA (2009), Research and Test Facilities Required in Nuclear Science and Technology, OECD, Paris

6. Appendix: User facility data sheets

6.1. Belgium

6.1.1. Belgian Reactor No. 2 (BR-2) with Laboratory for High and Medium Activity (LHMA)

Location:

BR2 is located at SCK•CEN, Mol, Belgium

Web address:

Information on the facility can be found on the following links:

www.sckcen.be/en/Research/Infrastructure/BR2

www.sckcen.be/en/Research/Infrastructure/Labos

<http://academy.sckcen.be>

Category:

Test reactor and hot lab

Facility description:

- BR2: ~80 irradiation channels with different flux levels combined with different irradiation rigs for irradiation of materials and fuels;
- LHMA: ~25 hot cells with various post-irradiation examination equipment for mechanical testing (tensile, impact, bend testing, SSRT in autoclave for IASCC, ...), non-destructive analyses (irradiated fuel) and microstructural analyses (OM, SEM, TEM, XRD, FIB, ...).

Annual number of users:

- ~70 PhD students, 15-25 new ones each year (not all using the BR2/LHMA);
- ~130 scientific visitors, post-docs, Bachelor/Master students and interns on annual basis (not all using the BR2/LHMA).

User interface:

- SCK•CEN Academy hosts scientific visitors and students (Bachelor, Master, PhD, postdoc, for thesis work or internship) (http://academy.sckcen.be/en/Your_thesis_internship).
- Reactor stakeholder manager (S. Van den Berghe, svdbergh@sckcen.be) or Business development office (business@sckcen.be) as contact point for requesting information or access.
- BR2 safety review process (CEE-process) through internal procedures.

User amenities:

- SCK•CEN operates its own residential neighbourhood (dormitory, apartments, studios, etc.) (www.sckcen.be/en/About/Behind_scenes/Residence).
- The Lakehouse is a hotel/restaurant serving as the SCK•CEN Guesthouse (<http://lakehouse.sckcen.be/>).
- SCK•CEN has a cafeteria on-site.
- The Sports club is a fully equipped sports centre operated jointly by the nuclear companies in the vicinity (www.nuclea.be/).

User organisation:

- The SCK•CEN Academy for Nuclear Science and Technology (<http://academy.sckcen.be>) serves as a user organisation and provides users with a framework and guidance. A buddy system is used in which experienced PhD students will help new PhD students to get acquainted with the SCK•CEN and more broadly living in the Mol area.
- The SCK•CEN and more particularly the BR2 reactor is currently in review for an ICERR certification by the IAEA as an International Centre of Excellence operating a Research Reactor (www.iaea.org/sites/default/files/18/09/sckcen-belgium.pdf).
- SCK•CEN is actively working to develop a European version of the US NSUF system (<https://nsuf.inl.gov/>) in which the open access to the BR2 reactor and the LHMA hot lab would be included.

Table 1. Belgium user facilities for nuclear materials work list

User facility	Website
Belgian Reactor No. 2 (BR-2) with Laboratory for High and Medium Activity (LHMA)	www.sckcen.be/en/Research/Infrastructure/BR2 www.sckcen.be/en/Research/Infrastructure/Labos http://academy.sckcen.be

6.2. China**6.2.1. High-Flux Engineering Test Reactor (HFETR) and Min Jiang Test Reactor (MJTR)***Location:*

HFETR and MJTR are located at the Nuclear Power Institute of China (NPIC), China National Nuclear Corporation, No.328, Section 1, Changshun Avenue, Shuangliu sub-district, Chengdu, 610200 China.

Web address:

<http://en.npic.ac.cn>

Category:

Test Reactor

Facility description:

HFETR has been involved in commercial nuclear power plant fuel elements irradiation testing, reactor structural materials testing, high-specific activity radioisotopes R&D. HFETR has already operated safely over 35 years, and built the capability of PIE devices. It currently includes the facilities of HFETR, MJTR and affiliated post-irradiation examination (PIE). Key parameters for the instruments are listed in the following.

- HFETR (High-Flux Engineering Test Reactor)
 - design power: 125 MW;
 - reactor type: tank;
 - core height: 1 000 mm;
 - maximum thermal neutron flux: 6.2×10^{14} n/(cm²·s);
 - maximum fast neutron flux: 1.7×10^{15} n/(cm²·s);
 - fuel and material test loops: 2;
 - vertical channels: 9 (diameter larger than 150 mm).
- MJTR (Min Jiang Test Reactor)
 - fuel: discharged fuel of HFETR;
 - reactor type: pool;
 - core height: 1 000 mm;
 - maximum thermal neutron flux: 7.3×10^{13} n/(cm²·s);
 - maximum fast neutron flux: 1.3×10^{14} n/(cm²·s);
 - vertical channels: 9 (diameter larger than 120 mm).

In addition, PIE instruments, including TEM, SEM, UT, DSC and a series of mechanical test machines are available, for non-destructive testing, physical and mechanical properties testing, metallurgical studies, burn-up determination and materials chemistry heat-carrying agent chemical.

Annual number of user:

The annual number of users depends on operational days of HFETR and MJTR.

User interface:

Requests for irradiation time are submitted by proposal. Contact can be made directly with the NPIC user office (Sun Shou-hua, email: 1319049712@qq.com).

User amenities:

The NPIC Guest House provides accommodation for all users, with a 15-minutes' walk to HFETR. Lodging is available at a range of local hotels for short stay and rental accommodation for longer stay.

Users organisation:

Annual user's meeting

6.2.2. Shanghai Synchrotron Radiation Facility (SSRF)

Location:

SSRF is located at the National Science Centre (in preparation), 239 Zhangheng Road, Pudong New District, Shanghai 201204, P. R. China

Web address:

<http://e-ssrf.sinap.cas.cn/>

Category:

Synchrotron light source

Facility description: 14 operating beam lines

- infrared beamline;
 - soft X-ray spectromicroscopy beamline;
 - soft X-ray interference lithography beamline (XIL);
 - high-resolution and wide energy range photoemission spectroscopy;
 - beamline (dreamline);
 - X-ray imaging and biomedical applications beamline;
 - X-ray absorption fine structure spectroscopy beamline (XAFS);
 - X-ray diffraction beamline;
 - hard X-ray micro-focusing beamline;
 - small-angle X-ray scattering beamline (SAXS);
 - macromolecular crystallography beamline;
 - high-throughput protein crystallography beamline;
 - protein micro-crystallography beamline;
 - protein complex crystallography beamline;
 - biological small-angle X-ray scattering beamline (BioSAXS).
- storage ring
 - The 3.5 GeV SSRF storage ring lattice is a 20-cell double bend achromat lattice structure with 4 super-periods and each super-period contains a 12 metres long straight section and four 6.5 meters standard straight sections. Two of the long straight sections have been used for accommodating injection elements and for installing three superconducting radio-frequency (RF) cavities respectively, the other eighteen straight sections are used to install various insertion devices.

- storage ring parameters.

Injection energy (GeV)		0.15
Extraction energy (GeV)		3.5
Beam current (mA)	Single bunch	1.6
	Multi bunch	10
Circumference (m)		180
Cell number/Super-periods		28/2
Natural emittance (nm rad)		108
Betatron tune (n_H/n_V)		8.18/5.22
Nature momentum spread		7.799×10^{-4}
RF frequency (MHz)		499.65
RF voltage (MV)		1.8
Repetition rate (Hz)		2

Annual number of users:

More than 2 000 users work on more than 1 000 projects.

User interface:

Access is granted through merit-based peer review of submitted research proposals. The SSRF conducts two open solicitations each year (every April and October).

For very important experiments which are not time-consuming, the application is open at any time throughout the year and the kind of experiment can be performed after the discussion of the laboratory director and the corresponding experts. Besides, there is an extra application for general important projects every June.

Contracting with SSRF user office (ssrf-user@sinap.ac.cn) and visit a SSRF website (<http://ssrf.sinap.ac.cn/proposals/>) for getting detail information about proposal submission.

User amenities:

Chemical Sample Preparation Room, Biochemical Laboratory, the SSRF Users' Office

The SSRF users' office is mainly responsible for issues related to users. The main responsibility of users' office includes:

- user registration, user cards printing, distributing and collecting;
- completing user forms and necessary training;
- proposals for beam time;
- radiometry distribution and collecting;
- accommodation for Guest House;
- annual users' meeting's organisation.

User organisation:

Annual users' meeting is organised.

The SSRF is managed by the SSRF National Science Centre (in preparation). The Shanghai Institute of Applied Physics, Chinese Academy of Science is in charge of the light source management.

6.2.3. Beijing Synchrotron Radiation Facility (BSRF)

Location:

BSRF is located at the Institute of High Energy Physics (IHEP) of the Chinese Academy of Sciences, 19 Yuquan Road, Haidian District, Beijing 100049, China.

Web address:

<http://english.ihep.cas.cn/rs/fs/srl/>

Category:

Synchrotron light source

Facility description:

Three experimental halls including 14 beam lines providing synchrotron radiation photons from Vacuum UV to hard x-rays. X-ray imaging technology, GIXRD, SAXS, X-ray fluorescence, LIGA and X-ray lithography, etc.

Annual number of users:

More than 1 000 users registered from more than 100 affiliations.

User interface:

Access is granted through merit-based peer review of submitted research proposals. The BSRF conducts two open solicitations each year (every March and September).

For very important non-time-consuming experiments, the application is open at any time throughout the year and the kind of experiment can be performed after the discussion of the laboratory director and the corresponding experts.

User amenities:

No on-site amenities but amenities can be found in Beijing.

User organisation:

The BSRF is managed by the Beijing Electron Positron Collider National Laboratory. As a part of Beijing Electron Positron Collider (BEPC) project, Beijing Synchrotron Radiation Facility (BSRF) was constructed almost in parallel with BEPC and has been opened to users since 1991.

A scientific committee has been appointed by the National Laboratory to manage the facility. This committee reviews the quality and the timelines of the research programmes and advises the National Laboratory on the performance of the BSRF and the update of the beamlines in meetings its objectives.

The BSRF also has an independent users group consisting of 18 experts. The users group represents users of the facility. Their role is to advocate for the facility and to facilitate the sharing of information, forming collaboration and organising research efforts among users.

6.2.4. National Synchrotron Radiation Laboratory (NSRL)

Location:

NSRL can be found on the Western Campus of the University of Science and Technology of China, No.42 Hezuohua South Road, Shushan District, Hefei, Anhui, P.R.China 230029.

Web address:

<http://en.nsrl.ustc.edu.cn/>

Category:

Synchrotron light source

Facility description:

NSRL is the first dedicated synchrotron radiation facility in China, which is affiliated with University of Science and Technology of China (USTC) and locates on the West Campus of USTC, in Hefei, Anhui Province.

It is one of the key issues of China's investments on large-scale scientific research facilities. Its construction began on Nov. 20, 1984, and was completed with a national review in December 1991. After Phase II Project from 1999 to 2004 and Upgrading from 2012 to 2014, NSRL now owns a fully upgraded soft X-ray synchrotron radiation facility. The synchrotron radiation is close to the 3rd generation light source level, and the facility is now with ten ready-to-use end stations.

Ten beamlines are operating:

- infrared spectroscopy and micro-spectroscopy;
- combustion and flame;
- mass spectrometry;
- soft X-ray microscopy;
- spectral radiation standard and metrology;
- atomic and molecular physics;
- photoelectron spectroscopy;
- catalysis and surface science;
- X-ray magnetic circular dichroism;
- angle resolved photoemission spectroscopy.

Annual number of users:

More than 100 registered affiliations and 350 programmes in total.

User interface:

NSRL accept users and applications throughout the year. All experimental stations are open to users. Users can apply for the beam time through the website www.nsrl.ustc.edu.cn/User/News/201501/t20150130_211210.html (Chinese Version) and mail your application form at the same time.

Also, the user office can be contacted directly.

User office:

Jiang Fang

Tel: 0551-63602018

Fax: 0551-65141078

Email: jiangf@ustc.edu.cn

User amenities:

The Guest House which is located nearby the laboratory is provided for users. You can get accommodation after you check in. You can contact the user office to get detailed information.

User organisation:

The National Synchrotron Radiation Laboratory (NSRL), located in the west campus of the USTC, is the first dedicated synchrotron radiation facility in China.

A User & Experts Advisors Committee has been founded by NSRL to manage the whole facility for all users. According to the feasibility and importance of the user's application, the committee arranges a reasonable experimental time based on the discussion of committee experts. If the user cannot conduct the experiment in the scheduled time, the User Committee will arrange another time according to particular circumstances.

6.2.5. China Advanced Research Reactor (CARR)*Location:*

CARR is based at the China Institute of Atomic Energy (CIAE), Beijing, China.

Web address:

www.ciae.ac.cn

Category:

Research Reactor (60 MW)

Facility description:

Irradiation and production of radionuclides

- Sixteen vertical channels with different diameters and different neutron flux level and the automatic processing transportation systems can be used for production of radio isotopes in industrial scale, which are widely used in national defence, in scientific researches, in radio medicine, in industry and agriculture.

In-pile (irradiation) tests

- To meet the need of conducting experimental researches of nuclear fuels, structural materials and component elements, specific testing facilities or systems have been built for carrying out irradiation tests, such as the high-temperature high-pressure testing loop for irradiation test of high-performance nuclear fuel elements.

Neutron scattering facilities:

- High-Resolution Powder Diffractometer (HRPD);

- High-Intensity Powder Diffractometer (HIPD);
- Four-Circle Neutron Diffractometer (FCD);
- Residual Stress instrument (RSI);
- Texture Diffractometer (TD);
- Thermal Triple Axis Spectrometer (Thermal-TAS I);
- Thermal Triple Axis Spectrometer (Thermal-TAS II);
- Small-Angle Neutron Spectrometer (SANS);
- Vertical Neutron Reflectometer (REF-V) (under construction);
- Cold Triple Axis Spectrometer (Cold-TAS)(under construction);
- Multi-Axis Crystal Spectrometer (MACS)(under construction);
- Industrial Application Diffractometer (IAD)(under construction);

Neutron Imaging Facilities: (under construction):

- Thermal Neutron Imaging Facility(TNI);
- Cold Neutron Imaging Facility(CNI);

Neutron activation analysis facilities: (under construction):

- Neutron Activation Analysis System (NAA System);
- Prompt Gamma Thermal Neutron Activation Analysis (PGAA System I);
- Prompt Gamma Cold Neutron Activation Analysis (PGAA System II).

User organisation:

CARR is owned and operated by the CIAE. The 60-MW China Advanced Research Reactor (CARR) at CIAE has reached the first criticality in May, 2010 and got full power in March 2012. It is a tank-in-pool-type reactor using a D2 reflector for inverse neutron trap, and the expected maximum undisturbed thermal neutron flux is 8×10^{14} n/cm².s. The reactor experiment hall houses a set of instruments connecting to nine horizontal neutron beam tubes. Additionally, cold neutrons produced by a liquid hydrogen cold source are transported via six guide systems to the 30×60 m² guide hall, where a suite of scattering instruments are placed.

As a multipurpose research reactor, CARR is devoted to neutron scattering, neutron imaging, radioisotopes production, neutron transmutation doping silicon and neutron activation analysis, etc. As the major research field, the Neutron Scattering Laboratory at CARR (NSL-CARR) is responsible for neutron scattering and neutron imaging research programmes, opening to users from universities, industry and government labs in China and abroad.

Since 2004, the neutron scattering user meeting was held every year in China. Its goal is to promote communications and collaborations between neutron sources and users. At present, more and more Chinese scientists have found the unique capabilities of neutron scattering method and the requirements are increasing rapidly. In future, there will be a large neutron scattering user community in China. Mission of NSL-CARR is just dedicated to serve neutron users from China and abroad for materials research with reliably optimised, progressively upgradable, and safely operated facilities and a devoted staff.

6.2.6. Beijing Radioactive Ion beam Facilities (BRIF)

Location:

BRIF is located at the CIAE, Beijing, China.

Web address:

www.ciae.ac.cn/eng/brif/index.htm

Category:

Ion beam

Facility description: proton cyclotron: 100 MeV, 200 μ A;

- isotope separator online (ISOL): mass resolution of 20 000;
- tandem accelerator: H to U beams, 13 MV terminal voltage;
- superconducting LINAC: boost the beam energy by 2 MeV/q;
- Q3D spectrograph: momentum resolution of 10 000.

Annual number of users:

About 50 experiments per year are performed at tandem accelerator. More users will be expected following operation of proton cyclotron, ISOL and LINAC.

User interface:

Contacting directly with user office (email: hi-13nl@ciae.ac.cn) for getting detail information about proposal submission. All proposals should be sent to user office by email.

User amenities:

The Guest House of CIAE provides accommodation, food and beverage service.

User organisation:

The Programme Advisory Committee (PAC) is responsible for review of submitted proposals. The PAC meeting is held at the end of each year.

6.2.7. Heavy Ion Research Facility in Lanzhou (HIRFL)

Location:

HIRFL is based at the Institute of Modern Physics (IMP), Chinese Academy of Sciences, Lanzhou, 730000, China.

Website:

<http://english.imp.cas.cn/rs/fs/>

Category:

Ion Beam

Facility description:

The Heavy Ion Research Facility in Lanzhou (HIRFL) consists of the sector focusing cyclotron (SFC), the separated sector cyclotron (SSC), the cooler storage ring (CSR) and a number of experimental terminals. After half a century of development, it became the largest facility producing high-energy heavy ions in China. As a national laboratory, HIRFL is opened to national and international users. HIRFL produces medium and high-energy ion beams from proton to uranium. In recent years, HIRFL has operated 7 000 hours each year and delivered 5 000 hours of beam time for experiments. At HIRFL, numerical fundamental researches in nuclear, atomic physics, biology and material science have been conducted. The main research focuses on nuclear reactions, nuclear spectroscopy, the properties of nuclear matter, the chemistry of super-heavy elements and synthesis of new super-heavy isotopes, key reactions in stellar evolution, high-energy density physics, highly charged heavy ion interactions, cancer therapy and irradiation effects in materials and electronic devices.

There are currently three terminals available for irradiation effects of materials. They are TR-3 (at SSC) and SFC-T1 and T2 (both at SFC). The terminals include energy degraders (which can facilitate the homogenous distribution of radiation damage and injected ions in specimens), specimen stage (with temperature control from liquid-N₂ cooling to 900 K). The typical energy of ions is around 30 MeV/u at TR-3 and is around 6 MeV/u at SFC-T1 and T2. The beam intensity is around 1 000 enA.

Annual number of users:

About 120

User interface:

Access is granted through merit-based peer review of submitted research proposals. HIRFL conduct one call every year (in March). Contact can be made directly with S&T office at IMP (hirfl@impcas.ac.cn).

User amenities:

HIRFL is situated at Institute of Modern Physics (IMP), CAS in Lanzhou, China. Lodging is available at a range of local hotels for short stay and rental accommodation for longer stay.

User organisation:

The facilities of HIRFL are opened to any users.

6.2.8. Advanced Nuclear Materials Testing Facility (ANMT)*Location:*

ANMT is located at Institute of Modern Physics (IMP), Chinese Academy of Sciences, 509 Nanchang Road, Lanzhou, 730000 China.

Web address:

<http://english.imp.cas.cn/rs/fs/>

Category:

Ion Beam

Facility description:

ANMT is one-of-a-kind research facility that provides intense heavy ion beams for scientific research of advanced nuclear structural materials. ANMT currently has four instruments which are specially designed to study properties and performances of novel materials on irradiation resistance, swelling resistance, liquid-metal corrosion and synergistic effects. Key parameters for the four instruments are listed in the following:

- 320 KV Multifunctional research platform
 - ion: P- U;
 - charge: high charge state such as Xe^{n+} ($n \leq 27$);
 - energy: 25 kV- 320 kV;
 - beam current: 0.1- 100.0 μA ;
 - irradiation temperature: RT-1200⁰C;
 - displacement detection system;
 - with two high precision raster scanners (larger than 20×20 mm²).
- In-beam creep test apparatus

This instrument is installed at the HIRFL for material studies under high temperature and high stress.

- ion: P- U;
- energy: 1.0-10.0 MeV/u;
- beam current: 0.5-15.0 μA ;
- test temperature: RT-1200⁰C;
- maximum load: 1 000 N;
- displacement detection system;
- two high precision raster scanners;
- with energy-degrade device.
- High-temperature irradiation instrument

This equipment consists of ion beam scanning and detector system, high-temperature load system, stress load system, water cooling system as well as telecommunication and control system. The x-y scanning area with high uniformity is larger than 40 mm × 40 mm.

- ion: P-U;
- energy: 1.0-10.0 MeV/u;
- beam current: 0.1-2.0 μA ;
- irradiation temperature: RT-1200⁰C;
- maximum load: 1 200 N;
- two high precision scanners.

In addition, TEM, SEM and a series of mechanical test machines are available for materials characterisation.

- LBE corrosion/ion irradiation synergistic effect instrument

It is a research platform that can fast simulate synergistic effect of liquid-metal corrosion and neutron irradiation.

- temperature : 200-600⁰C;
- liquid-metal flow velocity: 0-2.0 m/s;
- ion: C- U;
- ion energy: 0.08-8.5MeV/u.

Annual number of users:

Annual number of users will depend on operational hours of 320 kV accelerator and HIRFL. In recent years, a 320 kV accelerator has operated for 8 000 hours each year and delivered over 7 000 hours of beam for experiments.

User interface:

Requests for beam time should be submitted through a proposal. Contact can be made directly with IMP user office (email: office@impcas.ac.cn) or visit IMP website (<http://english.imp.cas.cn/>) for getting detail information about proposal submission.

User amenities:

The IMP Guest House provides accommodation for all users, within a short walk to IMP. Lodging is available at a range of local hotels for short stay and rental accommodation for longer stay.

User organisation:

Annual user's meeting

6.2.9. EN Tandem Accelerator; 4.5 MV Van de Graaff Accelerator and 2 x 1.7 MV SDH2 Tandem Accelerator

Location:

EN is located at the State Key Laboratory of Nuclear Physics and Technology (SKLNPT), Peking University, Beijing, China.

Website:

<http://sklnpt.pku.edu.cn/english/>

Category:

Ion Beam

Facility description: EN tandem accelerator:

The EN tandem accelerator at Peking University was manufactured by the European High-Voltage Engineering Corporation (HVEC) in 1962. It was running in Oxford University before 1985 before being delivered to Peking University. This machine is one of the three main accelerators having the ability to supply heavy ions with energy larger than 10 MeV in China. At present, the high-energy particles of H, C, O, Si, Cl, Br can be supplied to various experiments and the energy ranging from

3-50 MeV depending on the type of the particles and ion charge state. The basic research experiments in biology, nuclear materials and semiconductors have been carried out using this machine.

- 4.5 MV Van de Graaff accelerator:

4.5 MV Van de Graaff accelerator was designed and constructed at Peking University and it has been operated over 20 years. This facility has been used in research about the cross-section measurement of nuclear reaction, neutron emission spectrometry diagnostics for Tokamak, irradiation of nuclear materials. There are two beam lines assembled, irradiation beam line and nuclear reaction beam line. This accelerator could supply four kinds of ion, H, D, ^4He and ^3He . The energy range will be from 0.7-3.5 MeV and the ion current will be up to 10 μA . The system will consist of a vacuum chamber combined with heating controlling, which can achieve the irradiation under 1 000 $^{\circ}\text{C}$. In addition, by coupling 2 \times 6 MV tandem accelerator and 4.5 MV single end electrostatic accelerator, a double beam irradiation system has been assembled and tested to study the synergistic effects of displacement damage, helium or hydrogen irradiation effects on microstructural changes of materials, as the experimental simulation of irradiation damage in reactors.

- 2 x 1.7 MV SDH2 tandem accelerator:

The 2 \times 1.7 MV tandem accelerator was purchased from National Electrostatics Corporation (NECV), US in 1985 and the model is 5SDH-2. It has been used for high-energy (MeV) ion implantation and irradiation and ion beam analysis (including proton fluorescence, nuclear reaction analysis, Rutherford Backscattering Spectroscopy (RBS), RBS channelling, Elastic Recoil Detection Analysis (ERDA), etc.). The accelerator can also produce different ions, cluster ions for material irradiation, ion implantation and mixing, atomic collisions, cluster physics, radiation-induced gene mutations and other areas. The chamber for nuclear material irradiation combined with heating controlling, which can achieve the irradiation under 1 000 $^{\circ}\text{C}$.

Annual number of users:

More than 500

User interface:

Access is granted through merit-based peer review of submitted research proposals. The SKLNPT conducts one open call every year (March).

Contracting directly with SKLNPT office (huahe@pku.edu.cn)

User amenities:

SKLNPT is situated at Peking University in Beijing, China. Lodging is available at a range of local hotels for short stay and rental accommodation for longer stay.

User organisation:

The facility managed by SKLNPT is opened for any user all over the world.

Table 2. China user facilities for nuclear materials work list

User facility	Website
High-flux engineering test reactor (HFETR) and Min Jiang test reactor (MJTR)	http://en.npic.ac.cn
Shanghai Synchrotron Radiation Facility (SSRF)	http://e-ssrf.sinap.cas.cn/
Beijing Synchrotron Radiation Facility (BSRF)	http://english.ihep.cas.cn/rs/fs/srl/
National Synchrotron Radiation Laboratory (NSRL)	http://en.nsrl.ustc.edu.cn/
CARR (China Advanced Research Reactor)	www.ciae.ac.cn
Beijing Radioactive Ion beam Facilities (BRIF)	www.ciae.ac.cn/eng/brif/index.htm
Heavy Ion Research Facility in Lanzhou (HIRFL)	http://english.imp.cas.cn/rs/fs/
Advanced Nuclear Materials Testing Facility (ANMT)	http://english.imp.cas.cn/rs/fs/
EN Tandem Accelerator; 4.5 MV Van de Graaff Accelerator and 2x1.7 MV SDH2 Tandem Accelerator	http://sklnpt.pku.edu.cn/english/

6.3. European Union

6.3.1. European Synchrotron Radiation Facility (ESRF)

Location:

ESRF is based at The European Synchrotron, 71, Avenue des Martyrs, Grenoble, France.

Web address:

www.esrf.eu/

Category:

Synchrotron

Facility description:

The European Synchrotron Radiation Facility (ESRF) is the most powerful synchrotron radiation source in Europe.

The ESRF Experiments Division has built more than 40 specialised beamlines that are installed by the ESRF for use by the international scientific community. These beamlines are designed for research in areas as diverse as engineering, physics, chemistry, crystallography, earth science, biology and medicine, surface and materials science. In addition, several Collaborating Research Groups (CRGs) made up of institutes from countries participating in the ESRF, build and operate beamlines at the ESRF with independent funding.

ESRF beamline groups in the ESRF Experiments Division work in the following research areas:

- structural biology;
- structure of materials;
- electronic structure and magnetism;
- dynamics and extreme conditions;
- structure of soft matter;
- X-ray imaging;

- collaborating research groups;
- theory;
- scientific infrastructure.

User interface:

Access to some 40 experimental stations, the “beamlines”, is free of charge for academic and non-proprietary industrial research if the user teams are prepared to submit their project to peer review and publish the results of their experiment. For proprietary industrial research, a fee is payable according to the amount of beam time and ESRF staff expertise required. In this case there is no obligation to publish results and the intellectual property of the client’s discoveries belongs to the client.

Applications for beam time for experiments are submitted electronically for two deadlines each year: 1st March and 1st September. In special cases, where projects require a commitment over a longer, three-year period, the ESRF also accepts a limited number of long-term projects. Applications for proprietary research can be made at any time, through the dedicated services for industry section.

Proposals for public beam time are selected and beam time allocations are made through peer review. There are ten review committees, corresponding to groups of beamlines of similar techniques or activities.

User amenities:

Arrangements for meals and accommodation for all users are made by the ESRF, in order to allow experimental teams to concentrate entirely on science. The ESRF contributes to the travel and subsistence expenses of three scientists (four scientists for BAG and LTP experiments) per experiment for scientists affiliated with laboratories in contracting party countries. However, industrial scientists do not receive a contribution to their expenses.

User organisation:

The purpose of the ESRF Users Organisation is to promote research at the ESRF by providing an organised framework for discussion within the users community and a direct link between the users and the ESRF management. Anyone who has used the ESRF in the past five years is automatically a member of the organisation. The Users Organisation Committee, elected by the members, organises the annual users meeting and conducts the day-to-day business of the organisation. Details are set forth in the Users Organisation Charter.

6.3.2. SOLEIL Synchrotron

Location:

SYNCHROTRON SOLEIL is located at L’orme des Merisiers – BP 48, 91190 Saint Aubin, France.

Web address:

www.esrf.eu/

Category:

Synchrotron

Facility description:

SOLEIL is a source of the third generation type. This generation of synchrotrons was built in the 1990s and is characterised by a synchrotron light emission all along the storage ring circumference, in the bending magnets – which bend the electrons trajectory – as well as in the straight sections equipped with the wigglers and the undulators. At SOLEIL, more than 42% of the storage ring circumference was reserved to these exceptional light sources called “The insertion devices”.

The storage ring characteristics condition part of the performance of the whole installation. SOLEIL storage ring is extremely compact and however reserves a very large part to the most powerful light source. It was also conceived to satisfy all the categories of users, as well by the choice of the nominal energy of machine operation as by the two possible operating modes.

SOLEIL machine is made up of 2 accelerators (a linear accelerator, the LINAC, and a circular one, the BOOSTER) and of a storage ring, a 354 m perimeter polygon – it accommodates the magnetic elements (dipoles and “undulators”) which bend the electrons trajectory. With each curve, then, the electrons lose energy, which produces synchrotron light.

The third generation synchrotrons, such as SOLEIL, use magnetic devices called “undulators”, which are inserted along the storage ring perimeter. They consist of sets of coils or permanent magnets juxtaposed along two jaws which force the electrons into an undulated movement. With each undulation, the electron bunches emit a thin beam of coherent light.

User interface:

Users of SOLEIL’s benefit from varied types of access and collaboration adapted to their problems, operating limits and capabilities.

“Public” mode use of SOLEIL equipment

The person requesting access prepares a project that is examined by experts from seven thematic committees. The selection, which is necessary due to the fact that requests for access greatly outweigh what is available, is made on the basis of the scientific interest (innovativeness, major advance in knowledge, etc.) of the project.

Acceptance of the project grants free access to SOLEIL’s equipment for a time of 4 to 9 months, with the obligation to rapidly publish the experimental results.

- “billed” mode use of SOLEIL equipment;
- direct overseeing of measurements by SOLEIL;
- “à la carte” analytical service ;
- long-term partnerships.

User amenities:

The SOLEIL Guest House is available 24 hours a day. The canteen is open for breakfast, lunch and dinner.

User organisation:

SOLEIL is managed as a part of a French public company. Members of the SOLEIL Synchrotron Company are the CNRS and the CEA. The company is open to French and foreign partners. The Ile de France region, the General Council of Essonne, and, more recently, the Centre region, desired to contribute to the project and are essential partners.

Table 3. EU user facilities for nuclear materials work list

User facility	Website
European Synchrotron Radiation Facility (ESRF)	www.esrf.eu
SOLEIL Synchrotron	www.synchrotron-soleil.fr/

6.4. France

6.4.1. ORPHEE reactor + Leon Brillouin Laboratory [1]

Location:

ORPHEE is based at CEA/Saclay, 91191 Gif-sur-Yvette, France.

Web address:

www-llb.cea.fr/index.php

Category:

ORPHEE is a neutron beam research reactor. It is a pool-type reactor with a thermal power of 14 MW and a neutron flux of 3.10^{14} neutrons $\text{cm}^{-2}.\text{s}^{-1}$.

Facility description:

Core height allows nine horizontal, wide-section thimbles to be placed simultaneously on three levels. These thimbles, in turn, make it possible to extract from the reactor cavity 20 neutron beams, to be directed to 26 experimental areas.

The neutron flux maintained in the heavy water vessel mainly contains thermalised neutrons with an energy of about 25 millielectronvolts (meV). In order to provide either low-energy (<5 meV), or high-energy (> 100 meV) neutrons for the experiments, “secondary” moderators are used. These devices, positioned in the heavy water vessel, allow for the neutron energy level to be altered locally.

Two cold neutron sources, using three intermediate channels, feed eight cold beams that provide 19 out of the 26 experimental areas of the facility. Every cold neutron source consists of a gourd-shaped cell containing liquid hydrogen at 20 K (-253°C), placed in a safety containment under vacuum.

Similarly, a hot neutron source, consisting of a graphite block heated to about 1 400 K (1 127°C) by the γ power deposition from the core, allows 4 hot neutron beams to be fed.

As a second step, a more elaborate selection of useful neutrons is performed: a monochromator collects, in the beam, the neutrons which exhibit a wavelength within a given band, in order to direct them to the sample to be studied.

The other neutrons of the beam (that is 90-99 % of the total amount) go through the monochromator, and are absorbed in specific materials (the so-called “beam catchers”). The end of the device consists of diffractometers (for measuring neutron changes of direction) and spectrometers (for measuring neutron energy levels) installed around each experimental station.

The experimental areas are arranged either in a specific zone, i.e. around the reactor cavity inside the reactor, or in a much broader experimental hall (the so-called “guide hall”) neighbouring the reactor containment. In the second case, specific devices, neutron guides, are used to transport neutron beams over several dozens of metres. Neutron guides (hollow glass blocks covered with a nickel

multilayer) allow beams of very low incidence to be propagated according to a principle similar to that of an optical fibre.

Concerning analysis of the activated samples, they are sent by a pneumatic connection to the Pierre Süe Laboratory, a joint facility of the CEA and the CNRS.

User amenities:

Lodging is available at a range of local hotels close to Saclay CEA Centre.

User organisation:

In the case of ORPHEE/LLB, reactor operation is assumed by the Nuclear Energy Division and the experimental part by a CEA/CNRS joint unit, the Léon Brillouin Laboratory (a unit integrated in the CEA's Fundamental Research Division).

6.4.2. JHR (Jules Horowitz Reactor; under construction)

Location:

JRH is being constructed at the CEA in Cadarache.

Web address:

www.cea.fr/Pages/domaines-recherche/energies/energie-nucleaire/reacteur-de-recherche-jules-horowitz-RJH.aspx

Category:

JHR is an irradiation reactor for research on reactor materials and fuels under irradiation. It will also supply radioisotope for medical purposes.

The nuclear unit is composed of only one civil engineering structure supporting two zones with different containments: the reactor building (RB) and the nuclear auxiliary building (NAB). The objective of this single structure is to contain all the radioactive materials in one place.

The reactor is a pool-type reactor cooled with light water. The maximum thermal power is 100 MW. This power is dissipated via the primary and the secondary circuit to the external cold source during irradiation; the core, the primary circuit and experimental rigs, are completely enclosed in the RB. The reactor pool is connected to several storage pool and hot cells located in the NAB through a water block

Facility description:

General description of the nuclear unit:

The core (600 mm fuel active height) is cooled and moderated with water. It will be operated, as a reference solution with a high-density low-enriched fuel (U enrichment lower than 20%), density 8 g.cm^{-3} , requiring the development of UMo fuel.

The fuel element is of circular shape (set of curved plates assembled with stiffeners) and comprises a central hole. The reference UMo fuel, is under development within an international collaboration (UMo/Al dispersion solutions and monolithic UMo solution) and is not at the time being an industrial product.

Consequently, as a back-up solution, the JHR will start with an U_3Si_2 fuel with a larger enrichment (typically 27%).

The core area is surrounded by a reflector which optimises the core cycle length and provides intense thermal fluxes in this area. The reflector area is made of water and beryllium elements.

Irradiation devices can be placed either in the core area (in a fuel element central hole or in place of a fuel element) or in the reflector area.

In core, experiments will address typically material experiments with high fast flux capability up to 5.10^{14} n.cm⁻².s⁻¹ perturbed fast neutron flux with energy higher than 1 MeV.

In reflector, experiments will address typically fuel experiment with perturbed thermal flux (lower than 0.625 eV) up to 5.10^{14} n.cm⁻².s⁻¹.

Experiments can be implemented in static locations, but also on displacement systems as an effective way to investigate transient regimes occurring in incidental or accidental situations.

This provides a flexible experimental capability able to create up to 16 dpa/year for in-core material experiments (with 260 full power operation days per year) and 600 W.cm⁻¹ (on 1% ²³⁵U enriched fuel) for in reflector simple fuel experiments.

Consequently, as a back-up solution, the JHR may start with U₃Si₂ fuel using a slightly higher enrichment depending on the requested power.

The JHR experimental capacity:

JHR is a 100 MW tank pool reactor. The core area is inserted in a small pressured tank (section in the order of 740 mm diameter) with forced coolant convection (low pressure primary circuit at 1.5 MPa, low-temperature cooling, core inlet temperature in the order of 25°C). Reactor primary circuit is completely located inside the RB.

The RB is divided into two zones. The first zone contains the reactor hall and the reactor primary cooling system.

The second zone hosts the experimental areas in connection with in-pile irradiation (eg. typically ten loops support systems, gamma scanning, fission product analysis laboratory etc.).

The Fission Product Laboratory will be settled in this area to be connected to several fuel loops either for low activity gas measurements (HTR, ...) or high activity gas measurements (LWR rod plenum, ...) or water measurements (LWR coolant, ...) with gaseous chromatography and mass spectrometry.

Bunkers and laboratories in the experimental area will use 300 m² per level on three levels.

Pools in the RB are limited to the reactor pool (including neutronography for experiments) and an intermediary deactivation pool (for temporary storage of fuel elements, reflector elements or replaced core mechanical structures).

During reactor shutdown, experimental devices can be temporarily stored in a dedicated rack in the reactor pool.

Hot cells, laboratories and storage pools are located in the nuclear auxiliaries building.

The experimental process will make use of two hot cells to manage experimental devices before and after the irradiation. Safety experiments are an important objective for JHR and require an "alpha cell" to manage devices with failed experimental fuel.

A fourth hot cell will be dedicated to the transit of radioisotope for medical application and to the dry evacuation of used fuel.

Three storage pools are dedicated respectively to spent fuel, experimental devices and mechanical components management.

6.4.3. High-Flux Reactor (HFR; operated by the ILL [Laue-Langevin Institute])

Location:

HFR is located at the Institut Laue-Langevin, 6, rue Jules Horowitz, Grenoble, France.

Web address:

www.ill.eu/

Category:

The HFR is a neutron beam research reactor. It is a pool-type reactor with a thermal power of 58.3 MW and thermal neutron flow of $1.5 \cdot 10^{15} \text{ n.cm}^{-2}.\text{s}^{-1}$.

Facility description:

The Laue-Langevin Institute (ILL) is the top neutronic research installation in Europe. It operates the high-flux reactor (HFR), the world's most intense neutron source and delivers neutron beams to 34 high technology scientific instruments. Due to its unique, highly compact fuel element and the excellent thermo-hydraulic conditions, the reactor delivers thermal neutron flow of $1.5 \cdot 10^{15} \text{ n.cm}^{-2}.\text{s}^{-1}$ with a thermal power of 58.3 MW.

The single fuel element sits in the centre of a tank of 2.5 m diameter containing the heavy water moderator. Cooling and moderation is by heavy water circulation passing through heat exchangers. The moderator partly reflects thermalised neutrons back towards the fuel element. Biological shielding is provided by a light water swimming pool surrounding the reflector tank encased in dense concrete.

The reactor operates continuously for a 50 day cycle, followed by a shutdown to change the fuel element. In addition, there is a longer shutdown to enable necessary maintenance work to be carried out. Normally there are four cycles a year, providing 200 days for science.

There are in total:

- 13 horizontal beam tubes;
- 4 inclined beam tubes;
- 2 neutron guide halls;
- 5 guides for thermal neutrons;
- 8 guides for cold neutrons;
- 1 vertical guide for very cold and ultra-cold neutrons.

Neutron fluxes available:

The thermal neutron flux, in equilibrium with the heavy water moderator (300 K), has a peak in the Maxwellian distribution at 1.2 Å. For certain beams and guide tubes this is modified by the inclusion of special moderators:

- hot source (10 litres of graphite at 2 400 K): it enhances the neutron flux at wavelengths below 0.8 Å;
- vertical cold source (20 litres of liquid deuterium at 25 K): it enhances the neutron flux at wavelengths above 3 Å ($4.5 \times 10^{14} / \text{cm}^2 \text{ sec}$);

- horizontal cold source (6 litres of liquid deuterium at 25 K): it enhances the neutron flux at wavelengths above 3 Å (8.0×10^{14} /cm² sec).

In the reactor hall, neutron beams are available from thermal, hot and cold beam ports and from one cold neutron guide connected with the horizontal cold source.

In the neutron guide hall 1, neutron beams are available from four thermal and six cold neutron guide tubes.

In the neutron guide hall 2, neutron beams are available from two cold neutron guide tubes.

The instrumental facilities at the ILL are identified by the instrument's symbols which correspond to closely related experimental techniques:

- D-neutron diffraction: powder, single-crystal and small-angle diffractometers, reflectometers;
- IN – inelastic neutron scattering: three-axis, time-of-flight and high-resolution spectrometers;
- PF and PN – nuclear and particle physics.

The list of instruments (see website for update information) is summarised below:

- powder diffractometers: D1A, D1B*, D2B, D20, SALSA;
- liquids diffractometer: D4;
- polarised neutron diffractometers: D3, D23*;
- single-crystal diffractometers: D9, D10, D15*;
- large-scale structures diffractometers: D19, DB21, LADI, VIVALDI;
- strain imager: SALSA;
- small-angle scattering: D11, D22;
- low momentum-transfer diffractometer: D16;
- reflectometers: ADAM *, D17, FIGARO;
- diffuse scattering and polarisation analysis spectrometer: D7;
- three-axis spectrometers: IN1, IN8, IN12*, IN14, IN20, IN22*;
- time-of-flight spectrometers: IN4, IN5, IN6, BRISP*;
- backscattering and spin-echo spectrometers: IN10, IN11, IN13*, IN15, IN16;
- nuclear physics instruments: PN1, PN3;
- physics instruments: PF1, PF2, S18 *.

Details on the instruments can be found on the web under www.ill.eu/instruments-support.

Annual number of users:

Around 2 000 researchers from more than 30 countries perform over 800 experiments selected by a scientific review committee.

User interface:

There are different ways of submitting a proposal to the ILL:

- Standard submission of a research proposal (twice a year) via the Electronic Proposal System (EPS);
- EASY access system (EASY) throughout the year;
- Director's Discretion Time application (DDT) throughout the year;
- Block Allocation Groups (BAGs);
- Long-Term Proposal (LTP) once a year;
- special access for industrial users is also possible at the ILL;
- CRG proposal.

For a standard submission application for beam time is organised electronically, via the visitor's club website (www.ill.eu). Proposals can be submitted to the ILL twice a year, usually in February and in September. The web system is activated two months before each deadline.

There are normally four reactor cycles yearly, each of which lasts 50 days. Successful proposals submitted by February will receive beam time in the second half of the year; those submitted by September receive beam time in the first half of the following year.

User organisation:

The ILL is managed by France, Germany and Great Britain. It conducts scientific partnerships with other European countries and India.

The institute has a director and two associate directors who represent each of the associate countries. A scientific council comprising external scientists from the member countries advises the directors on scientific priorities and how to develop the instrument and technical infrastructures. The governing body is the Steering Committee which meets twice yearly and is made up of the associates and the scientific members together with the directors and staff representatives.

6.4.4. JANNuS Saclay

Location:

JANNUS is based at CEA/ DEN/DANS/DMN/SRMP, 91191 Gif-sur-Yvette, France.

Web address:

www-centre-saclay.cea.fr

Category:

Ion beam

Facility description:

This facility is located at CEA Saclay and connects three electrostatic ion accelerators: the 3 MV ÉPIMÉTHÉE, the 2.5 MV PANDORE, and the 2 MV tandem JAPET. The Pelletron is equipped with an electron cyclotron resonance (ECR) source of multi-charged ions.

The first accelerator, named Épiméthée, is devoted to produce the highly damaging beams for the simulation of irradiation damage. Large energies, hence high ranges, are obtained thanks to an ECR source able to provide high charge states. This source (Pantechnik, Nanogan type) is adapted in a 3 MegaVolt single-ended electrostatic accelerator (3-UH-2 PelletronTM, National Electrostatics Corp.)

with enlarged tank. Four gases and two metals are available simultaneously in the source. Preliminary ion selection at the source exit is performed by a Wien filter and electrostatic deflection. Maximal intensities delivered to the targets are at least 3.9 E14 pps (particles per second) for protons, 8.8 E14 pps ${}^4\text{He}^+$, 2.2 E14 pps ${}^4\text{He}^{2+}$, 1.8 E12 pps ${}^{132}\text{Xe}^{10+}$, 8.2 E12 pps ${}^{40}\text{Ar}^{8+}$, 2.6 E12 pps ${}^{56}\text{Fe}^{8+}$ and 1.1 E12 pps ${}^{58}\text{Ni}^{11+}$. The choice of an ECR source gives the possibility to explore a large range of dose rate, using charge states with low yield and, when possible, isotopes of low abundance in addition to the flexibility of the focusing and to beam rastering. This accelerator provides irradiation or Ion Beam Analysis (IBA) beams in the triple-beam chamber and in another single beam irradiation chamber. Its selecting magnet will allow adding three other irradiation or IBA lines in the future.

The 2.5 MV PelletronTM (NEC) Pandore is used mainly for helium/hydrogen implantation and IBA. Its radio-frequency (RF) source can produce essentially light ions from gases (hydrogen, deuterium, helium). In addition to its line towards the triple-beam chamber, it keeps one IBA line (RBS, ERDA, PIXE, PIGE, NRA).

The third machine, Japet, is a 2 MV tandem (6SDH-2 PelletronTM accelerator from National Electrostatics corp.) equipped with an argon gas stripper and a SNICS II ion source. The ion source is able to deliver 3.12 E14 pps for protons, 3.12 E13 pps for ${}^{32}\text{S}^{2+}$, 3.12 E12 pps for ${}^{35}\text{Cl}^{4+}$ and 3.12 E12 pps for ${}^{127}\text{I}^{5+}$ at 2 MV terminal. Other ions such as ${}^7\text{Li}$, ${}^{12}\text{C}$, ${}^{27}\text{Al}$, ${}^{28}\text{Si}$, ${}^{31}\text{P}$, ${}^{58}\text{Ni}$, ${}^{63}\text{Cu}$ and ${}^{197}\text{Au}$ are available.

The triple-beam chamber has the following characteristics:

- beam incidence of each beam: 15°;
- vacuum: $10^{-7} - 10^{-8}$ mbar;
- sample holder: liquid N₂ temperature to 800°C;
- sample size requirements:
 - maximum diameter 47 mm, maximum thickness 25 mm;
 - irradiated area (beam scanning) : 20 mm x 20 mm;
- energy degrader for each beam;
- multi-Faraday cup for each beam;
- in situ Raman.

User interface:

These instruments are made available to the national and international community in the EMIR network of facilities.

Access to beam line is through a submission of proposal process.

All information is accessible on <http://emir.in2p3.fr>.

The EMIR organisation is the following:

- Management Board: The Management Board monitors the scientific, administrative and financial management of the network. After review of the selection committee, it selects the selected experiments. The committee also validates the annual report of the network. It is composed of the five platform responsible, and three external members representing consumers, appointed by the steering committee.
- Programme Advisory Committee: The Programme Advisory Committee reviews the experimental proposals assessing their scientific quality and their feasibility in accordance

with the characteristics of the request accelerator. It is composed of six high-level scientific members proposed by the co-ordinating committee and appointed by the steering committee. This committee will meet twice a year.

User amenities:

Lodging is available at a range of local hotels.

User organisation:

This facility is owned and operated by the Commissariat à l'énergie atomique et aux énergies alternatives.

6.4.5. Centre de Spectrométrie Nucléaire et de Spectrométrie de Masse (CSNSM) – JANNuS-Orsay

Location:

CSNSM is located at the Université PARIS-SUD 11 bât 104 et 108, 91400 Orsay, France.

Web address: www.csnsm.in2p3.fr

Category:

Ion beam and TEM

Facility description:

This facility couples a 2 MV Tandem accelerator (ARAMIS) and a 190 kV ion implantor (IRMA) to a 200 kV transmission electron microscope.

ARAMIS is a tandem Type 2MV accelerator, developed by the CSNSM/SEMIRAMIS group. Two ion sources are used for the two working modes of the device:

- Tandem mode: A sputtering negative ion source allows using the tandem mode. High negative ions current are produced from such an ion source. With an energy of 150 keV they are injected inside the accelerator, where they receive a first acceleration. In the centre part of the accelerator, a nitrogen stripper changes the ion charge sign and multiplies it. The ion then receives a second acceleration proportional to its charge.
- Van de Graaff mode: The ion beam is produced from a Penning ion source, placed at the accelerator high-voltage terminal. Gaseous elements like hydrogen, helium, nitrogen and oxygen can be produced with this source.

IRMA is an ion implanter used to modify materials inside the 0 to 500 nm depth region. Almost all the elements are available, thanks to the Bernas-Nier positive ion source (see below produced elements table). The produced single-charged ions currents can reach hundreds of μA , depending of the element. The energy can be between 5 and 190 keV for single-charged ions and can be up to 570 keV, for multiple-charged ions.

The 200 kV microscope (TEM FEI Tecnai G2 20) has a magnification range from 70 to 700 000. Ultra-thin heating and cooling sample-holders – from liquid nitrogen to 800°C – have been designed. Analysis systems include: EDX analysis EDAX, Energy Filter GIF TRIDIEM GATEAN, STEM Bright field and Dark Field detector, HAADF GATANT.

User interface:

This facility is made available to the national and international community in the EMIR network of facilities.

Access to beam line is through a submission of proposal process.

All information is accessible on <http://emir.in2p3.fr>

The EMIR organisation is the following:

- **Management Board:** The Management Board monitors the scientific, administrative and financial management of the network. After review of the selection committee, it selects the selected experiments. The committee also validates the annual report of the network. It is composed of the five platform responsible, and three external members representing consumers, appointed by the steering committee.
- **Programme Advisory Committee:** The Programme Advisory Committee reviews the experimental proposals assessing their scientific quality and their feasibility in accordance with the characteristics of the request accelerator. It is composed of six high-level scientific members proposed by the co-ordinating committee and appointed by the steering committee. This committee will meet twice a year.

User amenities:

Lodging is available at a range of local hotels.

User organisation:

This facility is managed by the French National Center for Scientific Research (CNRS: Centre National de la Recherche Scientifique).

6.4.6. CEMHTI (Conditions extrêmes et matériaux: Hautes Température et Irradiation)*Location:*

CEMHTI is based 1Avenue de la Recherche Scientifique, 45071 ORLEANS Cedex 2, France.

Web address:

www.cemhti.cnrs-orleans.fr/

Category:

Ion beam

Facility description:

The cyclotron site of CEMHTI comprises a cyclotron with variable energy, a Van de Graaff accelerator and two positron accelerators that allow studying materials under irradiation, ageing and defects or producing positron emitting nuclei used for PET imaging.

The cyclotron of CEMHTI delivers beams of neutrons (8 MeV), protons, deuterons, ^3He and alpha particles (10-45MeV). It is used to characterise materials (collaboration in Europe, CEA, AREVA, EDF), the study of archaeological materials (collaboration IRAMAT), the production of

isotopes for clinical or preclinical studies and imaging (collaborations CBM, ICOA, TAAM, Subatech Nantes).

The Van de Graaff can accelerate beams of light elements (H^+ , D^+ , $3He^+$, $4He^+$, T^+). It allows various analyses:

- Rutherford Back Scattering – RBS for analysis of thin films;
- Nuclear Reaction Analysis – NRA for analysis of light elements;
- Observation of X-rays and gamma emitted under irradiation (PIXE or PIGE) for multi-element analysis.

The positron accelerator delivers beams of positrons of variable energy allowing the characterisation of defects and voids in materials.

User interface:

These instruments are made available to the national and international community in the EMIR network of facilities.

Access to beam line is through a submission of proposal process.

All information is accessible on <http://emir.in2p3.fr>

The EMIR organisation is the following:

- Management Board: The Management Board monitors the scientific, administrative and financial management of the network. After review of the selection committee, it selects the selected experiments. The committee also validates the annual report of the network. It is composed of the five platforms responsible, and three external members representing consumers, appointed by the steering committee.
- Programme Advisory Committee: The Programme Advisory Committee reviews the experimental proposals assessing their scientific quality and their feasibility in accordance with the characteristics of the request accelerator. It is composed of six high-level scientific members proposed by the co-ordinating committee and appointed by the steering committee. This committee will meet twice a year.

User amenities:

Lodging is available at a range of local hotels.

User organisation:

The accelerators of CEMHTI are co-financed by the Centre region and FEDER European funds.

6.4.7. CIMAP (Centre de Recherche sur les Ions, les Matériaux et la Photonique)

Location:

CIMAP-GANIL, BP 5133 – Bd H. Becquerel – 14070 Caen Cedex5, France.

Web address:

<http://cimap.ensicaen.fr/>

Category:

Ion beam

Facility description:

Interdisciplinary researches with the GANIL ion beams are managed by the CIMAP. For this research, CIMAP has developed beam lines and specific equipment to all levels of ion acceleration.

The GANIL/IRRSUD line uses ion ranging from C to U with an energy ranging from 0.3 to 1 MeV/A. Scanning devices are under vacuum for temperature between 8 K and 1 200 K. The online characterisation comprises X-ray diffractometer and infrared spectrometry gas analysis.

The GANIL/SME line uses ion ranging from C to U with an energy ranging from 4.5 to 13 MeV/A. Scanning devices are under vacuum or controlled atmosphere for temperature between 8 K and 1 200 K. The online characterisation comprises X-ray diffractometer and infrared spectrometry gas analysis.

The GANIL facility offers other beam lines which are not under the CIMAP auspices. For instance, the CIME is a room temperature, compact, medium energy cyclotron devoted to acceleration of radioactive ions.

User interface:

To perform an interdisciplinary experiment at GANIL, a demand should be made through different access:

- the i-PAC (interdisciplinary Programme Advisory Committee at GANIL) which meets on a bi-annual basis <http://pro.ganil-spiral2.eu/laboratory/ciril/submit-a-proposal>;
- for a research on materials under irradiation, two others access are available:
 - If your current employer is based in an EU member state or associated state (except France), you may apply for SPIRIT Trans-National Access;
 - For French or non-EU people, you may apply for French National Network for the study of materials under irradiation (EMIR).

User amenities:

Lodging is available at a range of local hotels and at the GANIL Guest House. To book a room in the Guest House contact accueil@ganil.fr.

User organisation:

The GANIL Programme Advisory Committee (PAC) The PAC meets approximately once per year to consider new proposals for nuclear physics experiments that can be scheduled during the coming year(s). During this open meeting, the PAC will hear brief oral presentations made by the spokesperson (or their representative) for each of the experimental proposals submitted before the PAC deadline. After all of the presentations, PAC will meet in a closed session to rank the experiments and recommend to the directors those experiments that should be selected to receive beam time. Each spokesperson will be advised of the recommendation of PAC through email within a few days of PAC meeting.

The GANIL User Board (BUG) has been formed to represent the Users Community of GANIL in all aspects. The role of the BUG is to act as an interface between external experimenters and the staff of the GANIL facility, to monitor users' experience and to recommend possible changes to the GANIL direction.

6.4.8. LSI (Polytechnique – Laboratoire des Solides Irradiés)

Location:

LSI is located at École Polytechnique, 91128 Palaiseau Cedex, France.

Web address:

www.lsi.polytechnique.fr.

Category:

Electron beam

Facility description:

SIRIUS is an irradiation facility based on a high-energy electron Pelletron accelerator from NEC, three irradiation lines (in particular the possibility to make irradiation at high-current and low temperatures) and different in situ measurements during irradiation like spectroscopic methods (UV-Visible absorption, luminescence) and conductivity measurements. The SIRIUS facility is planned to work 300 days per year and is open to a large user community from France and abroad.

The characteristics are the following:

- energy range: 0.15 to 2.5MeV;
- irradiation equipment: high doses (GGy), low temperatures (20 K), large surfaces;
- online characterisation: optical spectroscopy (absorption, fluorescence, IR), micro-electrochemistry, electrical measurements (resistivity, conductivity, hall), measurement of desorbed gas.

User interface:

Two ways are at disposal for obtaining irradiation time at the SIRIUS facility. The first is to make a proposal through the EMIR network. The second way is to send directly to us a proposal at sirius@polytechnique.fr.

User amenities:

Lodging is available at a range of local hotels.

User organisation:

The Irradiated Solids Laboratory (LSI), is a joint research unit of the Commissariat à l'Énergie atomique et aux énergies renouvelables (CEA), the Centre National de la Recherche Scientifique (CNRS) and the École Polytechnique. At CEA, the LSI is part of the Physical Sciences Division (DSM), Saclay Institute of Matter and Radiation (IRAMIS). At the CNRS, it belongs to the Institute of Physics (INP), and the Institute of Chemistry (INC).

6.4.9. ARRONAX

Location:

GIP ARRONAX is located 1 rue Aronnax – CS 10112 – 44817 SAINT-HERBLAIN Cedex France.

Web address:

www.cyclotron-nantes.fr

Category:

Light ion beam (H, D, He)

Facility description:

The ARRONAX cyclotron is a high-intensity (up to $2 \times 375 \mu\text{A}$) multi-particle accelerator aiming at R&D on material and radiolysis and production of radioisotopes. The maximum energy is 70 MeV for proton beam. The cyclotron is coupled to a hot cell able to manage radioactive samples.

User interface:

Contact the facility management by email: plandemanip@arronax-nantes.fr. There is a radiolysis group studying alpha irradiation's effect on material's corrosion in water.

User amenities:

Lodging is available at a range of local hotels.

6.4.10. ANAFIRE

Location:

ANAFIRE is located at IPN Lyon, Domaine scientifique de la doua, Bâtiment Paul Dirac, 4 rue Enrico Fermi, 69622 Villeurbanne cedex, France.

Web address:

www.ipnl.in2p3.fr

Category:

Light ion beam (H, D, He @ 4 MeV) + co-implantation ions métalliques (400 keV).

Facility description:

The ANAFIRE facility has a 4MeV Van de Graff accelerator. It uses a Penning type source and can deliver a beam intensity of up to a few nA. R&D on material's irradiation and radiolysis effects can be carried out in collaboration upon request. The ACE laboratory carries out research on nuclear waste irradiation effects.

Gamma and beta dosimetry

Annual number of users:

20-30

User interface:

Contact the head of the ACE laboratory (N. Moncoffre, moncof@ipnl.in2p3.fr).

User amenities:

Lodging is available at a range of local hotels.

User organisation:

This facility is managed by the French National Center for Scientific Research (CNRS: Centre National de la Recherche Scientifique).

Table 4. France user facilities for nuclear materials work list

User facility	Website
ORPHEE reactor and Leon Brillouin Laboratory	www-llb.cea.fr/index.php
Jules Horowitz Reactor (under construction)	www.cea.fr/Pages/domaines-recherche/energies/energie-nucleaire/reacteur-de-recherche-jules-horowitz-RJH.aspx
High-flux reactor (HFR)	www.ill.eu
JANNuS	www-centre-saclay.cea.fr
Centre de Spectrométrie Nucléaire et de Spectrométrie de masse (CSNSM)	www.csnsm.in2p3.fr
Conditions Extrêmes et Matériaux: Haute Température et Irradiation (CEMHTI)	www.cemhti.cnrs-orleans.fr/
Centre de Recherche sur les Ions, les Matériaux et la Photonique (CIMAP)	http://cimap.ensicaen.fr
ANAFIRE	www.ipnl.in2p3.fr
Accélérateur pour la Recherche en Radiochimie et Oncologie à Nantes Atlantique (ARRONAX)	www.cyclotron-nantes.fr/

6.5. Korea

6.5.1. High-flux Advanced Neutron Application Reactor (HANARO)

Location:

The High-flux Advanced Neutron Application Reactor (HANARO) is located at the Korea Atomic Energy Research Institute (KAERI), Daejeon, Korea

Web address:

<http://hanaro.kaeri.re.kr/main.html>

Category:

Research Reactor (30 MW_{thermal})

Facility description:

Neutron beam facilities:

- Neutron radiography facility (NRF);
- High-resolution Powder Diffractometer (HRPD);
- Four-circle Neutron Diffractometer (FCD);
- Residual Stress Instrument (RSI);
- Vertical Neutron Reflectometer (REF-V);
- Horizontal Neutron Reflectometer (REF-H);

- High-intensity Powder Diffractometer (HIPD);
- Ex-core Neutron Irradiation Facility (ENF) ;
- Neutron Activation Analysis System (NAA System);
- Prompt Gamma Neutron Activation Analysis (PGAA System).

Cold Neutron Research Facilities (under way):

- 12 M and 40 M Small-angle Neutron Spectrometer (SANS);
- High-resolution Small-angle Neutron Spectrometer (HR-SANS);
- Cold Triple Axis Spectrometer (Cold-TAS);
- Vertical Neutron Reflectometer (REF-V);
- Horizontal Neutron Reflectometer (REF-H);
- BIO Neutron Reflectometer (BIO-REF).

Neutron Irradiation Test Facilities:

- Irradiation Rabbit System;
- Non-instrumented and Instrumented Irradiation Capsule System;
- Fuel Test Loop (FTL);
- 5, 6, 8 inch Neutron Transmutation Doping (NTD) System.

Two hot cell laboratories are capable of providing the complete range of facilities to support all radioactivity levels required to underpin the post-irradiation examinations of the nuclear fuels and the reactor core structural materials irradiated at HANARO.

- Irradiated Material Examinations Facility (IMEF);
- Post-Irradiation Examination Facility (PIEF).

HANARO is supplying radioisotopes and their application technologies, which have been utilised in various areas at home and abroad. Currently, HANARO-produced RIs are used in such various areas for medicine, industry, agriculture and life sciences.

HANARO will focus its efforts on developing new radio-materials, along with its production and application technology for RIs, while expanding the application scope and the export overseas.

Annual number of users:

Annual number of users in HANARO will depend on an operation day of the reactor.

In 2011, HANARO recorded 259 annual number of users of neutron beam, 46 of neutron activation analysis, and 50 of neutron irradiation.

User interface:

Contracting directly with HANARO user office (email: useroffice@kaeri.re.kr) and visit a HANARO website (<http://hanaro4u.kaeri.re.kr>) for getting detailed information about proposals submissions. All proposals for foreigner should be sent to a HANARO user office by email. The proposal should be included a proposer's information, proposal title, requested instrument, scientific background, aim of proposal, impossible date for experiment and total request time etc.

User amenities:

HANARO is situated on KAERI in Daejeon. Lodging is available at a range of local hotels for short stay and rental accommodation for longer stay.

User organisation:

HANARO is owned and operated by KAERI. KAERI is the first science and technology research institute in Korea to be mandated to achieve energy self-reliance through nuclear technology. KAERI is utilising the 30 MW capacity of HANARO, the nation's first multipurpose research reactor, constructed by its own technologies in 1995 for various R&D activities.

The HANARO (High-flux Advanced Neutron Application Reactor) is a 30 MWth multipurpose research reactor generating high neutron flux (fast flux: 2.1×10^{14} n/cm²/s, thermal flux: 4×10^{14} n/cm²/s). The industrial, academic and research demands on the utilisation of the HANARO have increased in various fields such as nuclear in-pile tests, production of key radioisotopes, neutron transmutation doping, neutron activation analysis, neutron beam research, radiography, environmental science, health science, agriculture, bio-engineering, etc.

6.5.2. High-voltage electron microscope*Location:*

Korea Basic Science Institute (KBSI), Daejeon, Korea.

Web address:

<http://hvem.kbsi.re.kr>

Category:

Electron Microscopy

Facility description:

- model name: ARM1300S;
- manufacturer: JEOL;
- Accelerating Voltage = 1250 keV;
- point resolution = 1.17 Å;
- spherical aberration $C_s = 2.65$ mm;
- chromatic aberration $C_c = 4.1$ mm;
- goniometer : $\alpha = \pm 60^\circ$, $\beta = \pm 45^\circ$;
- post-column type gatan imaging filter;
- auxiliary devices: cryo system, tomography system, GIF CCD(2k), EELS.

Annual number of users:

Average 90 projects of HVEM/year

User interface:

Visit a HVEM website (<http://hvem.kbsi.re.kr>) for getting detail information about proposal submission.

User amenities:

HVEM is situated at KBSI in Daejeon. Lodging is available at a range of local hotels for short stay and rental accommodation for longer stay.

User organisation:

Annual user's meeting

6.5.3. Pohang light source*Location:*

Pohang Light Source is located at Pohang Accelerator Laboratory (PAL), Pohang, Kyungbuk, Korea.

Web address:

<http://paleng.postech.ac.kr>

Category:

Synchrotron Light

Facility description:

27 operating beam lines:

- X-ray microprobe;
- magnetic spectroscopy;
- micro-beam photoemission spectroscopy;
- angle resolved ultraviolet photoelectron spectroscopy;
- X-ray absorption fine structure spectroscopy I;
- X-ray scattering I;
- high-flux macromolecular crystallography;
- photoemission spectroscopy II;
- small-angle X-ray scattering I;
- small-angle X-ray scattering II;
- high-flux X-ray scattering;
- X-ray micro-diffraction PAL-GIST II;
- X-ray scattering GIST I;
- macromolecular crystallography I;
- macromolecular crystallography II;

- high-resolution photoemission spectroscopy I/X-ray absorption spectroscopy;
- X-ray microscopy;
- X-ray absorption fine structure spectroscopy I;
- spectro-microscopy;
- X-ray scattering/absorption;
- high-resolution powder diffraction;
- U-SAXS (ultra small-angle X-ray scattering);
- X-ray nano-micro machining;
- HFXAXS;
- XRS KIST PAL;
- X-ray scattering II;
- EUV lithography.

Storage ring:

- the 2.5 GeV PLS storage ring has a 12-period triple bend achromat lattice and is designed to be a low-emittance third generation machine (see machine parameters);
- there is a total of 32 beam ports and 22 from bending magnets and 10 from insertion devices;
- the maximum length available for an insertion device in a straight section is 4.3 metres;
- storage ring parameters;
- energy (GeV): 2.5;
- stored current (mA): 190;
- emittance (nm rad): 19;
- lifetime (hrs);
- @ 100mA in 400 Bunches: ~30;
- bunch length (psec): ~20;
- betatron tunes;
- horizontal (ν_x): 14.28;
- vertical (ν_y): 8.18;
- synchrotron tune: 0.01;
- linear coupling (%): ~1.

Linear accelerator:

- the PLS 2.5 GeV electron linear accelerator is the full energy injector to the storing ring;
- in the LINAC tunnel, there are 44 SLAC-type accelerating columns and seven quadrupole triplets that form the 160 metre-long LINAC;

- the LINAC is powered by twelve 80 MW klystrons, 200 MW modulators and 11 pulse compressors;
- the accelerated electron beam is brought to the storage ring injection area via the 98 m-long beam transport line;
- LINAC parameters;
- beam energy (GeV): 2.5;
- beam pulse length (ns): 1, 2, 40;
- pulse beam current (A) : > 2;
- energy spread (%): 0.6;
- number of columns: 44;
- operating mode: $2\pi/3$;
- operation frequency (MHz): 2,856;
- klystron pulse length (μ s): 4.0;
- number of klystrons: 12;
- klystron output power (MW): 80;
- number of energy doublers: 11;
- energy doubler gain factor: 1.5~1.6;
- total length of the LINAC (m): 160.

Annual number of users:

Average 1 000 experiments/year

User interface:

Contracting directly with PAL user office (plsbl@postech.ac.kr) and visit a PAL website (<http://paleng.postech.ac.kr>) for getting detail information about proposal submission.

User amenities:

The Guest House provides accommodation for the PLS users. To stay at the Guest House, users need to make a reservation in advance at website (<http://paleng.postech.ac.kr>).

User organisation:

Annual user's meeting

Table 5. ROK user facilities for nuclear materials work list

ROK User facility	Website
HANARO	http://hanaro.kaeri.re.kr/main.html
High-voltage electron microscope	http://hvem.kbsi.re.kr
Pohang light source	http://paleng.postech.ac.kr

6.6. Russia

6.6.1. Critical Assembly BFS-2

Location:

BFS-2 is located in the Joint Stock Company “State Scientific Centre of the Russian Federation – Institute for Physics and Power Engineering named after A.I. Leypunsky”, 249033, Bondarenko sq. 1, Obninsk, Kaluga region, Russia.

Web address:

www.ippe.ru/ibasa/ust.php

Category:

Test Reactor

Facility description:

- critical assembly type: models of fast reactor cores;
- critical assembly diameter: up to 5.0 m;
- critical assembly height: up to 3.7 m;
- admissible power: up to 1.0 kW.

Reactor materials (pellets): fissile materials, lead and lead-bismuth, breeder materials, constructional materials, absorbers and moderators.

Annual number of users:

2-3 users

User interface:

Without any limitation.

User amenities:

Taking into account its proximity, Obninsk can be easily reached from the three airports of Moscow and vice versa both by public/private transport and by taxi: the driving time is approximately 1.5-3 hours depending on the airport. A commuter train can also be used, which takes 1 hour 20 minutes to travel between Moscow Kievskaya and Obninskoe stations. There are a variety of hotels of various levels available in Obninsk. They are scattered throughout the town territory and many of them are situated in convenient locations within walking distance of the main infrastructure facilities. The restaurants and bars of Obninsk offer the menus of various national cuisines, from European to Russian and Oriental.

User organisation:

State Corporation “Rosatom”, its organisations and enterprises.

6.6.2. Hot laboratory, Radiochemical complex

Location:

Joint Stock Company “State Scientific Centre of the Russian Federation – Institute for Physics and Power Engineering named after A.I. Leypunsky”, 249033, Bondarenko sq. 1, Obninsk, Kaluga region, Russia.

Web address:

www.ippe.ru/ibasa/matk.php

Category:

Electron Microscopy

Facility description:

- hot cells, compartments;
- dissolution, extraction, deposition equipment;
- metallographics;
- measurement equipment, etc.

Annual number of users:

2-3 users

User interface:

In accord with internal regulations.

User amenities:

Taking into account its proximity, Obninsk can be easily reached from the three airports of Moscow and vice versa both by public/private transport and by taxi: the driving time is approximately 1.5-3 hours depending on the airport. A commuter train can also be used, which takes 1 hour 20 minutes to travel between Moscow Kievskaya and Obninskoe stations. There are a variety of hotels of various levels available in Obninsk. They are scattered throughout the town territory and many of them are situated in convenient locations within walking distance of the main infrastructure facilities. The restaurants and bars of Obninsk offer the menus of various national cuisines, from European to Russian and Oriental.

User organisation:

State Corporation “Rosatom”, its organisations and enterprises.

6.6.3. Tandem Accelerator Tandetron

Location:

Joint Stock Company “State Scientific Centre of the Russian Federation – Institute for Physics and Power Engineering named after A.I. Leypunsky”, 249033, Bondarenko sq. 1, Obninsk, Kaluga region, Russia.

Web address:

www.ippe.ru/ibasa/usk-kom-2.php

Category:

Ion Beam

Facility description:

Tandem accelerator 3 MV:

- tandetron 4130 MC+ has three beam lines;
- terminal voltage 0.2–3.3 MV; Vacuum Level – 4×10^{-7} torr;
- allowable cascade rectifier load current – 1.3 mA;
- monoenergetic neutron beams with energies of 150 keV to 9.1 MeV;
- neutron flux density up to 10^9 n/cm²·s;
- hydrogen isotope pulse beams: 0.5 – 4 MeV; 2 ns; 125 kHz – 4 MHz;
- average beam current: – 4.8 μ A (4 MHz).

Continuous accelerated beam intensities:

¹ H ⁺ – 20 (50) μ A	¹² C ³⁺ – 40 μ A	⁵⁸ Ni ³⁺ – 20 μ A
² D ⁺ – 15 (30) μ A	¹⁶ O ³⁺ – 40 μ A	⁵⁸ Fe ³⁺ – 2 μ A
⁴ He ²⁺ – 4 μ A	¹⁹ F ³⁺ – 20 μ A	⁶³ Cu ²⁺ – 8 μ A
⁷ Li ²⁺ – 2 μ A	³¹ P ³⁺ – 20 μ A	⁷⁵ As ²⁺ – 5 μ A
¹¹ B ³⁺ – 12 μ A	²⁸ Si ³⁺ – 48 μ A	¹⁹⁷ Au ²⁺ – 20 μ A

Annual number of users:

8-12 users

User interface:

Without any limitation.

User amenities:

Taking into account its proximity,

Obninsk can be easily reached from the three airports of Moscow and vice versa both by public/private transport and by taxi: the driving time is approximately 1.5-3 hours depending on the airport. A commuter train can also be used, which takes 1 hour 20 minutes to travel between Moscow Kievskaya and Obninskoe stations. There are a variety of hotels of various levels available in Obninsk. They are scattered throughout the town territory, and many of them are situated in convenient locations within walking distance of the main infrastructure facilities. The restaurants and bars of Obninsk offer the menus of various national cuisines, from European to Russian and Oriental.

User organisation:

State Corporation “Rosatom”, its organisations and enterprises.

6.6.4. Research Institute of Atomic Reactors

Location:

433510, Dimitrovgrad-10, Dimitrovgrad, Ulyanovsk region, Russian Federation.

Web address:

www.niar.ru

User amenities:

Dimitrovgrad is situated in the middle Volga region. The nearest large cities are Ulyanovsk (100 km) and Samara (160 km). It takes 2 hours to get to the airport in Ulyanovsk and 1.5 hours to the airport Samara – Kurumoch (130 km) by car or bus. The railway station is in Dimitrovgrad.

User organisation:

The State Scientific Centre of Russian Federation “Research Institute of Atomic Reactors” (RIAR) is the Enterprise of the Russian Government Atomic Corporation (Rosatom).

Category:

Test and Experimental Reactors

Annual number of users:

10-15

User interface:

Bi- and multilateral contracts between laboratories and institutions, degree of utilisation: 80-90%.

*Facilities description:***Table 6. RIAR operational research reactors: Overview of current capabilities for material testing research**

Research reactor scheduled and planned life- time operation cycle
<p>SM-3 Scheduled/planned life time- 2017/2030 Operating time at power – 250 days/year Fuel cycle – 10–14 days Outage period – 2–6 days Maintenance period – 40 days</p>
<p>BOR-60 Scheduled/planned life time – 2015/2020 Operating time at nominal power – 240 days/year, fuel cycle – 45–90 days, number of fuel cycles per year 4–5, outage period 20–40 day</p>
<p><i>RBT-6</i> Scheduled/planned life time – 2020/2030 Operating time at nominal power – 260 days/year, fuel cycle – 6–40 days, outage period –2–6 days, maintenance period –40 days</p>
<p><i>MIR.M1</i> Scheduled/planned life time – 2027/2035 Operating time at nominal power – 240 days/year, fuel cycle – 15–25 days, outage period – 2–6 days, maintenance period – 40 days</p>
Power coolant moderator reflector
<p>90–100 MW (thermal) High-flux, vessel-type reactor Light water as coolant and moderator Beryllium reflector</p>
<p>60 MW(th) Experimental fast sodium reactor Coolant: primary and secondary circuits – sodium, third circuit – water Radial reflector – SS Axial reflector – natural UO₂</p>
<p>6 MW Open pool HEU, UO₂, H₂O, Light water as coolant, moderator and reflector</p>
<p>100 MW(th) channel-type in water pool Light water as coolant Beryllium as moderator and reflector</p>

Irradiation positions, flux, estimated dpa/year in steel
<p>Total irradiation positions (IP) – 81, height of IP 350–400 mm Trap positions: 27 IP with \varnothing 12 mm Neutron flux: total $\leq 5.0 \times 10^{15}$ n-cm⁻²·s⁻¹ fast (E>0.1 MeV) $\leq 1.5 \times 10^{15}$ n-cm⁻²·s⁻¹, dpa/year ≤ 11–16 Core positions: 24 IP with \varnothing 12 mm, 4 IP with \varnothing 24.5 mm Neutron flux: total $\leq 4.3 \times 10^{15}$ n-cm⁻²·s⁻¹ fast (E> 0.1 MeV) 2.3×10^{15} n-cm⁻²·s⁻¹, dpa/year ≤ 16–25 Reflector positions: 30 IP with \varnothing 68 mm Neutron flux: total $\leq 1.6 \times 10^{15}$ n-cm⁻²·s⁻¹ fast (E> 0.1 MeV) $\leq 5.3 \times 10^{14}$ n-cm⁻²·s⁻¹ dpa/year ≤ 0.1–6.0</p>
<p>Irradiation positions (IP) in the core up to 25 (depends on core configuration), height of IP 450–500 mm, flat to flat size of hexagonal cell – 44 mm Neutron flux: total $\leq 3.6 \times 10^{15}$ n-cm⁻²·s⁻¹, fast (E> 0.1 MeV) $\leq 3.0 \times 10^{15}$ n-cm⁻²·s⁻¹ dpa/yea ≤ 10–25 IP in the radial reflector – unlimited, height of IP 450–500 mm, flat to flat size of hexagonal cell – 44 mm Neutron flux: total $\leq 1.8 \times 10^{15}$ n-cm⁻²·s⁻¹, fast (E> 0.1 MeV) $\leq 1.1 \times 10^{15}$ n-cm⁻²·s⁻¹, dpa/year ≤ 5–10</p>
<p>Total irradiation positions (IP) – 16, height of IP 350–400 mm Core positions: 8 IP with $\varnothing \leq 69$ mm Neutron flux: total $\leq 2.2 \times 10^{14}$ n-cm⁻²·s⁻¹ fast (E>0.1 MeV) $\leq 5.6 \times 10^{13}$ n-cm⁻²·s⁻¹ Dpa/year ≤ 0.6 Reflector positions 8 IP with $\varnothing \leq 160$ mm Neutron flux: total $\leq 3.2 \times 10^{13}$ n-cm⁻²·s⁻¹ fast (E> 0.1 MeV) $\leq 1.2 \times 10^{13}$ n-cm⁻²·s⁻¹ Dpa/year ≤ 0.1</p>
<p>Total irradiation positions (IP) – 49, height of IP 1100 mm Core positions: 11 cells for loop channels, with $\varnothing \leq 148.5$ mm Neutron flux: total $\leq 6.0 \times 10^{14}$ n-cm⁻²·s⁻¹ fast (E> 0.1 MeV) $\leq 2.0 \times 10^{14}$ n-cm⁻²·s⁻¹ Dpa/year ≤ 1.5; 38 IP with $\varnothing \leq 34$ mm Neutron flux: total $\leq 6.0 \times 10^{14}$ n-cm⁻²·s⁻¹ fast (E> 0.1 MeV) $\leq 3.0 \times 10^{14}$ n-cm⁻²·s⁻¹ Dpa/year ≤ 5</p>

Test configuration, test environment temperature and pressure range
<p>Test environment of ampoule rigs in the core and reflector: water, boiling water – ≤350°C, ≤16 MPa; Pb, Pb – Bi –650°C, ≤1 MPa; supercritical water ≤650°C, ≤23 MPa; gas (He, Ne, N₂) – 400–2500°C, ≤10 MPa High-temperature water loop in the core and reflector ≤350°C, ≤18 MPa Low-temperature water loop ≤ 100°C, ≤ 5 MPa Instrumented irradiation devices for in-pile investigation creep, stress relaxation, stress corrosion cracking etc.</p>
<p>Test environment of ampoule rigs in the core and reflector: Na, Pb, Pb – Bi –320–720°C, ≤1 MPa Gas (Ar, He, Ne and mixture) 330–1100°C, ≤ 1 MPa Na, Pb, Pb – Bi in-vessel loop facilities –330–720°C, ≤ 1 MPa</p>
<p>Capsules only Test environment of ampoule rigs in the core and reflector: water, boiling water – ≤ 350°C, ≤ 16 MPa; –supercritical water – ≤650°C, ≤ 23 MPa; gas (He, Ne, N₂) – 400–2500°C, ≤ 10 MPa Instrumented irradiation devices for in-pile investigation creep, stress relaxation, stress corrosion cracking etc.</p>
<p>Test environment in the water loop facilities: water –temperature ≤350°C, pressure ≤17 MPa (2 facilities with 2 channels each) Test environment in the boiling water loop facilities: water – temperature ≤350°C, pressure ≤ 17 MPa, volume vapour content (2 facilities with 2 channels each) Test environment in the vapour loop facilities: superheating steam–temperature ≤ 1100°C, pressure ≤20 MPa (1 facility, with 1 channel) Test environment in the gas loop facility: N, He, He-Xe–temperature ≤ 1100°C, pressure ≤ 4 MPa (1 facility, with 1 channel)</p>
Instrumentation and control (in-pile temperature, pressure, fission gas monitoring, stress strain, etc.)
<p>Temperature: chromel-alumel thermocouples up to 1100°C W-Re thermocouples up to 2300°C Geometry change: linear differential inductosyn transducer (LDIT) Pressure, stress and strains: bellows rolling diaphragm + LDIT Neutron flux: Rh-, V-, Hf – direct charge detectors Neutron fluence: activation monitors</p>
<p>Temperature: chromel-alumel thermocouples up to 1100°C Melting monitors, SiC monitors Pressure, stress and strains: bellows rolling diaphragm, spring Neutron fluence activation monitors</p>
<p>Temperature: chromel-alumel thermocouples up to 1100°C, W-Re thermocouples up to 2300°C Geometry change: linear differential inductosyn transducer (LDIT) Pressure, stress and strains: bellows rolling diaphragm + LDIT Neutron flux: Rh-, V-, Hf – direct charge detectors Neutron fluence: activation monitors</p>
<p>Temperature: chromel-alumel thermocouples up to 1100°C, W-Re thermocouples up to 2300°C Geometry change: linear differential inductosyn transducer (LDIT) Pressure, stress and strains: bellows rolling diaphragm + LDIT Neutron flux: Rh-, V-, Hf – direct charge detectors Neutron fluence: activation monitors</p>

Auxiliary facilities (beams, neutron activation analysis, gamma-ray, etc.)
Chemistry control and measurement systems of water and gas environment for ampoule rigs, Fission products monitoring and measurement facilities Loop systems for simulation of PWR, WWER conditions 1 hot cell in the reactor building
Chemistry control and measurement systems of gas environment for ampoule rigs Fission product monitoring and measurement facilities 1 hot cell in the reactor building 9 vertical channels located outside the reactor vessel with \varnothing 90–230 mm Neutron flux: total $\leq 1.8 \times 10^{13}$ n·cm ⁻² ·s ⁻¹ fast (E>0.1MeV) $\leq 8 \times 10^{12}$ n·cm ⁻² ·s ⁻¹ 2 horizontal beams Neutron flux: total $\leq 1 \cdot 10^9$ n·cm ⁻² ·s ⁻¹ fast (E>0.1 MeV) $\leq 3 \times 10^8$ n·cm ⁻² ·s
Chemistry control and measurement systems of gas environment for ampoule rigs Fission products monitoring and measurement facilities 1 hot cell in the reactor building
Chemistry control and measurement systems of water and gas environment for ampoule rigs, Fission products monitoring and measurement facilities Loop systems for simulation of PWR, WWER, RBMK, HTGR conditions Experimental facilities for investigation of steady-state transient, accidental conditions (LOCA, LOFT, RIA) 1 hot cell in the reactor building
On-site PIE capabilities (hot cells, gloveboxes, tools for stress analysis, etc.)
More than 110 equipment in the material testing complex Burn-up; fission products release; metallographic and ceramographic, micro-hardness; density and porosity; thermal conductivity and electric resistance; X-ray analysis; TEM, SEM, EPMA, AES, SIMS; mechanical testing (tensile, compression, bending, impact etc.)
More than 110 equipment in the material testing complex Burn-up; fission products release; metallographic and ceramographic, micro-hardness; density and porosity; thermal conductivity and electric resistance; X-ray analysis; TEM, SEM, EPMA, AES, SIMS; mechanical testing (tensile, compression)
The material testing complex houses more than 110 equipment Burn-up; fission products release; metallographic and ceramographic, micro-hardness; density and porosity; thermal conductivity and electric resistance; X-ray analysis; TEM, SEM, EPMA, AES, SIMS; mechanical testing (tensile, compression)
The material testing complex housing more than 110 equipment Burn-up; fission products release; metallographic and ceramographic, micro-hardness; density and porosity; thermal conductivity and electric resistance; X-ray analysis; TEM, SEM, EPMA, AES, SIMS; mechanical testing (tensile, compression, bending, impact etc.)
Design, manufacturing, disposition, shipping, waste handling and other capabilities
Department for design of reactor components and experimental facilities Plant for manufacturing reactor components and experimental facilities Facilities and technologies for investigation and production of nuclear fuel Radiochemical complex to study and produce transplutronics, radioisotopes and sources for industrial and medical purposes Facilities to dispose radwaste and spent nuclear fuel and materials

Method of access and degree of utilisation
Bi- and multilateral contracts between laboratories and institutions Degree of utilisation: 80–90%
Bi- and multilateral contracts between laboratories and institutions Degree of utilisation: 80–90%
Bi- and multilateral contracts between laboratories and institutions Degree of utilisation: 40–50%
Bi- and multilateral contracts between laboratories and institutions Degree of utilisation: 50–60%
Miscellaneous and readiness for material testing research
Suitable for high-flux instrumented tests of new materials and fuels of innovative reactors
Suitable for high-flux instrumented tests of new materials and fuels of innovative reactors
Suitable for in-pile instrumented tests under medium and low fluxes of new materials, testing for pressure vessels possible
Good for in-pile instrumented loop tests of fuel under steady-state transient, accidental conditions (LOCA, LOFT, RIA)

Table 7. Russia user facilities for nuclear materials work list

User facility	Website
Critical assembly BFS-2	www.ippe.ru/ibasa/ust.php
Hot laboratory, Radiochemical complex	www.ippe.ru/ibasa/matk.php
Tandem Accelerator Tandetron	www.ippe.ru/ibasa/usk-kom-2.php
Research Institute of Atomic Reactors	www.niiar.ru

6.7 Spain²

6.7.1. ALBA Synchrotron Light Source

Location:

Carretera de Cerdanyola del Vallès a Sant Cugat del Vallès, Cerdanyola del Vallès Barcelona, Spain.

Web address:

www.cells.es

Category:

Synchrotron light source

Facility description:

ALBA is a third generation synchrotron light facility located in Cerdanyola del Vallès, Barcelona, Spain and it is the newest source in the Mediterranean area. It is governed by a public consortium created in March 2003: The Consortium for the Construction, Equipping and Exploitation of the Synchrotron Light Source (CELLS), owned and financed in equal part by the Spanish and the Catalanian Administration. ALBA has been identified as a “Singular Technological and Scientific

2. <http://portal.meril.eu/>, <http://www.idi.mineco.gob.es/>.

Infrastructure” among the Spanish scientific infrastructures. It is networked with other synchrotron light sources in and outside Europe through common European projects and bilateral collaboration agreements. The facility is based on a chain of accelerators which produce, accelerate up to 3 GeV and store in a synchrotron ring electron beams which emit synchrotron light ranging from infrared up to hard X-ray of tens of keVs. Up to 31 ports are available to extract the light as well as the space for the corresponding beamlines and related experimental hutches. Buildings for conventional technical systems and for specialised laboratories complete the facility.

- **Equipment: Beamlines**

The initial seven ALBA beamlines can be classified into three groups according to their main scientific application areas:

- those devoted to life sciences;
- those devoted to condensed matter physics, especially magnetic structures, electronic properties and nanoscience;
- those devoted to chemistry with applications in materials science and different multi-disciplinary areas.

User interface:

- **Beamtime access**

ALBA is a public institution serving the academic world and public research institutes. At the same time one of its strategic priorities is to foster industrial R&D activities through technological transfer and private utilisation of beamtime. The ALBA vision is to become a centre of excellence in synchrotron light scientific and industrial applications and to achieve the status of a recognised world class facility in its field. Its mission is to research in, deliver and maintain methods and techniques with which to conduct cutting edge synchrotron light-based research and development, in such a way that knowledge and added value are pumped into the scientific and industrial communities, particularly the Spanish ones, with the ultimate goal of contributing to the improvement of well-being and progress of society as a whole.

User amenities:

VILA 2 and Hotel Campus propose a joint accommodation offer to ALBA users. You can choose either the autonomy offered by an apartment at VILA 2 or the comfort of a hotel room at Hotel Campus, both located on the Autonomous University of Barcelona (UAB) Campus and close to the ALBA facility. You may use the public bus line connecting Belleterra FGC train station, Cerdanyola RENFE train station, UAB Hotel and ALBA. This service is covered by the Barcelona Metropolitan Area “Tarifa Integrada” tickets. The canteen of the ALBA synchrotron is located on the basement floor. The canteen is open from 8 a.m. to 4 p.m. on working days.

6.7.2. CNA (National Accelerator Centre)

Location:

CNA is located 7, Av. Thomas Alva Edison|41092 Sevilla | Andalucía. Spain.

Web address: www.cna.us.es

Facility description:

Four joined accelerators, a scanner PET/CT for humans, a scanner PET/CT for animals and a ⁶⁰Co irradiator where many techniques, skills and equipment are common to these facilities. It is a building

with space to house equipment, laboratories, workers and researchers, own budget, which allows flexibility for regular operation. Increase in experimental activity of Spanish research groups should increase demand for the use of CNA facilities European co-operation in large projects should allow finding activities in which “small” accelerators as CNA can contribute to European large-scale facilities. Increased activity in PET medical imaging is an opportunity for CNA, which can produce PET radionuclides, synthesise radiopharmaceuticals and provide PET imaging equipment. It can be important to train highly qualified technicians in medical imaging. National collaborative programmes, such as the CONSOLIDER-CPAN Project on Particle, Astroparticle and Nuclear Physics, stress the importance of increasing the number of highly specialised technicians. CNA is an IAEA collaborator Centre and participates in European projects such as DITANET, LA3NET and oPAC.

Research Service(s): Measurements by IBA techniques:

- service of measurements by IBA techniques, which provide multi-elemental analysis by XRF, channelling, PIGE, PIXE, RBS and NRA methods for experiments such as material science, archaeology, environmental sciences, irradiation experiments, nuclear physics and nuclear instrumentation;
- production of PET radionuclides;
- radionuclides used in positron emission tomography;
- PET and CT scanners for small animals and humans;
- measurements by accelerator mass spectrometry;
- measurements of the content of plutonium, iodine, beryllium and carbon isotopes have been performed in environmental and historical samples;

^{14}C dating; equipment: 3 MV tandem accelerators:

- accelerator used to IBA measurements (PIXE, PIGE, NRA, RBS, CHANNELING);
- 1 MV Tandetron accelerator;
- accelerator used to long-life radionuclides mass spectrometry ($^{239-240}\text{Pu}$, ^{129}I , ^{41}Ca , ^{14}C , ^{10}Be);
- cyclotron 18/9 MeV;
- accelerator used to IBA (Ion Beam Analysis) measurements and radionuclides PET production;
- PET/CT scanners for small animal and for humans;
- scanners for positron emission tomography and computerised tomography;
- ^{60}Co irradiator;
- equipment used to irradiation of aerospace technology by photons;
- MiCaDaS (Mini radiocarbon Dating System);
- accelerator used to ^{14}C dating only.

Annual number of users:

Average number of national users per year: 42.

Average number of European users per year: 16.

Average number of international users per year: 5.

Main status: Operational from 1999.

RI Type: Single-sited

User interface:

The use of CNA facilities requires the authorisation of the scientific committee, which will evaluate the applications.

6.7.3. Centre for micro analysis of materials (CMAM)

Location:

Centro de Microanálisis de Materiales. C/Faraday 3, Universidad Autónoma de Madrid Campus de Cantoblanco E-28049, Madrid, Spain.

Web address:

www.cmam.uam.es/

Category:

Ion accelerator

Facility description:

The Centre for Micro Analysis of Materials (CMAM) is a research centre belonging to the Universidad Autónoma de Madrid (UAM) whose main experimental tool is an electrostatic ion accelerator with a maximum terminal voltage of 5 MV, devoted to the analysis and modification of materials.

CMAM is the result of a project financed through the FEDER programme and developed under the guidance of the Instituto de Ciencia de Materiales Nicolás Cabrera (INC).

The project was managed, since July 1998, by a Managing Technical Committee chaired by Prof. Fernando Agulló López, assisted by an Advisory Committee formed by outstanding members of the Spanish scientific, cultural and academic community.

In 2002 the UAM established that the INC had fully and satisfactorily accomplished the startup of CMAM that was officially inaugurated on 24 March 2003, becoming then a university research centre independent from the INC.

The experimental equipment consists of the accelerator, its beam lines and dedicated to various application areas and several ancillary equipment (micro-analytical techniques, sample preparation).

The accelerator, built by HVEE, is of the tandem type and the acceleration system is of the Cockroft-Walton type. It is provided with two sources: a plasma source for gaseous substances and a sputtering source for obtaining practically any element of the periodic table from a solid target.

User interface:

- Access to CMAM and its services

CMAM is an open facility with full competitive access to the accelerator beam time.

Starting from 31 July 2015 CMAM handles directly all access services to local and external users. For precise information on how to access the facility you must contact us. Information on the equipment and beamlines available can be found in the beamlines section.

The UAM's "Consejo Social" (Social Council) has approved fees for the use of beam time and additional services, applicable to enterprises and private users. At the same time it has decided a financial contribution to the running and service costs applicable to universities and public research institutions national and international. The costs are established by user category and can be found in the following document.

- Beam time request

Regardless of the user's category only proposals presented through our beam time request service will be considered. To access this service and submit beam time applications you must be previously registered. You will do so in the CMAM user's portal. You must enter the portal in the "Register as a new user" mode, which allows interactively the introduction and registration on the database of user's identifying data.

- Other services request

Services such as assistance of CMAM staff in mounting and carrying out experiments, data analysis including report, additional technical work can be requested. This can be done either in the special requirements section of a beam time request form or separately contacting.

6.7.4. LMA (Advanced Microscopy Laboratory)

Location:

Edificio I+D – Campus Río Ebro C/ Mariano Esquillor s/n 50018 Zaragoza.

Web address:

<http://lma.unizar.es/>

Category:

Microscopy

Facility description:

The Advanced Microscopy Laboratory, LMA, is a unique initiative at national and international levels aimed at providing the industrial and scientific communities with the most advanced infrastructures in nanofabrication, local probe and electron microscopies for the observation, characterisation, nano-patterning and handling of materials at atomic and molecular scale.

Microfabrication: dual beam, and micro-characterisation: SEM, XPS, and XRD areas:

- Nova200Cryogenic dual-beam nova 200;
- Clean room dual-beam helios nanolab 600 and 650;
- Quanta environmental scanning electron microscope SEM-Quanta FEG 250, ESEM;
- Inspect F50 field emission scanning electron microscope CSEM-FEG INSPECT 50;
- XRD: Bruker D8 advance high-resolution diffractometer;
- XPS-AES: Kratos AXIS Ultra DLD X-ray photoelectron spectrometer.

Transmission electron microscopy (TEM) area:

- TitanCube;
- TEM: titan high-base for high-resolution imaging. FEI TITAN3;

- Titan_Low_Base_tr TEM: analytical titan low-base. FEI TITAN low-base;
- F30 Transmission electron microscope (TEM): Tecnai F30;
- SamplePrep_1 TEM: sample preparation service.

Scanning probe microscopy (SPM) area:

- Moncayo;
- Low-temperature (LT), ultra-high vacuum (UHV-LT) SPM laboratory;
- SPM_HM SPM with high magnetic fields and low temperature;
- SPM_Env SPM in Environmental Conditions.

User interface:

Access without Proposal: To gain access to the LMA facilities without proposals you just have to fill out online the form available in the LMA web site. You will get an email in a few working days informing you about the dates in which you can use the instrument you requested in your application.

Access with proposal or ICTS Access: To gain access to the LMA facilities with proposal, which involves a significant discount in the rates, users have to submit a brief research proposal describing their requirements. A standardised proposal form is available at LMA website (Access with Proposal section), which has to be filled in and uploaded online. You will get an email in a maximum of ten working days with the outcome of your proposal. If your proposal has been accepted you will be informed about the dates in which you can use the instrument you requested in your application.

The research proposal to gain access will contain:

- administrative details of the requesting person or group leader;
- the scientific and/or technological aim to be carried out at LMA; the relevant technical issues and the scientific background of the applicant/s, and any special requirements which the projected work may have);
- the requested instrument(s);
- the requested access time to the instrument.

There will be a permanently open call for submission of proposals. Successful proposals will be then allocated for a measuring slot as soon as possible.

For every successful proposal, the area leader of the LMA will assign a technician to support the applicant. The applicant will be then notified of the acceptance of the proposal and invited to discuss details and dates of the experiment with the LMA technician.

All proposals will be treated as confidential and will be only revised by the Access Committee and the technician who will work on the project.

The evaluation of the proposals is performed by specialised committees in each of the three scientific divisions of the LMA. The committees are chaired by the corresponding responsible scientist of the TEM, SPM and Dual-Beam areas and are formed by the experienced external scientists.

Proposals will be sent through LMA web site and, depending on the requested instrument, they will reach the corresponding head of area, who will transfer it to a member of the User Selection Panel (USP). Each proposal will be assessed by the USP against the following selection criteria: scientific and/or technological merit of the proposal; research capabilities of the applicant(s); technical issues, feasibility of the experiment, actual need of the LMA equipment for the work proposed.

Proposals with a total ranking less than ten will be rejected. Rejection of a proposal will always be accompanied by a report written by the referee of the USP outlining the reasons for rejection. Where appropriate, the report will also include recommendations and suggestions for improvement and resubmission of a new proposal for accessing to the LMA.

Proposals will be accepted in strict order according to the ranking and the available measuring slots.

6.7.5. CNME (National Centre for Advanced Microscopy)

Location:

Centro Nacional de Microscopía Electrónica Facultad de Químicas Av. Complutense s/n 28040 Madrid.

Web address:

www.cnme.es

Category:

Microscopy

Facility description:

The National Centre for Advanced Microscopy (main transverse action of the Campus of International Excellence Moncloa) is designed to develop, implement and offer to the national scientific community and internationally the most advanced methods and techniques in transmission electron microscopy and scanning for structural analysis of materials. This centre consists of a series of art microscopes, tools and advanced techniques for sample preparation and the application of computational methods of image processing.

This set of instruments gives the centre an absolute uniqueness, because there is no such a set of microscopy techniques in any Spanish or international laboratory and therefore enables a co-ordinated work and the best methodological conditions for the entire process from sample preparation to advanced mathematical calculations for the resolution of structures.

ICTS management is regulated by the FG UCM and the Research and Science Policy of the UCM, which ensures their maintenance, providing technical and human resources to ensure its operation.

ICTS runs as a service under prices that are different for members of the UCM, and external, public or private users.

Instruments: JEOL JEM 1010, JEOL JEM 2000FX, JEOL JEM 2100, JEOL JEM 3000F, JEOL JEM ARM200cF, JEOL JSM 6335F, JEOL JSM 6400, JEOL JSM7600F, JEOL. Superprobe JXA-8900 M, Atomic Force Microscope (AFM), PHILIPS CM200FEG.

User interface:

To gain access to the CNME facilities, eligible users should submit a research proposal describing their requirements. A standardised proposal form is available on the CNME website and can be filled online. The research proposal should contain the administrative location of the requesting person or group leader and should describe:

- the scientific aim of the project, including;
- the state of the art;

- the expected output;
- the potential industrial applications;
- possible special requests (for example: use of particular stages, precautions, low temperature, gas atmosphere, low voltages...);
- the requested instrument(s) including measuring conditions and sample preparation facilities, if needed;
- the requested access time to the instrument and sample preparation time (if any);
- the preferred dates for the measurements;
- the requested time for computing/data treatment and analysis time (if any).

There will be a permanently open call for submission of proposals. The proposals will be collected and reviewed by the proposals co-ordinator. Successful proposals will be then allocated for a measuring slot. For every successful proposal, the proposals co-ordinator of the CNME will select a scientific in-house correspondent (local contact). The applicant will be then notified of the acceptance of the proposal and invited to communicate details and dates of the experiment with the local contact at the CNME.

User amenities:

The Accommodation Office in the Excellence Moncloa Campus has interesting offers of rent houses, programmes for coexistence, residence and residence hall.

This service is directed to students of the UCM and UPM, Administrative and Service Staff as well as Teaching and Research Staff of our universities.

Accommodation Office: alojamientoenlaucm@rect.ucm.es

Table 8. Spain user facilities for nuclear materials work list

User facility	Website
ALBA Synchrotron Light Source	www.cells.es
CNA (National Accelerator Centre)	www.cna.us.es
CMAM (CENTRE FOR MICRO ANALYSIS OF MATERIALS)	www.cmam.uam.es/
LMA (Advanced Microscopy Laboratory)	http://lma.unizar.es/
CNME (National Center for Advanced	http://www.cnme.es

6.8. Switzerland

6.8.1. Swiss Spallation Neutron Source (SINQ)

Location:

Paul Scherrer Institut, 5232 Villigen PSI, Switzerland.

Web address:

www.psi.ch/science/large-scale-facilities

Category:

Irradiation and Neutron Scattering facilities

Facility description:

SINQ is one of MW-class spallation neutron source in the world. The SINQ Target Irradiation Programme (STIP) is the unique irradiation programme in the world conducting irradiation experiments under a mixed spectrum of high-energy (550 MeV) protons and spallation neutrons. Every STIP irradiation experiment lasts for two years with irradiation doses up to about 25 dpa in steels.

SINQ is also a neutron scattering laboratory that provides various instruments for materials research, in particular three beam lines for high-radioactive materials such as fuel cladding tubes and specimens irradiated in STIP. For a specific list of instruments go the following web link: www.psi.ch/lns/laboratory-for-neutron-scattering.

Annual number of users:

More than 800

User interface:

For neutron scattering experiments the beam time is granted through the general user programme, which is open to all. A research proposal can be submitted online: www.psi.ch/sinq/call-for-proposals.

For STIP irradiation experiments any requests can be discussed with the STIP responsible person: Dr Yong Dai (email: yong.dai@psi.ch/Tel: +41 56 310 4171).

User amenities:

PSI Guest House provides clients, visiting researchers and other visitors with convenient, on-site lodging. Online booking is available using link: www.psi.ch/gaestehaus/guesthouse.

User organisation:

SINQ is one of PSI's large research facilities. A user office (www.psi.ch/useroffice/useroffice) provides service to all users of neutron scattering science.

STIP irradiation experiments are currently conducted by the Advanced Nuclear Materials (ANM) Group with financial support of PSI and external users.

6.8.2. Swiss Light Source (SLS)

Location:

Paul Scherrer Institut, 5232 Villigen PSI, Switzerland.

Web address:

www.psi.ch/sls/swiss-light-source

Category:

Synchrotron light

Facility description:

The Swiss Light Source (SLS) at the Paul Scherrer Institut is a third generation synchrotron light source. With an energy of 2.4 GeV, it provides photon beams of high brightness for research in materials science, biology and chemistry.

Annual number of users:

More than 3000

User interface:

For experiments at SLS the beam time is granted through the general user program, which is open to all. A research proposal can be submitted online: www.psi.ch/useroffice/proposal-deadlines.

User amenities:

PSI Guest House provides clients, visiting researchers and other visitors with convenient, on-site lodging. Online booking is available using link: www.psi.ch/gaestehaus/guesthouse.

User organisation:

SLS is one of PSI's large research facilities. A user office (www.psi.ch/useroffice/useroffice) provides service to all users of neutron scattering science.

6.8.3. Hot laboratory at PSI (AHL)*Location:*

Paul Scherrer Institut, 5232 Villigen PSI, Switzerland.

Web address:

www.psi.ch/ahl/hot-laboratory-division

Category:

Handling and characterisation of highly radioactive materials

Facility description:

The hot laboratory is the single Swiss laboratory authorised by the safety authorities to handle large quantities of radioactive materials including commercial as well as experimental nuclear fuel. The main working fields of the division are:

- examine and understand high burn-up LWR fuel behaviour (UO₂ and MOX);
- analyse damage of core structural components;
- provide a significant contribution to safety and economy of existing and next generation power plants;
- ensure an immediate support of Swiss nuclear power stations in case of urgent need of material investigation;
- act as user lab for the users of other PSI research facilities with radioactive materials.

Annual number of users:

More than 100

User interface:

A research proposal can be submitted by the AHL division head

Dr Didier Gavillet (email: didier.gavillet@psi.ch).

User amenities:

PSI Guest House provides clients, visiting researchers and other visitors with convenient, on-site lodging. Online booking is available using: www.psi.ch/gaestehaus/guesthouse.

User organisation:

The hot laboratory is operated with financial support of PSI, Swiss nuclear industry and external users.

6.8.4. Electron Microscopy Facility at PSI (EMF)

Location:

Paul Scherrer Institut, 5232 Villigen PSI, Switzerland.

Web address:

www.psi.ch/lbr/electron-microscopy

Category:

Characterisation of inactive and radioactive materials

Facility description:

The Electron Microscopy Facility at PSI is presently sustained by three research departments of PSI. With its two transmission electron microscopes, a focused ion beam instrument and plenty of preparation tools, it offers a direct access to electron-microscopic techniques highly required in research fields of various materials, including biological materials and high-radioactive structural materials. The facility is unique within Switzerland as it also allows the investigation of radioactive materials.

Annual number of users:

More than 50

User interface:

A research proposal can be submitted EMF manager, Dr Elisabeth Müller (elisabeth.mueller@psi.ch).

User amenities:

PSI Guest House provides clients, visiting researchers, and other visitors with convenient, on-site lodging. Online booking is available using: www.psi.ch/gaestehaus/guesthouse.

User organisation:

The Electron Microscopy Facility is operated with financial support of the three research departments and external users.

Table 9. Switzerland user facilities for nuclear materials work list

Swiss User facility	Website
Swiss Spallation Neutron Source (SINQ)	www.psi.ch/science/large-scale-facilities www.psi.ch/sinq/
Swiss Light Source (SLS)	www.psi.ch/sls/swiss-light-source
Hot Laboratory (AHL)	www.psi.ch/ahl/hot-laboratory-division
Electron Microscopy Facility (EMF)	www.psi.ch/lbr/electron-microscopy

6.9. United Kingdom

The National Nuclear User Facility (NNUF) (www.nnuf.ac.uk) aims to provide the UK nuclear R&D community with research facilities in three complementary facilities at the Central Laboratory of the National Nuclear Laboratory (NNL), the Culham Centre for Fusion Energy (CCFE) and the Dalton Cumbrian Facility. The NNUF provides equipment for experiments on materials that are too radioactive for university laboratories.

6.9.1. NNUF (National Nuclear Laboratory)

Location:

Cumbria, United Kingdom.

Web address:

www.nnl.co.uk/NNUF

Category:

Ion Beam Milling, Electron Microscopy, X-ray Tomography

Facility description:

Facilities available for sample preparation (FIB and sample preparation suite), materials characterisation (on-site post-irradiation examination, PIE of active materials, material transfer (transfer of lower active materials for off-site PIE).

- Focused ion beam

FEI Helios instrument currently capable of handling trace active samples and following fully active commissioning the instrument will be able to handle more highly irradiated structural materials and fuels. It is also suitable for preparation of active samples for transmission electron microscopy (TEM) and atom probe tomography (APT) that transported for analysis at universities or other research facilities. NNL can currently provide access to its active TEM (JEOL 2100 fitted with 80 mm² Oxford Instruments EDX detector) and a FEGTEM as part of the NNUF facility (see below). The current TEM is capable of 5-10 nm spatial resolution for the analysis of irradiated samples and is typically used to characterise irradiated cladding. An electron energy loss spectroscopy (EELS) upgrade (Gatan Quantum 965ER) is in progress.

- Field emission gun – transmission electron microscope (FEGTEM)

JEOL ARM200CF: This is the highest resolution analytical S/TEM currently available and provides atomic resolution composition mapping. It has 80 pm probe size, a 0.98Sr EDX detector and will be fitted with the Gatan Quantum system.

- X-ray microtomography

Bruker Skyscan 1172 working in an active lab, which provides computerised CT scanning with micron scale resolution. Samples up to 27 mm (or 50 mm using multiple scans) can be accommodated.

User interface:

Contracting directly with NNUF.

User amenities:

Facilities in Cumbria are located close to the Dalton Cumbrian Facility.

User organisation:

Strategic direction for the National Nuclear User Facility is provided by a steering group that currently comprises the Imperial College London, the universities of Oxford, Manchester, Lancaster and Leeds, representatives from each of the user facilities – Culham Centre for Fusion Energy, NNL Central Laboratory and Dalton Cumbrian Facility, and; EPSRC (observer).

6.9.2. Dalton Cumbrian Facility (DCF)

Location:

Cumbria, United Kingdom.

Web address:

www.nnuf.ac.uk/uom.html

Category:

Ion beam and electron microscopy

Facility description:

5 MV Tandem Van de Graaff accelerators (from September 2012) produce M^{Z+} ions with energy $5(Z+1)$ MeV:

- high-current TORVIS source providing 10 MeV $^1\text{H}^+$ at 100 μamps , 15MeV $^4\text{He}^{2+}$ at 15 μamps ;
- low-current SNICS source providing partially and fully stripped heavy ions e.g. 35 MeV $^{12}\text{C}^{6+}$ at 150 namps;
- six beamlines with two high precision raster scanners;
- two irradiation vaults to enable parallel working and minimised downtime.

Foss therapy model 812 ^{60}Co self-contained high-dose rate gamma irradiator:

- 15 kCi in dual source rod assemblies (equivalent to central chamber dose rate ~ 16.5 kRAD);
- 9 litres (8" wide x 10" deep x 12" high) sample chamber.

UHV controlled atmosphere chamber with low-energy electron gun (2 – 50 eV) and laser induced fluorescence for surface science studies.

Available instruments:

- FT-IR spectrometer/FT-Raman spectrometer/Raman microscope;
- field emission gun environmental scanning electron microscope;

- mass spectrometer;
- high-performance liquid chromatograph;
- gas chromatograph;
- ion chromatograph;
- surface area and porosity analyser (BET method);
- fluorescence spectrophotometer;
- UV-Vis spectrometer;
- micro-hardness tester;
- total organic carbon analyser;
- Karl Fischer Titrator.

Academic access to National Nuclear Laboratory's Research & Development complex (Central Laboratory) at the nearby Sellafield site.

Central Laboratory comprises:

- highly active alpha/beta/gamma cells (awaiting active commissioning);
- plutonium active laboratories; (subject to ongoing commissioning);
- low active and inactive laboratories;
- uranium-active rig hall;
- non-active rig hall, incorporating a vitrification test rig;
- supporting infrastructure to meet the requirements of 300 technologists.

The Central Laboratory is capable of providing the complete range of facilities to support all disciplines and radioactivity levels required to underpin the full range of nuclear fuel cycle operations, including; oxide and metal fuel reprocessing, high-level waste vitrification, intermediate-level waste treatment and storage, low-level waste disposal, mixed oxide fuel production and decontamination and decommissioning.

Available instruments for analysing irradiated samples include ESEM, TEM and, potentially, FIB dual-beam SEM.

Annual number of users:

Details to be confirmed as the facility is newly created. DCF will house up to 50 people of which around 30 will be researchers. Annual number of users will depend on the detail of research projects but is anticipated that it will be >100.

User interface:

Contracting directly with the University of Manchester.

User amenities:

DCF is situated on the Westlakes Science and Technology Park in West Cumbria and is close to the Lake District National Park.

Lodging is available at a range of local hotels for short stay and rental accommodation for longer stay. A project is being delivered to create a flexible range of short and medium stay accommodation units adjacent to the Science Park, with first units available during 2012.

Dining is available at a range of local restaurants and hotels with daytime catering available on the Science Park.

Child day care is available in the nearby towns of Whitehaven & Egremont.

User organisation:

The Dalton Cumbrian Facility is owned and operated by the University of Manchester, the UK's largest campus based university. The University is a public university with the primary goals of research, higher learning and social responsibility. Manchester is ranked in the top 3 UK universities in terms of "research power" and the University has an annual research expenditure of over GBP 400 million. Manchester is delivering an extensive GBP 650 million capital investment programme and, as part of this programme, the University's Dalton Nuclear Institute created the Dalton Cumbrian Facility (DCF) through an initial investment of GBP 20 million.

DCF was created by the Dalton Nuclear Institute to provide the UK with an international user facility for radiation science that, together with the University's access to NNL's Central Laboratory, establishes a unique research capability that will engage fully with international research programmes.

6.9.3. Materials Research Facility (Culham Centre for Fusion Energy)

Location:

Culham, United Kingdom.

Web address:

www.ccf.ac.uk/mrf.aspx

Category:

Ion Beam Milling, Electron Microscopy, Nanoindentation

Facility description:

The MRF at Culham provides academic and industry users with a unique resource for micro-characterisation of materials. It bridges the gap between the university or industrial laboratory and large facilities at nuclear licensed sites, with affordable, convenient lab access. The new MRF building allows use of radioactive material, with hot cells for processing and micro-characterisation of neutron-irradiated samples. It will have the capacity to cut, polish and encapsulate individual Charpy-style samples up to the TeraBecquerel level for analysis either on-site or back at the user's institute.

The initial on-site analysis equipment include a dual beam focused ion beam, a scanning electron microscope with EBSD and EDS, and a nanoindenter.

- Scanning electron microscope

Mira3 XMH for chemical analysis and microstructural analysis (EBSD) is designed for data collection using low-probe currents.

- Focused Ion Beam (FIB) scanning electron microscope

- dual-beam Helios NanoLab 600i;

- nanoindentation;
- agilent nanoindenter G200;

Annual number of users:

Detail to be confirmed as the facility is newly created.

User interface:

Contracting directly with the Materials Research Facility.

User organisation:

The MRF is part of the UK NNUF. Strategic direction for the National Nuclear User Facility is provided by a steering group that currently comprises Imperial College London, the universities of Oxford, Manchester, Lancaster and Leeds, representatives from each of the user facilities – Culham Centre for Fusion Energy, NNL Central Laboratory and Dalton Cumbrian Facility and EPSRC (observer).

Table 10. UK user facilities for nuclear materials work list

UK User facility	Website
NNUF (National Nuclear Laboratory)	www.nnl.co.uk/NNUF
Dalton Cumbrian Facility (DCF)	www.nnuf.ac.uk/uom.html
Materials Research Facility (CCFE)	www.ccfе.ac.uk/mrf.aspx

6.10. United States

6.10.1. Nuclear Science User Facilities (NSUFs)

Location:

Idaho National Laboratory, PO Box 1625, Idaho Falls, Idaho, 83415-3553, US.

Web address:

<https://nsuf.inl.gov/>

Category:

Test reactors, advanced microscopy, materials characterisation, post-irradiation examination, ion beam.

Facility description:

- reactors: ATR, ATRC, MIT reactor, NCSU PULSTAR and HFIR;
- beam lines: IIT- APS, NCSU PULSTAR, University of Michigan Ion Beam Lab, University of Wisconsin Tandem Accelerator Ion Beam;
- post-irradiation examination (PIE) and materials characterisation: Idaho National Laboratory (INL), the Pacific Northwest National Laboratory (PNNL), Oak Ridge National Laboratory (ORNL) and Westinghouse.

Annual number of users:

45

User interface:

Access is granted through merit-based peer review of submitted research proposals. The NSUF conducts one open solicitation each fiscal year for major irradiation, PIE and beamline experiments lasting up to seven years total project lifetime. In addition, NSUF also offers rapid turnaround experiments. This kind of experiment can be performed quickly (~six months or less) and for less than USD 50K. The call for rapid turnaround experiments is open throughout the year.

User amenities:

No on-site amenities but amenities can be found in Idaho Falls.

User organisation:

NSUF is managed by the Idaho National Laboratory for the US Department of Energy (DOE). INL Deputy Laboratory Director for Science and Technology has appointed a Scientific Director of the NSUF to manage the facility. The NSUF director receives programme direction input from DOE, INL management and from an independent Scientific Review Board and from the independent NSUF Users Group. The NSUF Scientific Review Board is as an independent oversight body formed to ensure that the NSUF is performing its intended research and development mission. The board reviews the quality and the timeliness of the research and programmes conducted at the NSUF and advises INL's Deputy Laboratory Director for Science and Technology on the performance of the NSUF in meetings its objectives. The NSUF also has an independent users group. The users group represents users of the facility. Their role is to advocate for the facility and to facilitate sharing of information, forming collaboration and organising research efforts among users. Members of the users group leadership are appointed to also serve on the Scientific Review Board to represent the user base.

6.10.2. Advanced Photon Source (APS)

Location:

Building 401, 9700 S, Cass Avenue, Argonne, IL 60439. US.

Web address: www.aps.anl.gov/

Category:

Synchrotron Light Source

Facility description:

Over 700 beam-position monitors, 600 corrector magnets and 80 computer systems monitor and correct the electron orbit, steering X-ray beams onto experiment samples to micro tolerances. See website for more specific details.

Annual number of users:

More than 3 500

User interface:

The machine operates for a three-month runs (or cycles) each year, with a one-month shutdown between runs. The runs typically span February to April, June to August, and October to December.

In general, the advanced photon source (APS) makes beam time available to the international scientific community in two ways: General User access and Partner User access. Specific requirements govern modes of access.

- General users are those who require less than 10% of the beam time on a beamline in a given cycle. Proposals from general users are considered through a web-based process three times a year.
- Partner users are those whose work involves a greater scope and greater commitment by both the user and the APS.

Link to apply for beam time: www.aps.anl.gov/Users/apply_for_beamtime.html.

User amenities:

The Argonne Guest House is located in the Argonne National Laboratory campus, within 5 minutes by car to any part of the campus and a short walk to the advanced photon source and the APS Conference Centre.

The Guest House has 157 rooms, including 2-bedroom premiere suites with parlours and 4-bedroom suites with parlours. All suites have kitchenettes.

User organisation:

Advanced Photon Source Users Organisation (APSUO)/Steering Committee:

The APS Users Organisation (APSUO) is responsible for advising the APS Associate Laboratory Director in the following areas:

- The organisation will serve as an advocacy group for the Facility and its user community.
- The organisation will provide advice to the ALD on matters affecting the user community.
- The organisation will assure good communication between the APS user community and the APS management.

In addition, the APS has a Partner User Council (PUC). Much of the research is conducted and facilitated by partner users, which have entered into agreements with the APS either to build and operate facilities at the APS or to otherwise significantly enhance the programmes of the APS. As a result, partner user organisations represent significant commitments and investments from non-APS and non-DOE sources. Effective communication between the partner users and the APS is essential to achieving their common goals and to carrying out their joint mission. Consequently, the various partner users have come together to create a council to discuss issues and to facilitate communication with APS management. The Council shall be advisory to the Associate Laboratory Director for the advanced photon source.

6.10.3. Spallation Neutron Source (SNS)*Location:*

PO Box 2008 MS-6477, Oak Ridge, TN, 37831-6477, US.

Web address:

<http://neutrons.ornl.gov/facilities/SNS/>

Category: (synchrotron light, neutron scattering, electron microscopy, test reactor, nanotechnology, ion beam):

Neutron Scattering facility

Facility description:

SNS is a one-of-a-kind research facility that provides the most intense pulsed neutron beams in the world for scientific research and industrial development. SNS currently has 13 instruments available for users. For a specific list of instruments go the following web link: <http://neutrons.ornl.gov/instruments/SNS/>.

Annual number of users:

More than 1 700

User interface:

Beam time is granted through our general user programme, which is open to all. In addition, there are opportunities for extended collaboration through programmes such as internships and postdoctoral programmes.

The instruments at SNS can be used free of charge with the understanding that researchers will publish their results, making them available to the scientific community. The facilities are also available for proprietary research for a fee.

ORNL User Portal

The ORNL User Portal gives access to all the resources needed as a new or returning user, such as the proposal system, data access and analysis systems, sample handling information and visitor information. Simply create an account to have your own personalised portal every time you visit our site.

User amenities:

The Guest House is located at 8640 Nano Centre Drive at Chestnut Ridge facility complex.

The purpose of the ORNL Guest House is to provide convenient, on-site lodging to ORNL User Facility clients, visiting researchers and other ORNL visitors. The Guest House does not serve families (spouses and children). Service animals will be allowed. A visitor's pass is required to enter ORNL and stay at the Guest House. The following is a web link to the ORNL Guest House: www.ornl.gov/adm/fo/ls/hospitality/guesthouse/.

User organisation:

SNS-HFIR Users Group (SHUG)

The SNS-HFIR User Group (SHUG) consists of all persons interested in using the neutron scattering facilities at Oak Ridge. It provides input to the management on user concerns, provides a forum for keeping the entire community informed of issues and progress at these facilities and serves as an advocacy group for neutron scattering science at these facilities.

The initial bylaws for SHUG were adopted at the first SNS user meeting in the fall of 1998. The Executive Committee for SHUG was nominally formed in the summer of 1999 and had its first meeting by conference call in January of 2000. Officers were elected in April of 2000.

The SHUG by Bylaws and Charter can be found at:
<http://neutrons.ornl.gov/users/shug/bylaws.shtml>.

6.10.4. High-Flux Isotope Reactor (HFIR)

Location:

PO Box 2008 MS 6398, Oak Ridge, TN, 37831-6398, US

Web address:

<http://neutrons.ornl.gov/facilities/HFIR/>

Category:

Reactor, Neutron Scattering

Facility description:

Operating at 85 MW, HFIR is the highest flux reactor-based source of neutrons for research in the United States and it provides one of the highest steady-state neutron fluxes of any research reactor in the world. The thermal and cold neutrons produced by HFIR are used to study physics, chemistry, materials science, engineering and biology. For details on capability and instruments at HFIR please go to the following link: <http://neutrons.ornl.gov/instruments/HFIR/>.

Annual number of users:

More than 1 300

User interface:

Beam time is granted through our general user programme, which is open to all. In addition, there are opportunities for extended collaboration through programmes such as internships and postdoctoral programmes.

The instruments at HFIR can be used free of charge with the understanding that researchers will publish their results, making them available to the scientific community. Our facilities are also available for proprietary research for a fee.

ORNL User Portal

The ORNL User Portal gives access to all the resources needed as a new or returning user, such as the proposal system, data access and analysis systems, sample handling information and visitor information. Simply create an account to have your own personalised portal every time you visit our site.

User amenities

The Guest House is located at 8640 Nano Center Drive at Chestnut Ridge facility complex.

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(spouses and children). Service animals will be allowed. A visitor's pass is required to enter ORNL and stay at the Guest House.

Web link to the ORNL Guest House: www.ornl.gov/adm/fo/ls/hospitality/guesthouse/.

User organisation

SNS-HFIR Users Group (SHUG)

The SNS-HFIR User Group (SHUG) consists of all persons interested in using the neutron scattering facilities at Oak Ridge. It provides input to the management on user concerns, provides a forum for keeping the entire community informed of issues and progress at these facilities and serves as an advocacy group for neutron scattering science at these facilities.

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The SHUG by Bylaws and Charter can be found at: <http://neutrons.ornl.gov/users/shug/bylaws.shtml>

6.10.5. Los Alamos Neutron Science Center (LANSCE)

Location:

Los Alamos National Laboratory, MS H831, Los Alamos, NM, 87545, US

Web address:

<http://lansce.lanl.gov/>

Category:

Neutron Scattering

Facility description:

Isotope Production Facility, Lujan Neutron Scattering Center, Materials Test Station (MTS), Proton Radiography (pRad), Ultra-Cold Neutrons (UCN), Weapons Neutron Research Facility (WNR).

User interface:

Typically LANSCE has two calls for proposals each year for each run cycle of the accelerator. The following is a link to user resources: <http://lansce.lanl.gov/uresources/proposals.shtml>.

User amenities: (Lodging, restaurants, day care)

No on-site amenities but amenities can be found in the city of Los Alamos or White Rock.

User organisation:

The LANSCE User Group (LUG)

The LANSCE User Group (LUG) is comprised of current users. LUG provides direct input to LANSCE management, primarily through LUG's Executive Committee. The LUG Executive Committee is typically comprised of 12 members; one member is a student or postdoctoral researcher. The new members will serve three-year terms and the graduate student or postdoctoral researcher will serve a one-year term. Membership terms are staggered to maintain continuity. The members are

elected by the vote of the LUG membership, with candidates chosen to reflect the principle scientific activities at LANSCE.

The LUG Executive Committee and LANSCE management have monthly conference calls. These calls provide an opportunity for management to keep the Executive Committee apprised of the status of LANSCE activities and for the Executive Committee to bring user issues to management's attention. The calls are also used to discuss strategies for the future of LANSCE facilities.

6.10.6. Electron Microscopy Centre (EMC) for Materials Research and IVEM

Location:

Argonne National Laboratory, Building 212, 9700 South Cass Ave, Argonne, IL, 60439, US

Web address:

www.msd.anl.gov/groups/emc/index.php

Category:

Electron Microscopy, Ion Beam (IVEM)

Facility description:

The EMC currently operates and administers seven full-time user instruments together with support facilities that include specimen preparation, image analysis and computational resources. These instruments include:

- ACAT: Argonne Chromatic Aberration-corrected TEM;
- IVEM-Tandem Facility (a Hitachi H-9000NAR, interfaced to two ion accelerators);
- FEI Tecnai F20ST TEM/STEM;
- Zeiss 1540XB FIB-SEM;
- FEI CM30T – analytical transmission electron microscope (AEM);
- Hitachi S-4700-II – high-resolution, high vacuum SEM;
- FEI Quanta 400F – high-resolution environmental and variable-pressure SEM.

User interface:

All research access to the EMC is through peer-reviewed proposals. The goal of the proposal review is to ensure that the best scientific outcomes are realised and that the EMC resources are used for maximum scientific impact. All proposals first undergo a technical review by EMC staff. Following the technical review, each proposal is reviewed by the independent EMC Proposal Review Committee. To register to become an EMC users go to the following website: www.msd.anl.gov/groups/emc/becomingauser.php.

User amenities:

The Argonne Guest House is located in the Argonne National Laboratory campus, within five minutes by car to any part of the campus and a short walk to the advanced photon source and the APS Conference Centre.

The Guest House has 157 rooms, including 2-bedroom premiere suites with parlours, and 4-bedroom suites with parlours. All suites have kitchenettes.

User organisation:

EMC Users Group Executive Committee

The EMC Users Committee will have four members. The EMC users group will elect two new members each year. The outgoing members are welcome to be ex-officio, non-voting members for one additional year, if they choose. A tie will be decided by a coin-flip. The only named position on the EUC will be the Chair. The committee will elect the Chair internally on an annual basis. The Chair can serve a maximum of two consecutive terms. The Chair's responsibilities are: 1) calling meetings of the EUC as needed; 2) setting the agenda for the meetings with the inputs of the other committee members; 3) running the meetings; 4) sending out the minutes of the meetings to the EUC for approval and then the users; 5) organising or acting as the point of contact for the annual EMC Users Meeting; 6) serving as a representative of the users to the Scientific Advisory Committee, if invited.

6.10.7. National Synchrotron Light Source (NSLC)

Location:

Brookhaven National Laboratory, Photon Sciences Directorate, Building 817, P.O. Box 817, Upton, NY, 11973-5000, US

Web address:

www.bnl.gov/ps/

Category:

Synchrotron Light Source

Facility description:

- two synchrotron storage rings producing X-ray, ultraviolet, and infrared beams;
- 65 experimental beamlines;
- an array of sophisticated imaging techniques;
- details on beamlines and instruments can be found at: www.bnl.gov/ps/nav/03.php.

Annual number of users:

2 100

User interface:

Requests for beam time are submitted by proposal. Proposals are submitted in a system called PASS.

User amenities:

Brookhaven National Laboratory offers on-site housing options and other services. Go to the following site for more information: www.bnl.gov/staffservices/onsitehousing.php.

User organisation:

The NSLC is managed by the Associate Laboratory Director for Photon Sciences. The Associate Lab Laboratory Director receives input from the following committees:

- Science Advisory Committee;
- Accelerator Systems Advisory Committee;
- Conventional Facilities Advisory Committee;
- Users' Executive Committee.

The Users' Executive Committee purpose is to promote and encourage research at Brookhaven's world leading synchrotron user facilities, to provide opportunities for the user community to exchange ideas and concerns and to communicate user needs to facility management. Facility management includes the Photon Sciences Directorate, Brookhaven National Laboratory and the Department of Energy. The Association also serves as a channel of dissemination of relevant information on facility plans and prospects to the user community.

- Organisation of users group

Membership:

The Brookhaven Photon Sciences Users' Association (herein after referred to as the Users' Association) membership will be open to all scientists who are interested in research at BNL synchrotron facilities, including students, staff, and all researchers who have used these facilities in the past or may use them in the future.

All facility users with active appointments and all members of Beamline Development Proposal Teams, Beamline Advisory Teams and Beamline Development Proposal Groups are automatically voting members of the Users' Association.

The Users' Association will also provide a mechanism for interested scientists that are not automatically registered to become members, and a mechanism for members to opt-out.

The Brookhaven Photon Sciences Users' Executive Committee.

The Brookhaven Photon Sciences Users' Executive Committee (UEC) will consist of members together with a number of ex-officio representatives. Four members will serve as the officers of the UEC (Chair, Vice Chair, Past Chair and Secretary).

Six members will be elected each year at the annual Users' Meeting for two-year terms as described in Section IV.

The slate of ex-officio representatives shall be determined as needed by majority consent of a quorum of the UEC and should be modified to reflect current user needs, but must minimally include the Photon Sciences Directorate User Administrator. Majority consent of a quorum of the UEC will be used to define which specific ex-officio representatives are given voting privileges.

6.10.8. Centre for Nanophase Materials Sciences (CNMS)*Location:*

Oak Ridge National Laboratory, P.O. Box 2008, Oak Ridge, TN, 37831-6496, US

Web address:

www.cnms.ornl.gov/

Category:

Nanotechnology

Facility description:

The Centre for Nanophase Materials Sciences (CNMS) at Oak Ridge National Laboratory (ORNL) integrates nanoscale science with neutron science, synthesis science and theory, modelling and simulation. Operating as a national user facility, the CNMS supports a multi-disciplinary environment for research to understand nanoscale materials and phenomena.

The CNMS provides users with access to a complete suite of nanoscience research capabilities (facilities and expertise) housed in an 80 000 ft² building adjacent to the Spallation Neutron Source at ORNL. For detailed descriptions of facilities, capability and instruments go to the following link: <http://cnms.ornl.gov/capabilities/cap.shtm>.

Annual number of users:

User interface:

Access to CNMS facilities will be determined through a peer-reviewed proposal.

- Process

User amenities:

The Guest House is located at 8640 Nano Center Drive at Chestnut Ridge facility complex.

The purpose of the ORNL Guest House is to provide convenient, on-site lodging to ORNL User Facility clients, visiting researchers and other ORNL visitors. The Guest House does not serve families (spouses and children). Service animals will be allowed. A visitor's pass is required to enter ORNL and stay at the Guest House. The following is a web link to the ORNL Guest House: www.ornl.gov/adm/fo/ls/hospitality/guesthouse/.

User organisation:

The Centre for Nanophase Materials Sciences User Group (CNMSUG).

The CNMSUG was officially founded on 7 September 2007 when its Charter was unanimously approved by the voting users. According to the Charter, all lead principal investigators on approved CNMS user projects and all badged CNMS users become CNMSUG members for three years from the initiation of their CNMS project. The stated purpose of the CNMSUG is: "to provide a formal and direct channel for the exchange of information and advice between the management of the CNMS and the investigators who perform experimental and computational nanoscience-focused research at the CNMS. The CNMSUG will also serve as an advocacy group for the experimental and computational nanoscience-focused research activities at the CNMS."

The User Executive Committee is an elected body of members that conducts the regular business of the CNMSUG. The UEC is expected to make recommendations to CNMS management on matters affecting the user community and to participate in planning the annual user meeting. Users are encouraged to contact any member of the UEC listed below to make suggestions for enhancing the benefits the research community receives from CNMS.

Table 11. US user facilities for nuclear materials work list

US User facility	Website
National Scientific User Facility (NSUF)	http://nsuf.inl.gov/
Advanced Photon Source (APS)	www.aps.anl.gov/
Spallation Neutron Source (SNS)	http://neutrons.ornl.gov/facilities/SNS/
High-Flux Isotope Reactor (HFIR)	http://neutrons.ornl.gov/facilities/HFIR/
Los Alamos Neutron Science Centre (LANSCE)	http://lansce.lanl.gov/
Electron Microscopy Centre (EMC) for Materials Research and IVEM	www.msd.anl.gov/groups/emc/
National Synchrotron Light Source (NSLC)	www.bnl.gov/ps/
Centre for Nanophase Materials Sciences (CNMS)	www.cnms.ornl.gov/

7. List of contributors

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