EMIR&A

French national network of accelerators for irradiation and analysis of molecules and materials

Nathalie Moncoffre

(http://emir.in2p3.fr)
About EMIR/EMIR&A

Research Federation created in January 2014 (FR 3618)
Research Infrastructure
Annual budget: 10 – 12 k€

Mainly attached to INP
Secondary attachment Institutes: INC and IN2P3

Until August 2019: Director Serge Bouffard (CIMAP, Caen)
New Head: Nathalie Moncoffre (IP2I, Lyon)

EMIR: A network of irradiation platforms for the study of materials

In 2019: EMIR evolution → EMIR&A
Until 2019:

- Research topics focused on irradiation studies in a wide range of materials
  - Fundamental research applications including those for energy.

How to extend the scope of EMIR to other accelerators and other scientific topics: relevance of opening EMIR to new facilities?

The main objectives:

- Federate the scientific community around accelerators
- Make it more visible nationally and internationally.
In 2019
To prepare the future of EMIR:

Working Group: (GrAcc)
Group on Accelerators for Irradiation and Analysis

M. France Barthe (CEMHTI, Orléans)
Serge Bouffard (CIMAP, Caen)
Denis Jalabert (INAC, CEA, Grenoble)
Isabelle Monnet (CIMAP, Caen)
Nathalie Moncoffre (IP2I, Lyon)
Ian Vickridge (INSP, Paris)
Pascal Yvon (CEA, Saclay)
Sophie Le Caër (CNRS, CEA Saclay)

Which research around accelerators around 3 axes:

- Irradiation of materials
- Radiolysis
- Ion beam analysis
Presentation of this project to the CNRS institutes (INP, INC, INP3) in June 2019

EMIR evolves in two poles

Pole 1: Irradiation of materials and molecules (including radiolysis)
Pole 2: Studies using Ion Beam Analysis (IBA)

EMIR&A
National Federation of Accelerators for the Irradiation and Analysis of Molecules and Materials
EMIR&A platforms

CEMHTI - Orléans, UPR CNRS/INC, Université d’Orléans
  Cyclotron 45 MV, Pelletron 3 MV

CIMAP - Caen, UMR CEA/DRF/IRAMIS, CNRS/INP, ENSICAEN, Univ. Caen-Normandie
  SME, IRRSUD

IJCLab - Orsay - UMR CNRS/IN2P3, Université Paris-Saclay
  JANNuS – Orsay, IRMA 190 keV implanter, ARAMIS, Tandem-VdG 2 MV

LSI - Palaiseau, UMR CEA/DRF/IRAMIS, CNRS/INP, École Polytechnique
  SIRIUS, 2.5 MeV electron accelerator

SRMP - CEA Paris Saclay
  JANNuS Saclay, EPIMETHEE, JAPET, PANDORE

SRMA - CEA Paris Saclay
  HVTEM (1.2 MeV electrons)

INSP - Paris-Sorbonne University
  SAFIR, 2.5 MV VdG accelerator

LCP - Orsay Université Paris-Saclay
  ELYSE, electron accelerator

8 platforms
13 accelerators
<table>
<thead>
<tr>
<th>Platforms</th>
<th>Accelerators</th>
<th>Beams</th>
<th>Commissioning/Age(years)</th>
<th>specificities</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEMHTI/INC</td>
<td>Cyclotron</td>
<td>p, d, He 10-45 MeV</td>
<td>1976</td>
<td>44 External beam/radiolysis</td>
</tr>
<tr>
<td></td>
<td>Pelletron 3 MV</td>
<td>p, d, He, 0.5 - 3 MeV</td>
<td>2016</td>
<td>4 RBS, NRA, ERDA</td>
</tr>
<tr>
<td>IJCLab/IN2P3</td>
<td>IRMA Implanter 190 kV</td>
<td>H – Bi 10 to 570 keV</td>
<td>1979</td>
<td>41 In-situ TEM</td>
</tr>
<tr>
<td>JANNuS-Orsay</td>
<td>ARAMIS Tandem - VdG 2 MV</td>
<td>H- Bi 0.5 to 11 MeV</td>
<td>1987</td>
<td>33</td>
</tr>
<tr>
<td>CIMAP –GANIL INP</td>
<td>SME</td>
<td>C – U 4.5 to 13 MeV/A</td>
<td>1989</td>
<td>31 X-ray diffractometer High temp. furnace</td>
</tr>
<tr>
<td></td>
<td>IRRSUD</td>
<td>C – U 0.3 to 1 MeV/A</td>
<td>2002</td>
<td>18</td>
</tr>
<tr>
<td>SRMP/CEA</td>
<td>EPIMETHEE</td>
<td>H – Bi (source ECR) 0.5 to 50 MeV</td>
<td>2006</td>
<td>14 Triple beam chamber In-situ Raman</td>
</tr>
<tr>
<td>JANNuS -Saclay</td>
<td>JAPET</td>
<td>H – Bi 0.5 to 18 MeV</td>
<td>2009</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>PANDORE</td>
<td>H, D, He 0.5 to 2.5 MeV</td>
<td>2016</td>
<td>4</td>
</tr>
<tr>
<td>SRMA/CEA</td>
<td>HVTEM</td>
<td>Electrons 0.3 to 1.2 MeV</td>
<td>1981</td>
<td>39</td>
</tr>
<tr>
<td>LSI/INP</td>
<td>SIRIUS</td>
<td>Electrons 0.15 to 2.5 MeV</td>
<td>2013</td>
<td>7</td>
</tr>
<tr>
<td>INSP/INP</td>
<td>SAFIR VdG 2,5 MV</td>
<td>P, d, He, C, N, O 100 keV to 2.5 MeV</td>
<td>1968</td>
<td>52 RBS, NRA, ERDA, MEIS</td>
</tr>
<tr>
<td>LCP/INC</td>
<td>ELYSE 2.5 MeV</td>
<td>Electrons 3 to 9 MeV</td>
<td>2002</td>
<td>18 Impulsions ps</td>
</tr>
</tbody>
</table>
Large domain
Z – Energy
Z = 1 -> 92 and 10 keV to GeV

These platforms are very complementary (energy, ions) to study irradiation effects in materials
Objectives of EMIR&A

• Organize access to the facilities
• Structure the network of platforms and create a link between these facilities,
• Organize the welcome of research teams (also internationally) at the facilities.
• Promote their evolution in order to better meet the demands of users and research programs.
• Lead our scientific community

- Think tank, a place for scientific exchanges
- Catalyst for collaborations
- Force to respond to calls for proposals, ANR, European projects, ......

Increase the visibility of the scientific community
Organisation

**Direction**
Nathalie Moncoffre, IP2I, Lyon
Marie-France Barthe, CEMHTI, Orléans, Isabelle Monnet, CIMAP, Caen

**Scientific Committee**
- Serge Bouffard, Caen,
- Krzysztof Bobrowski (Institute of Nuclear Chemistry and Technology, Warsaw, PL)
- Stephen Donnelly (University of Huddersfield, West Yorkshire, GB)
- Denis Jalabert (CEA, Grenoble)
- Katharina Lorenz (Technical University, Lisbonne, P)
- **Robin Schaeublin** (Centre of Research in Plasma Physics, PSI, Villigen, CH), **Président**
- Shamashis Sengupta, (IJCLab, Orsay)
- Guy Terwagne (Université de Namur, B)
- Thierry Wiss (JRC, Karlsruhe, D)

**Coordination Committee**
Cédric Baumier, IJCLab, Orsay
Eymeric Briand, INSP, Paris
Céline Cabet, CEA SRMP, Jannus, Saclay
Amine Cassimi, CIMAP, Caen
Sergey Denisov, LCP, Orsay
Aurélie Gentils, IJCLab, Orsay
Mehran Mostafavi (LCP, Orsay)
Michèle Raynaud, LSI, Palaiseau
Thierry Sauvage, CEMHTI, Orléans
Ollivier Tissot, CEA SRMA, Saclay
Ian Vickridge, INSP, Paris
Scientific issues

Fundamental research

Irradiation: A unique tool to create controlled damage
understand the evolution of material microstructure and properties under irradiation

- **Nuclear materials**
  - Interactions defects-impurities
  - Role of grain boundaries
  - Chemical segregations
  - Irradiation induced-processes (diffusion, corrosion, radiolysis)
  - Evolution of properties / mechanical, magnetic, ...

- **Theory – simulation**
  - Multi-scale modelling
  - Mesoscopic approach
  - Radiolysis effects (solids, interfaces solids/liquids)

Material modelling
Control of irradiation parameters (T, flux, dose)
Separate effect studies → mechanisms
Solid state physics

Irradiation = tool to understand solid properties

- Intrinsic properties- defects
  - Defect trapping, ...
  - Role of ballistic damage/electronic excitation, synergetic effects
  - Defect annealing
  - Defect impact on supraconductivity/ferromagnetism
  - ...

- Material characterization

  Irradiation + in-situ characterization
  Damage evolution (SEM, TEM)
Applications

Nuclear energy (fission, fusion)
- Material ageing: ions to simulate neutrons all kinds of materials in the nuclear fuel cycle
- Damage effects in different energy domains (dE/dx)
- Corrosion
- ...

Electronic
- implantation
- smart-cut process

Radiation environment
Robots for nuclear applications, satellites, Space applications

Nanostructuration
Trace formation, nanopores for functionalisation ...

Polymer reticulation
Cables, claddings, ...
Ion beam analysis

- Light element analysis (H, He, C, O)
- Isotopic tracing for corrosion studies,
- Diffusion mechanisms,
- ....

- Pulsed beams
  - Radiolysis studies
  - Rapid kinetics processes

- Importance of *in-situ* characterization tools
Two evaluation modes

- **Pole 1:**
  - Irradiation, Radiolysis

- **Pole 2:**
  - Ion beam analysis

- A pump priming evaluation for short experiments
  - < 3 days

- For longer duration proposals
  - (thesis, post-docs, ANR, European projects ...)

[Flowchart showing the evaluation process with connections to Scientific Committee and Platform team]
## EMIR&A – some data

<table>
<thead>
<tr>
<th>Platforms</th>
<th>Rates</th>
<th>EMIR&amp;A Allocated beam time</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEMHTI</td>
<td>Free</td>
<td>10 weeks</td>
</tr>
<tr>
<td>CIMAP-GANIL</td>
<td>Free</td>
<td>~60 days</td>
</tr>
<tr>
<td>HVTEM</td>
<td>Free</td>
<td>5 days</td>
</tr>
<tr>
<td>LSI</td>
<td>1500 €/day</td>
<td>50 days</td>
</tr>
<tr>
<td>JANNuS-Orsay</td>
<td>2000€/exp.</td>
<td>5 (+1) weeks</td>
</tr>
<tr>
<td>JANNuS-Saclay</td>
<td>2000€/exp.</td>
<td>5 weeks</td>
</tr>
<tr>
<td>SAFIR</td>
<td>Free</td>
<td>A few weeks</td>
</tr>
<tr>
<td>ELYSE</td>
<td>Free</td>
<td>50 days</td>
</tr>
</tbody>
</table>
- The EMIRUM workshop (EMIR User Meeting)
  - allows users to present their results.
  - opportunity for informal and very fruitful exchanges.

The next EMIRUM is planned in January 2021 at LSI, Ecole Polytechnique

Set up a session dedicated to technical aspects / accelerator operation
→ invite the engineers and technicians of EMIR&A's installations.

IBAF's RASTA (Réseau d'Aides Scientifiques et Techniques des Acélérateurs) network could be extended to EMIR&A.

- To organize thematic schools for students and young researchers

- Develop the website [http://emir.in2p3.fr](http://emir.in2p3.fr)
  Sébastien Grégoire, Cédric Baumier, IJCLab
Projects for EMIR&A

Frame: Renewal of the research infrastructure

→ New platforms?
   → Improve national and international attractiveness
   → Federate the scientific community around accelerators for the study of materials and molecules
   → Provide the scientific community with unique on line irradiation facilities and instrumentation: original, complementary

**Conditions:**
- opening rate at least of 30%
- enhanced help to experiments for non-specialists

**Equipex+?**
Structuring equipments for research – PIA3
*TEM, DRX line-IJCLab,* Baby Pelletron-CERMHTI, VdG-CIMAP, Acc. Compact-INSP
Thank you!