Research evaluation

EVALUATION REPORT OF THE UNIT

IRFM - Institut de recherche sur la fusion par confinement magnétique

UNDER THE SUPERVISION OF THE FOLLOWING ESTABLISHMENTS AND ORGANISMS:

Commissariat à l'énergie atomique et aux énergies alternatives - CEA

EVALUATION CAMPAIGN 2022-2023

GROUP C

Rapport publié le 30/08/2023

In the name of the expert committee[1] :

Philippe BALCOU, Président du comité

For the Hcéres[2] :

Thierry Coulhon, Président

Under the decree n° 2021-1536 of 29th November 2021:
[1] The evaluation reports "are signed by the chairperson of the expert committee". (Article 11, paragraph 2);
[2] The president of the Hcéres "countersigns the evaluation reports established by the expert committee and signed by their chairperson." (Article 8, paragraph 5).

This report is the result of the unit's evaluation by the expert committee, the composition of which is specified below. The appreciations it contains are the expression of the independent and collegial deliberation of this committee. The numbers in this report are the certified exact data extracted from the deposited files by the supervising body on behalf of the unit.

MEMBERS OF THE EXPERT COMMITTEE

Chairperson:	Mr Philippe BALCOU, CNRS Talence
Experts:	Mr Fernando FERRONI, Gran Sasso Science Institute, L'Aquila, Italie
	Mrs Eva KOVACEVIC, Université d'Orléans
	Mr Christophe NICOLAS, Soleil Synchrotron, Saint-Aubin
	Mr Sylvain PICAUD, CNRS Besançon
	Mr Barend VAN TIGGELEN, CNRS Grenoble

HCÉRES REPRESENTATIVE

Mrs Laurence Pruvost

CHARACTERISATION OF THE UNIT

- Name: Institut de recherche sur la fusion par confinement magnétique
- Acronym: IRFM
- Label and number: NA
- Number of teams: 6
- Composition of the executive team: M. Jérôme BUCALOSSI

SCIENTIFIC PANELS OF THE UNIT

ST Sciences and technologies
ST2 Physics

THEMES OF THE UNIT

With the ongoing global and energy transitions of mankind, the quest for new sustainable energy sources, able to mitigate the climate change and to provide high reliability energy for centuries to come, is of utmost importance. Within the 'Direction de la Recherche Fondamentale' of the CEA (Commissariat à l'Énergie Atomique et aux Énergies Alternatives), the 'Institut de Recherche sur la Fusion Magnétique' is dedicated to basic and applied research on nuclear fusion for energy by magnetic plasma confinement (Magnetic Fusion for Energy or MFE).

Supported by worldwide hopes that MFE will play a major role in the energy mix of future generations before conventional energy sources have either become exhausted or intolerated, a multibillion-euro international endeavour, the ITER tokamak, was launched almost 40 years ago. The ITER construction has been taking place right next to the location of IRFM in the CEA centre of Cadarache, France. The ITER project is both the flagship and the roadmap of the MFE scientific community: all research is focused on either supporting ITER, on planning future continuations of ITER, or on formulating alternative pathways to ITER. On all aspects, IRFM is on the front line.

The IRFM activities encompass i) numerical simulations of hot magnetised plasmas, ii) plasma experiments and diagnostics, iii) exploitation of tokamaks, both within IRFM and in collaborations, and iv) engineering of fusion components and devices. To fulfil this broad range of activities, the IRFM has been structured into three R&D departments: the *Service de Physique des Plasmas de Fusion* (SPPF), the *Service Tokamak Exploitation et Pilotage* (STEP), and the *Service d'Ingénierie des Internes et des Projets* (SI2P). The scientific focus of the evaluation was centred on only six groups within these departments: the magnet R&D group (GAIM), the group on experiments, heat and particle flux control (GECF), the group on plasma-facing components and materials (GCFPM), the group on experiments and scenario design (GEDS), the group on the protection of the first wall (GP3), and the theory and numerical simulations group (GTSN).

HISTORIC AND GEOGRAPHICAL LOCATION OF THE UNIT

The IRFM is located in the CEA centre of Cadarache, Bouches-du-Rhône, France, close to the city of Aix-en-Provence. Most of the IRFM personnel is in this main location; however, in specific cases, staff members can work either permanently or half-time in remote locations, mostly in Japan, Singapore, and Saclay. An important operational point is that the ultimate responsibility for security on the entire site is conducted by the Cadarache CEA centre director.

The history of IRFM before 2018 has been extensively summarised in the 2018 evaluation report, and has not changed since 2018.

Over the last six years, IRFM has first made a transition between the project phase for the WEST tokamak, to the exploitation phase. This resulted in a first partial reorganisation, with the dissolvement of the project team. A second deeper reorganisation was performed in 2020, in line with the recommendations made by the 2018 committee.

The first phase of the scientific project for the WEST tokamak was achieved in 2022, and the present evaluation took place shortly after the start of phase two. The evaluated period has also been subject to the COVID pandemic, which, together with important technical issues on WEST, has been the cause for a number of delays in the execution of experimental engagements.

RESEARCH ENVIRONMENT OF THE UNIT

IRFM is part of the « Division de la Recherche Fondamentale » (DRF) of the Commissariat à l'Énergie Atomique et aux Énergies Alternatives (CEA). The research unit has been given the formal responsibility of undertaking fusion studies for CEA, with the help of the DRF/IRFU and DRF/IRIG institutes for R&D for their expertise on cryomagnetism and of the Direction des Énergies for studies on tritium breeding.

The scientific environment of IRFM has several geographic scales, from regional up to international networks and consortia.

First, the IRFM participates in the ITER project through the European 'Domestic Agency' Fusion4Energy, and has launched a project that is de facto a test bed for specific issues relevant to ITER: the WEST tokamak project, which was operated internally, in the framework of EUROFusion, and as a Research Infrastructure.

At the scale of the Provence-Alpes-Côte d'Azur region, IRFM is part of the A*Midex Idex program; a strong partnership also exists with the University of Aix-Marseille, mostly through the PIIM and M2P2 joint research units.

At the national French academic level, IRFM is an active member of the 'Fédération de Recherche sur la Fusion par Confinement Magnétique' (FR-FCM), and has as such collaborations with all academic centres working on MFE.

IRFM is part of the European EUROFusion consortium, for which it acts as the official French representative. Together with French research centres of the FR-FCM, it proposes research actions to EUROfusion, which are discussed and selected at the European level.

At the European level again, but also at international levels, IRFM has several strong partnerships: with Japan in the frame of the 'Broader Approach' (JT-60SA tokamak); with the Singapore University NTU; with the Princeton Plasma Physics Lab. Finally, of particular interest are the collaborations with the European JET located in the UK, the Chinese EAST, and the Italian DTT tokamaks.

UNIT WORKFORCE: in physical persons at 31/12/2021

Permanent personnel in active employment	
Professors and associate professors	0
Lecturer and associate lecturer	0
Senior scientist (Directeur de recherche, DR) and associate	0
Scientist (Chargé de recherche, CR) and associate	0
Other scientists (Chercheurs des EPIC et autres organismes, fondations ou entreprises privées)	92
Research supporting personnel (PAR)	138
Subtotal permanent personnel in active employment	**230**
Non-permanent teacher researchers, researchers and associates	10
Non-permanent research supporting personnel (PAR)	29
Post-docs	5
PhD Students	29
Subtotal non-permanent personnel	**73**
Total	**303**

DISTRIBUTION OF THE UNIT'S PERMANENTS BY EMPLOYERS: NON-TUTORSHIP EMPLOYERS ARE GROUPED UNDER THE HEADING 'OTHERS'.

Employer	EC	C	PAR
CEA	0	92	138
Total	**0**	**92**	**138**

UNIT BUDGET

Recurrent budget excluding wage bill allocated by parent institutions (total over 6 years)	117,303
Own resources obtained from regional calls for projects (total over 6 years of sums obtained from AAP idex, i-site, CPER, territorial authorities, etc.)	428
Own resources obtained from national calls for projects (total over 6 years of sums obtained on AAP ONR, PIA, ANR, FRM, INCa, etc.)	2,273
Own resources obtained from international call for projects (total over 6 years of sums obtained)	45,495
Own resources issued from the valorisation, transfer and industrial collaboration (total over 6 years of sums obtained through contracts, patents, service activities, services, etc.).	25,884
Total in euros (k €)	**191,383**

GLOBAL ASSESSMENT

Over the evaluated period, IRFM has maintained a very strong scientific production and has succeeded in maintaining its outstanding international scientific recognition. Contributions from IRFM have indeed led to new ideas and developments in the field of hot plasmas and plasma-surface interactions. This was achieved thanks to an autonomous, in-house experimental competence supported by strong and innovative modeling activities, as well as to experimental platforms within IRFM, in connection with Institutes in France, Europe, Asia, America and Australia. For instance, work on the question of plasma-facing materials and work on new integrated modeling have both provided important new outputs, not only for ITER but also for projects like JET, DEMO or DTT. The full integration of WEST into the EUROFusion program, as was recommended by the previous committee, has been an essential step forward, and validated the strategic path that was chosen for IRFM. This involved the transformation of the old Tore Supra tokamak into the newer WEST tokamak, with a scientific program of direct relevance to the general ITER project. In 2023, IRFM has arrived halfway in this long-term programmatic approach. The internal organisation of IRFM is sound. Nevertheless, the gradual decrease of human resources over decades has become a genuine risk, and the future after 2027 is uncertain. An overview of the group evaluations will now be presented.

The GEDS group mixes the development of integrated modeling tools, the design of plasma scenarios, and the plasma diagnostics on which these scenarios can be evaluated. This organisation shows first-class results. One key success was the effective prediction of the neutron yield in one of the last JET runs.

The GAIM group masters all phases in the production chain of superconducting coils, from the design to the commissioning and maintenance. The group is engaged in several projects at the same time with the huge challenge that different projects are at different stages of the chain. The experimental platforms at IRFM operated by the team are equipped with first-class instruments that allow for most of the required qualification tests.

The GP3 group works on understanding the mechanisms of plasma-wall interactions as well as the behaviour of the components in the corresponding complex environment. It is strongly involved in the processing of measurements to preserve operation and exploitation by methods of detection-identification and feedback control, with applications mainly to the WEST machine.

The GTSN group plays a European and worldwide key role in the modeling of current and future Tokamak projects. A lot of effort has recently been made to obtain a single gyrokinetic code (SOLEDGE3X) that describes both transport and turbulence near the edges and near the X-point of the Tokamak. The code GYSELA has been further improved to understand the impact of impurity transport on fusion performance.

The multidisciplinary expertise of the GECF group allows it to address the heat transfer or turbulent transport problems, in the exhaust part of tokamak devices, from the modeling stage to their characterisations via measurements. The group is at the forefront of these challenges that remain crucial to reach the nominal performances of ITER and following machines. In charge of various diagnostics, essential for WEST operation, the group's strong know-how places it favourably towards future international projects calls in the ITER framework.

The GCFPM group has inter and multidisciplinary expertise in design, qualification and operation of actively cooled high heat flux plasma-facing components. The group also provides support for large projects in relation with PFCs, with priority for WEST and ITER, but also for the Asia-based machines (JT60-SA, EAST) and beyond. They meet challenges in the applied and fundamental research as well as in technologically innovative development.

Other groups were not evaluated in detail, although mentioned within the three services. To get a global view of the IRFM scientific activities, the Committee insists that all group activities should be included in the next evaluation, since all groups play a role within the Institute. At the time of the evaluation, the scientific field of Magnetic Confinement Fusion was in a state of turmoil, for reasons exogenous to IRFM. On the one hand, severe technical problems have recently been encountered by ITER. The geopolitical relations among ITER partners have deteriorated but this has so far no visible repercussions on ITER action. On the other hand, we have seen the irruption of a large number of start-up companies worldwide, that propose innovative technical approaches, challenging the choices made for ITER, as well as the current technical visions for DEMO. The current Magnetic Fusion roadmap that plans to have a smooth transition between ITER and DEMO, thus appears increasingly unrealistic. The upside is that this wave of new start-up companies comes from an international hype proposing new and cleaner nuclear technologies for the Energy Transition. Nuclear fusion is intrinsically at the core of any discussion on such new nuclear technologies for the future.

In parallel, the experimental flagship of IRFM, the WEST tokamak, is planned for decommissioning at the horizon of 2027. Paradoxically, this may turn out to be an asset for IRFM, provided that no hasty decision is taken on the decommissioning of WEST without first launching a major new experimental project. All the previous reasons give rise to a strong need to think about the future strategy of IRFM. This reflection has been started internally at IRFM, and should be extended to national (CEA, FR-FCM) level, and to European levels. Even if it is clear that budget and strategic support must come from outside, IRFM has to take the necessary actions and initiatives to adapt itself to a variety of possible scenarios that can happen in this rapidly changing environment. The final recommendation of the committee is that the IRFM should ensure that its limited flexibility is exploited to the full to remain a major player in the study of nuclear fusion for the energy transition.

CONDUCT OF THE INTERVIEWS

Date(s)

Start: 06 march 2023 at 8 a.m.

End: 08 march 2023 at 6 p.m.

Interview conducted on-site.

PARTICULAR POINT TO BE MENTIONED

Only six groups have been evaluated and seen.

GENERAL OBSERVATIONS OF THE SUPERVISORS

The supervising body has no observations to make.

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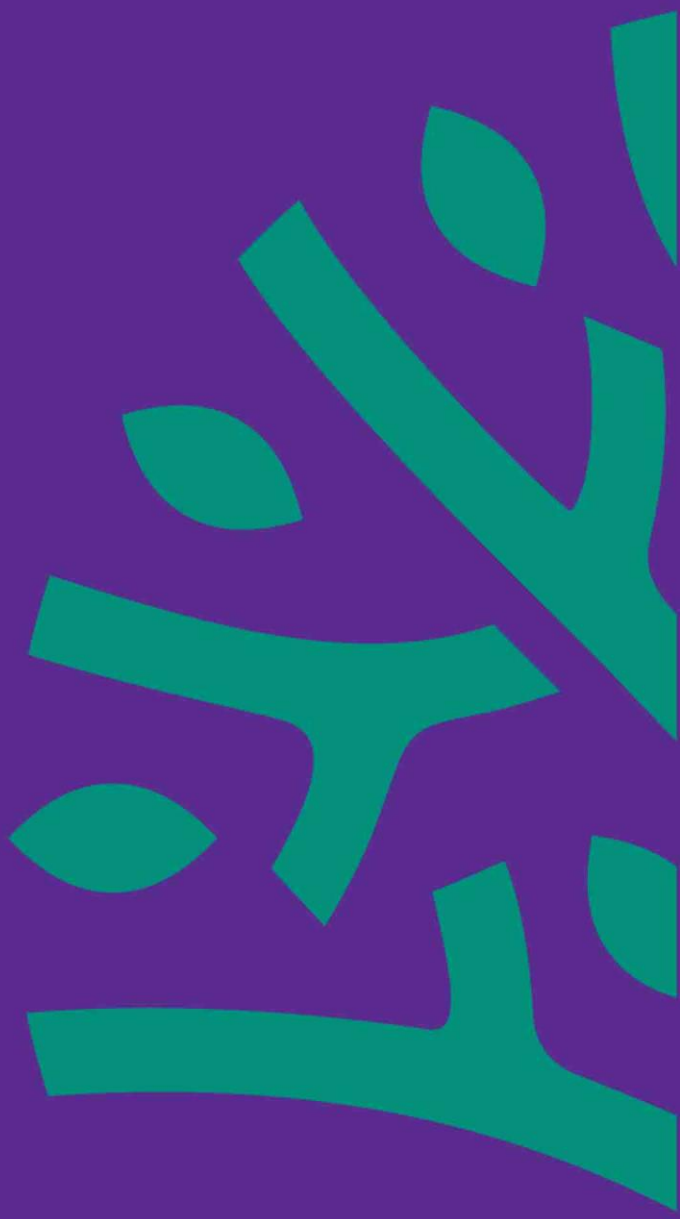
Evaluation of research units
Evaluation of the academic formations
Evaluation of the national research organisms
Evaluation and International accreditation



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