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RFX-MOD2 AND THE NEFERTARI PROJECT
A diffuse infrastructure for the study of magnetically confined plasmas for fusion

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Abstract

This paper describes the status of the implementation of the upgrades of the RFX-mod2 device, the second modification of the Reversed Field eXperiment (RFX). Many of the plants and diagnostic upgrades have been performed within the NEFERTARI project, funded by the Italian National Recovery and Resilience Plan within the framework of the Next Generation EU funding. The contributions of the network of Italian laboratories partners of the NEFERTARI project are also highlighted.

1 INTRODUCTION

RFX-mod2 [1] is the second upgrade of the Reversed Field eXperiment, a 2 MA Reversed Field Pinch device located in Padova, Italy, since the 1990s [2]. With respect to the previous version [3], RFX-mod2 is characterized by a thin copper stabilizing shell placed inside the vacuum vessel. It complements the existing network of 48x4 independently supplied saddle coils in order to ensure long term stability of Resistive Wall Modes (RWM) by means of real-time control. The active control system proved successful in mitigating the effects of wall-locked Tearing Modes [4], but the Inconel vacuum vessel was found to place a substantial limitation [5]. RFX-mod2 features also a new boundary immediately surrounding the plasma: new tiles with increased thermal conductivity will be held in place by the suitably stiffened stabilizing shell instead of the original vessel. Due to the change of the electrical resistivity (from Inconel to copper), regimes with fast rotating tearing modes are foreseen [6], likely improving the start-up phase, while the slight increase of plasma radius and reduction of plasma-stabilizing wall distance is expected to improve equilibrium control, reduce error field as well as the amplitudes of tearing modes and improve transport.

Upgrades of RFX-mod2 also include a layout of magnetic sensors, specifically designed for ohmic tokamak operations. This will allow completing studies on error fields control, tearing mode mitigation and disruption avoidance, runaway electron decorrelation by means of the active control system.
In the last two years, the manufacturing of the new RFX-mod2 vessel complex has significantly progressed, despite some technical issues, as it will be reported in Section 2.1.
Additionally, a substantial innovation of key RFX-mod2 technological plants and plasma diagnostics systems is being ensured by the NEFERTARI (New Equipment For the Experimental Research and Technological Advancement for the RFX Infrastructure) project [7], aimed at strengthening RFX within the framework of the Italian National Recovery and Resilience Plan [8], funded by Next Generation EU [9]. The project formally started in Nov 2022 and will end in Apr. 2026. Plants and related procurements are briefly described in sect. 2.2. The complete list of the diagnostics to be upgraded was presented in [10]: we report in Sect. 3 (core diagnostics) and Sect 4 (edge diagnostics) an update on the status of the implementation.
NEFERTARI brought about the opportunity to complement RFX-mod2 with developments in several other Italian laboratories: an advanced laboratory to experimentally characterize electrical insulation issues at very high voltages (not mentioned here); an infrastructure (BiGyM) for the study and test of innovative Plasma Facing components (Sect. 5.1); a laboratory for development, construction and test of nuclear diagnostics for fusion plasmas (Sect. 3.2); a laboratory devoted to the development, test and calibration of optical, emission and laser-aided diagnostics related to plasma exposed material measurements (Sect 5.2).

2 RFX-MOD2 REASSEMBLY STATUS

2.1 Vessel Complex reassembly

Fig. 1: closing the VTSS with the preliminary assembled PSS inside

Compared to RFX-mod, RFX-mod2 is characterized by a modified vessel complex composed by the Passive Stabilizing Shell (PSS) and the Vacuum Tight Support Structure (VTSS). The construction of these components has been completed and the machine is now undergoing a challenging and delicate assembly phase [11]. The PSS is a modified version of the RFX-mod 3-mm thick Copper torus designed to be inserted in the VTSS, which is the original RFX-mod stainless steel support structure, suitably modified to become a vacuum vessel.
At present, the whole PSS surface has been finally covered with a plasma sprayed thin alumina layer (~220 μm), a ceramic insulating material, to prevent electrical discharge [12] between gaps when high electric fields occur during plasma operations. The insulation procedure took significantly more time than initial foreseen due to the challenge of scaling up the characteristics of the alumina coating obtained during the sampling tests with adequate uniformity on the shell surface. The final assembly, started in 2025, is on-going. It is based on the experience gained with the preliminary assembly of the non-insulated PSS -. without installation of sensors, graphite tiles and cabling - that was successfully completed in the first half of 2024. This preliminary stage was used to develop strategies, including custom developed guide tools, with two goals: preventing damage to the ceramic insulation layer and compensating for deformations up to ±4, due to the low stiffness of the structure during assembly.
As far as the VTSS is concerned, the vacuum tightness test was completed in 2024, after correction of a welding leaks, together with the electrical insulation tests of the poloidal and toroidal gaps. The preliminary assembled PSS was then successfully inserted inside the VTSS, matching the ±0.5mm tolerance required, as shown in Fig. 1.
A total of approximately 1000 electric and magnetic transducers (corresponding to slightly more than 1500 signals) have been procured and calibrated on the bench [13]. In the next months, they are going to be assembled on the PSS internal surface either embedded in the new first wall (electrostatic sensors) or located in the narrow clearance between tiles and shell (magnetic sensors).

2.2 Auxiliary plants

The main RFX ***vacuum system***, which dated back to the initial RFX construction in the '90s, has being significantly revamped, thanks to NEFERTARI. Revamping of gas injection system is going to be performed next, with a separate funding.

Due to the gaps in all conducting structures, high temperature baking with induced currents will not be possible in RFX-mod2, wall conditioning will rely instead on ***Pulse Discharge Cleaning*** (PDC) ***and Glow Discharge Cleaning*** (GDC). The RFX PDC system, which was not used after its commissioning before the start of RFX-mod in 2000, has been restored and will be tested as soon as the final assembly of the vessel complex will be completed, in order to asses that proper insulation remains even after thermal expansion of the PSS.

Being RFX-mod2 first wall still composed by graphite tiles, proper density control requires the GDC system to reduce the hydrogen inventory in the graphite. The RFX-mod GDC system (inherited from RFX [14]) employed two insertable electrodes composed by a radio frequency (RF) antenna with a helical design and an integrated air-cooling system. This system was found to be affected by several limitations. Firstly, a significantly uneven spatial density profile has been documented in RFX-mod [15], due to the distance between the two electrodes, compromising the hydrogen removal efficiency. Secondly, increased maintenance was necessary due to an unexpected overheating of the ceramic insulators, related to deposition of B_4C compounds occurring during GDC performed boronization. Finally, an arc discharge could occur at the base of the electrode (therefore reducing cleaning efficiency) if the entire anode support were not at floating potential. To mitigate these issues, a new GDC system, based on a set of 8 fixed air-cooled electrodes acting as first wall components (FWCs) has been designed [16] and manufactured. The increased number of electrodes will ensure a greater spatial uniformity: they will be utilized to perform inter-shot GDC with helium gas injection. The GDC assisted boronization will still be performed by the two mobile electrodes with a redesigned antenna.

The ***Control and Data Acquisition System*** of RFX-mod2 has been significantly upgraded with respect to the RFX-mod one. On the one hand, it will retain the main architecture: MDSplus [17] and MARTe [18] frameworks will still be used for data acquisition and real-time control, respectively. On the other hand, the significantly increased number of real-time sensors required to design [19] a multichannel acquisition system for all magnetic and electrostatic sensors, that now, thanks to NEFERTARI have been developed and procured. The system is based on novel system design based on high-resolution analog-to digital converters (ADCs) that eliminates the need for analog integrators [20]. The system utilizes a 1 MSamples/sec, 20-bit resolution ADC, providing a resolution comparable to that of good analog integrators. To ensure accurate measurements, each acquisition channel is individually electrically isolated, effectively eliminating the ground loops generated by the experiment's magnetic fields, which often hamper the measurements. The digital acquisition followed by numerical integration performed directly onboard, ensures an error distribution comparable to analog integration. The cost and the size of each channel are significantly reduced: the procurement of the overall system (more than 1500 acquisition channels) has been completed in 2025.

2.3 Remote Handling Facility

RFX was equipped with a state-of-the-art manipulator for maintenance of internal tiles without disassembling the whole machine. Thanks to NEFERTARI and in collaboration with University of Napoli and University of Padova, RFX-mod2 will be equipped with a significantly upgraded manipulator, complemented with a mock-up facility for test and training. The aim is not only to ensure maintenance, but also to investigate advanced strategies for remote handling (RH) of in vessel components and a proper Virtual Reality Simulator improving the perception and awareness of the environment for the robots and the operators who must operate without the aid of exteroceptive sensors and must therefore base decisions on the system digital twin. A Remote Handling facility will enable the possibility to plan and test RH tasks and procedures and train operators offline without the need to access the real equipment.

3 CHARACTERIZING THE RFX-MOD2 CORE

When exploring high plasma current regimes (1MA < I_p <2MA), RFX-mod proved the existence of transient high confinement regimes characterized by a helical topology of SXR emissivity and peaked electron temperature profiles. High spatial resolution (85 points), but at 10ms intervals, was allowed by the existing Thomson Scattering diagnostic, while significantly higher time resolution was obtained (in the kHz range) with a multichord (19 lines of sight) Double

Filter. Differently from RFX-mod, time resolved ion temperature profiles will be available in RFX-mod2, thanks to the Diagnostic Neutral Beam, refurbished thanks to NEFERTARI, as stated below.

3.1 Electron temperature and SXR/Double filter tomography

A major upgrade of the electron temperature (Te) diagnostics in RFX-mod2 is currently being finalized, combining an upgrade of the existing Thomson Scattering (TS) system with an enhanced Soft X-ray (SXR) tomography based on the double filter (DF) technique.
As far as ***Thomson Scattering diagnostic*** is concerned, a new NdYAG laser, a Split Light Hybrid VIII by Innolas GmbH, capable of operating in burst mode at repetition rates (RR) up to 3 kHz, has been procured and installed, complementing the existing the existing 100Hz repetition rate one. Indeed, the upgraded diagnostic therefore relies on two coaxial Nd:YAG lasers (both at λ = 1064 nm), providing a unique combination of high spatial resolution (84 scattering volumes of ~5 mm diameter across the plasma radius) and high temporal resolution (kHz bursts). More in detail, the novel laser source can operate with selectable repetition rates (RR) either in single- or in burst-mode (0.3, 1, 2, 3 kHz). It generates bursts of up to 10 pulses (limited to 5 at 0.3 kHz), each with an overall energy of 4.11 ± 0.04 J (with a standard deviation < 1%) and a pulse duration FWHM of about 20 ns for all the selectable RR. In parallel, the TS diagnostic has been equipped with a new acquisition system based on CAEN digitizers. It consists of four high-speed VX1742B boards (12-bit, 5 GS/s, 32 channels each) and two VX2740B boards (16-bit, 125 MS/s, 64 channels each), allowing the simultaneous readout of all photomultipliers.
In order to improve measurements in the lower densities characterizing RFX-mod2 ohmic tokamak operations at 0.5T, a double-pass optical configuration, using a back-reflecting mirror instead of a beam dump is being designed. A dedicated manipulator to replace the beam dump is in its final stage of realization.
Concerning ***SXR and Double Filter tomography***, three additional pinhole heads are being procured, in order to implement temperature tomography [21]. The new heads, designed to replace the older ones, host 39 additional Lines of Sight complementing the existing 19 LOS, hosted on the horizontal diagnostic access. The radiation emitted in each LOS is actually gathered by three custom modified silicon detectors through a different thickness curved Be filter. Altogether, the tomography diagnostic will measure emissivity along 58 LOS with three different energy ranges, significantly enhancing spatial coverage. In addition, new detector arrays and remote-controlled amplifiers have been acquired, allowing flexible gain adjustment and improved signal-to-noise performance.

3.2 Neutron, SXR and Gamma diagnostics

Double Filter estimates of electron temperature depend on the assumption of a Maxwellian distribution of SXR emissivity [22], which may not be completely applicable to the SXR emission by particles accelerated during fast magnetic reconnection events occurring during RFP operations. Moreover, SXR signals have been observed during Runaway Electrons control experiments by Resonant Magnetic Perturbation in RFX-mod q(a)<2 ohmic tokamak plasmas [23]. On the other hand, during RFX-mod2 deuterium operations neutron emission is expected. It is therefore interesting to diagnose both SXR and neutron emission, with simultaneous energy, time and spatial resolution.
To this end, both neutron diagnostics and Gas Electron Multipliers (GEM) pixelated detectors [24], are being developed, constructed and tested in the neutron and gamma-ray detector development laboratory of CNR ISTP-MI, thanks to the upgrades funded by the NEFERTARI project. The laboratory essentially consists of two facilities, the Detector Assembly Unit (DAU) and the Test Irradiation Area (TIA). The DAU is essentially an integrated facility for the design and fabrication of non-sensitive detector components, such as frames, covers, supports, as well as other parts required to mount the detectors onto the RFX structure. The TIA is a laboratory equipped for the use of X-ray sources up to 100 kV and its main goal is to test large-dimension detectors.
As far as the GEM diagnostic is concerned, two GEM detectors are placed in the upper part of a poloidal sector of the RFX-mod2 device, with vertical lines of sight arranged in two fans, allowing to cover more than half of the plasma poloidal section. Each detector is built using a triple-GEM foil configuration [25]. This arrangement achieves photon-counting operation with a temporal resolution of ~10 μs, an energy resolution of ~30% at 8 keV, a count-rate capability of ~1 MHz/mm^2. Given the different expected levels of experimental signals (a few orders of magnitude in X-ray fluxes at the detector), two motorized pinholes and helium buffers are included in the diagnostic design for RFX-mod2 with the aim of precisely adjusting the aperture and controlling the X-ray attenuation, respectively. Simulation studies [26] have demonstrated the diagnostic's capability to obtain energy-resolved tomographic reconstruction,

allowing to discriminate between the thermal and suprathermal emissivity components, an aspect very relevant during magnetic reconnection events at RFX-mod2.
Concerning the neutron diagnostic, in the same cross section of the GEM detectors, a system of EJ-276D scintillators is being procured to be installed to monitor neutron counts, complemented with LaCl3 detectors to measure the neutron energy spectrum when the count rate is sufficiently high (e.g. possibly during magnetic reconnection events). Several centimetres of polyethylene and stacked lead rings will be employed to block scattered neutrons, to reduce the gamma rays background and to define the lines of sight. This should be useful to study the ion and electron acceleration processes with spatial, temporal and energy resolved SXR and neutron measurements.

3.3 Ion Temperature and internal magnetic field

Spatially resolved ion temperature measurements will be available in RFX-mod2, thanks to Charge eXchange Recombination Spectroscopy (CXRS). Ion temperature is derived from the Doppler-broadened emission lines of a neutral beam of ions. In RFX-mod, a 50 keV, 2A, ***Diagnostic Neutral Beam Injector (DNBI)*** was installed but, notwithstanding feasibility studies [27], several technical difficulties prevented to get stable and reliable measurements. In particular, the gas flowing from the torus back to the DNBI caused beam reionization and consequent beam losses, leading to too weak CXRS emissions at the plasma core. Thanks to NEFERTARI project, the beam duct and its pumping system have been redesigned to minimize beam losses [28]. The cryopump system of the DNBI is being replaced with closed-cycle pumps, to avoid He expensive consumption. Moreover, the High Voltage Deck (together with the associated insulation transformer and CAMAC control system), hosting the ion-source-related devices at 50 kV potential, is being upgraded for better safety and reliability [29].
On the detection side, CXRS will make use of a Czerny-Turner spectrograph of 750 mm focal length (F/# 9.7) and 1200 gr/mm diffraction grating, coupled to a new electron multiplying CCD of 512x512 pixel (16 μm pixel size) for improved sensitivity. For further sensitivity, a new ISOPLANE SCT-320 spectrograph (focal length 320 mm, 1800 and 2400 gr/mm gratings) with F/# down to 4.6 will be available. The instrumentation will also be used to observe the H_α emission of the beam in the plasma core, to measure the magnetic field intensity and magnetic field direction thanks to the Motional Stark Effect.
The ion temperature measurement from the DNBI will be complemented by the passive reconstruction of the distribution function of the neutrals produced by charge-exchange processes exiting the plasma and detected by the ***upgraded Neutral particle Analyzer (NPA).*** With respect to the existing one, this will be equipped with a larger number of detectors (from 11 to 15 channeltrons for each atomic species, H and D) for a wider energy scan and a faster (500 MHz) signal digitalization and acquisition system.

4 CHARACTERIZING THE RFX-MOD2 EDGE

In order to characterize the 3D properties of plasma-wall interaction in the variety of accessible magnetic configurations (included the shaped tokamak), RFX-mod2 is equipped with a complex system of electrostatic probes, measuring plasma density and temperature, plasma potential, particle and energy fluxes and floating potential fluctuations on the first wall. The probes, distributed over two toroidal arrays of 71 probes each on the high and low field sides, along with four poloidal arrays (made of 28, 36 and 2 x 17 elements) are presently under installation on dedicated graphite tiles.
The acquisition system for the electrostatic sensors has been specifically designed and is being procured, along with the whole set of power-supplies equipped with arc-protection systems to avoid probes overheating.
A ***fast-reciprocating manipulator (FaRM)*** for insertable probes (with insertion and extraction times of 50 ms) has been realized and is ready for the installation on RFX-mod2 from the bottom side of the machine [30]. The main purpose of the system is to host insertable probes in all the accessible plasma regimes, here included the X-point region of tokamak plasmas and the flat-top phase of the 2MA RFP discharges, characterized by an ohmic input power up to 60MW. In addition to standard probes the manipulator will host a novel diagnostic, named DIVO (Diagnostic for Ion Velocity Observation) [31] for the determination of the ion distribution function, by resolving both the parallel and the perpendicular (with respect to the local magnetic field) velocity components, thanks to a combination of an applied discriminating E and the local B fields. The aim is to investigate the relationship among turbulence, magnetic reconnection phenomena and ion acceleration/heating processes, mainly in the RFP plasmas.

The experimental analysis will be complemented by the first ***global boundary turbulence simulations*** of RFX-mod2 plasmas in both tokamak and RFP configurations. In particular, the GBS code [32] is being used to simulate plasma turbulence in a tokamak discharge in the presence of edge voltage biasing [33], with particular focus on turbulence suppression from the induced $E\times B$ flow shear and the subsequent steepening of the edge pressure profile [34]. GBS will also be extended thanks to the NEFERTARI project to allow for global boundary turbulence simulations of a RFP plasma, which will be the first-of-their kind.
A multi-channel very high frequency (up to 3GHz) acquisition system has been procured for the signals from the ***single-loop antennas*** to be installed at the edge of the plasma along three poloidal positions and devoted to the analysis of fast and transient phenomena (such as run-away electron induced whistler waves and ion cyclotron emission harmonics for the investigation of ion acceleration processes). The system has already been successfully tested in a small-scale plasma device for the characterization of beam-plasma induced Langmuir waves [35].
A ***new reflectometric diagnostic*** for real-time determination of tokamak plasma position is presently under development with the aim of testing the technique also proposed for DEMO [36]. This includes four ultrafast K band units (18-26 GHz) coupled to two antennas on the equatorial plane (from inner High Field Side and outer Low Field Side respectively) and two at the vertical top/bottom ports at the same toroidal position. The diagnostic complements the ***existing reflectometer*** devoted to the analysis of the RFP edge plasma density profile, which is under upgrades for a high time resolved (5 micro seconds) measurements, with a new full Ka band (26-40 GHz) microwave source driven by an innovated control circuit will replace. The acquisition systems have been procured, while part of the antennas, of the waveguides and the microwave units are under realization.
RFX and RFX-mod RFP Plasma Wall Interaction (PWI) did show marked poloidal and toroidal asymmetries, mainly due to the LCMS deformation generated by phase locked Tearing Modes. In RFX-mod2, given the expected change of TMs (reduction in amplitude and fast rotation regimes) significant changes of PWI is likely to occur. A series of diagnostics in RFX-mod2 is dedicated to characterize such an interaction. Among these, the ***Light Impurity Tomography (LIT)*** is a spectroscopic diagnostic designed for the characterization of the 2D structure of the emissivity of the edge plasma on a poloidal section. The diagnostic consists of 7 cameras, installed in 7 different portholes around the poloidal direction at a fixed toroidal angle, with changeable interferential filters (Hα at 656nm, He I at 668nm, and C III at 465nm). Each camera collects the line integrated plasma emissivity through a series of 3 objectives: a first lens with f=24mm collects the light from the plasma; a f=85 mm lens collimates the light beam, ensuring it impinges perpendicularly on the filter; a third f=85mm lens focuses the image on the camera. In order to widen the view and therefore increase the spatial resolution one or two mirrors are installed in vacuum in front of the first objective. 2D map of the emissivity of the specific ion species selected by the interferential filter is obtained by tomographic inversion with a pixel approach [37].
The experimental characterization of the plasma wall interaction in RFX-mod2 will be complemented by simulations of the magnetic field-lines topology. Similarly, as in RFX-mod, they will be reconstructed starting from equilibrium and edge magnetic measurements [38], especially during reconnection events in RFP plasmas [39]. In RFX-mod, the analysis shows that phase-locking between secondary m=1 tearing modes and the (0, 7) mode compete in shaping the PWI pattern [40]. The m = 0 driven PWI is weaker, which is a favourable perspective for the RFX-mod2 device: by mitigating the phase-locking contribution, a reduction of PWI is thus expected [41]. Furthermore, ORBIT simulations that account for the presence of an electrostatic potentials arising from magnetic flux variations indicate particle acceleration phenomena, which are characteristic of magnetic reconnection events both in astrophysical and laboratory plasmas.

5 PLASMA WALL/MATERIALS INTERACTION STUDIES

In the RFX-mod2 plasmas, ohmic power levels up to 60 MW can be coupled to the plasma when operated as a high current (up to 2MA) RFP, which makes the device an interesting environment for the investigation of, possibly localized, high power load effects on plasma facing components.

5.1 The BiGyM experiment

The laboratory hosting the linear plasma device GyM [42] of ISTP-Milan is one of the research facilities supporting the RFX-mod2 infrastructure within the framework of the NEFERTARI project. In this context, GyM is being upgraded to BiGyM, with the objective of extending its operational parameters toward conditions relevant for plasma–material interaction (PMI) studies in tokamak divertor environments. The main upgrade activities include:

- Installation of two 10 kW RF sources at 13.56 MHz, enabling the generation of helicon plasmas. This configuration is expected to enhance the plasma density (10^{18}–10^{19} m^{-3}) and particle flux (10^{22}–10^{23} m^{-2} s^{-1}), supporting PMI studies under divertor-relevant conditions.
- Integration of a new sample exposure system, capable of reproducing the operating conditions of ITER divertor components, in terms of temperature (up to 1500 K) and incident particle energy (300 eV).
- Implementation of a picosecond laser-induced breakdown spectroscopy (ps-LIBS), designed for surface compositional analysis of plasma-exposed materials and hydrogen isotope retention studies. This system complements nanosecond (ns-) and femtosecond (fs-) LIBS diagnostics of ISTP-Bari (see the details below).

In parallel with the hardware upgrade, numerical modelling activities are being conducted to predict the behaviour of BiGyM plasmas and support future experimental interpretation. Current modelling efforts include: (i) modelling of helicon wave propagation with COMSOL Multiphysics, (ii) prediction of plasma density, temperature, and particle flux profiles via the tokamak edge SOLPS-ITER package, (iii) investigation of sputtering and material migration using the ERO2.0 code, and (iv) modelling of laser–material interaction processes, in support of the LIBS diagnostic system, also conducted with COMSOL-based frameworks.
The BiGyM upgrade will enhance the experimental capabilities of the ISTP research infrastructure in the field of magnetic confinement fusion. It will provide support for the RFX-mod2 plasma–wall interaction program, serve as a versatile platform for diagnostic development and validation, and contribute to training activities in preparation for future large-scale devices such as DTT. Furthermore, the upgraded facility is expected to foster cross-sectoral applications in advanced technology domains including aerospace, solar thermal energy, and plasma-assisted catalysis.

5.2 Optical diagnostics laboratory

The optical diagnostics of election for surface analysis is LIBS (Laser-Induced Breakdown Spectroscopy). It involves two processes: laser ablation, to vaporize the material, and optical emission spectroscopy to inspect the composition of the vapour, which expands in the form of a hot plasma, assumed to reflect the chemical composition of the material. To preserve the possibility of depth profiling of the fuel retention on the wall surfaces, the ablation process must be sufficiently “gentle” and geometrically well defined as to drill regular craters in the material avoiding its melting. Femtosecond laser pulse duration is the best choice to this end [43] Using relatively small pulse energies, is also mandatory to avoid vaporize the retained fuel in few laser shots, preventing an accurate depth profiling. On the other hand, the Balmer lines of H, D and T have a large Stark broadening. Therefore, spectral isolation of these lines requires measuring the emission spectra in conditions of small plasma density. All these requirements have a heavy influence on the magnitude of the spectroscopic signal. We are studying strategies to maximize the signal in conditions of minimal laser energy and plasma density, with the aid of a laser with variable pulse duration from 400 fs to 10 ps and maximum pulse energy of 4 mJ (Light Conversion Pharos). Beyond the choice of the optimum pulse duration and delay of the measurement after the laser shot, we are studying further methods to enhance the LIBS signal, like glow-discharge assisted LIBS [44] and TALIF assisted LIBS. The latter consists in applying Two-Photon Absorption Laser Induced Fluorescence to measure the D atoms in the ablation plume.
The other face of Plasma-Wall interaction is the plasma itself, that needs thorough characterisation. To this end, the NEFERTARI laboratory for research and development of plasma optical diagnostics is also equipped with tuneable lasers for the laser spectroscopy of the gas phase.

6 SUMMARY

The RFX-mod2 device upgrade has reached its final critical phase, where all components are being thoroughly assembled. Additionally, the procurements related to the revamping of key technological plants and diagnostics, funded by the NEFERTARI project, in the framework of the Italian National Recovery and Resilience Plan are almost completed. Complete rebuilding of the device is expected in 2026.

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