MECHANICAL INTEGRATION OF THE IFMIF-EVEDA RADIO FREQUENCY QUADRUPOLE

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Abstract

The Linear IFMIF Prototype Accelerator (LIPAc) is an high intensity deuteron linear accelerator [1]; it is the demonstrator of the International Fusion Material Irradiation Facility (IFMIF) machine within the Engineering Validation Engineering Design Activities (EVEDA) scope. It is presently in an advanced installation phase at the International Fusion Energy Research Center (IFERC) site in Rokkasho, Aomori prefecture, Japan. The Radio Frequency Quadrupole (RFQ) - 5 Mev, 130 mA - is an Italian in-kind contribution, under the INFN responsibility.

This paper presents the various aspects of the RFQ integration inside the LIPAc, with details of the interfaces with other sub-components of the LIPAc and with the building and some results of the seismic calculation.

RFQ DESCRIPTION

The RFQ is a 9,8 m-long structure, made of 18 modules (Fig. 1). Each module is made of precise machined Cu-OFE elements, assembled by UHV furnace brazing with stainless steel components (i.e.vacuum, tuner and RF coupler ports, and cooling water flanges) [2].

In order to minimize the assembly time of the entire RFQ in Japan, and in accordance with the LIPAc assembly time frame, it has been decided to divide the RFQ in three SuperModules, pre-assembled in Europe and shipped via airfreight to the IFERC site, where they have been coupled and aligned [3].

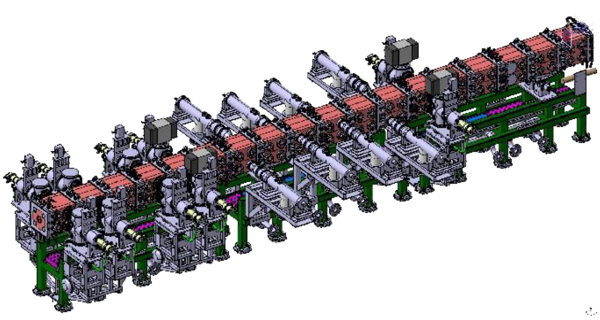

Figure 1: RFQ layout.

After the coupling and sealing of the three SuperModules, the bead-pulling measurement will define the final geometry of the slug tuners. The design of the slug tuners has been done in such a way that the final lathe machining for the precise penetration length is carried out after the brazing process of the tuners and it is compliant with the expected tuning range.

The SuperModule, assembled in a dedicated workshop at INFN LNL, is an stand-alone object, made of the RFQ modules, the mechanical supporting frame, the water manifolds, the coarse regulations of the support frame at the interface with the building and the fine alignment jigs of the RFQ modules.

FUNCTIONAL ASPECTS

The modules are aligned and assembled with a Laser Tracker, using temporary isostatic supports for each module (Fig. 2). During the assembly of the SuperModules the vacuum test for the leak tightness of the energized metallic gaskets between two adjacent modules is checked. After the complete assembly of the six RFQ modules, the temporary supports are replaced by the permanent 6-DOF set of mechanical supports for each SuperModule, which is finally sealed, filled with Nitrogen and set ready for the shipment.

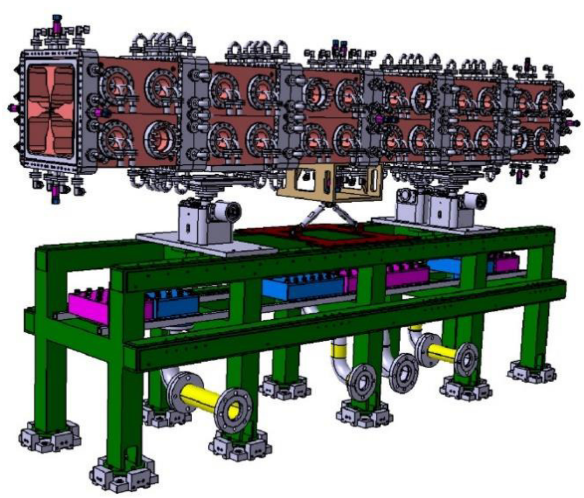

Figure 2: RFQ central SuperModule.

The peculiarities of the assembly and alignment tools of the RFQ SuperModules, which have to be pointed out, are:

- a coarse regulation, at the interface between the mechanical supporting frame and the floor which has to absorb the flatness tolerance of the floor and the position tolerance of the anchoring points; this regulation is also capable to align one SuperModule with respect of the other with a precision of ± 0,5 mm;
- a fine alignment system for each SuperModule, which is made of three supports for an isostatic positioning system, capable of a positioning accuracy of 50 μm;

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- a couple of two longitudinal guides above the fine alignment system, that it is necessary for the coupling and sealing of two SuperModules and for the longitudinal elongation of the RFQ during bake-out and in operation, being the central point of the RFQ set fixed.

A dedicated 4-ton-capacity lifting equipment has been designed and manufactured for the handling of the SuperModules in Italy during the assembly and in Japan for the RFQ installation (Fig. 3). Some features of the lifting tool to be mentioned are the regulations for the centering of the lifting hook with respects to the actual position of the center of gravity of the SuperModule and the shock absorbers to protect the load during the lifting. A temporary set of shock absorbers is coupled to the mechanical supporting frame to protect the load during the lowering.

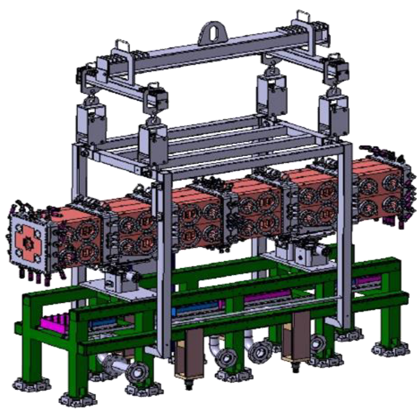

Figure 3: RFQ SuperModule lifting tool.

RFQ SYSTEM INTEGRATION

The RFQ is a complex system made of various components and sub-systems with different functionalities, such as the cooling water distribution, from the RFQ to the skid, the vacuum, with the pumping system and the He compressors, the RF couplers (Fig. 4).

Given the complexity of the RFQ, the detailed integration of the complete system has been done within the whole LIPAc 3D Mock-Up (3DMU) and the IFERC building under the coordination of F4E and the IFMIF Project team.

Some aspects that have arisen during the power test performed at INFN-LNL which have led to substantial modifications have been successfully integrated and checked in the 3DMU, taking into account their impact with the building, such as the vacuum pump supports decoupled from the RFQ mechanical support frame.

The final goal of the process of integration of the RFQ system has been to thoroughly check and validate each specific interface (i.e LEBT/RFQ, RFQ/MEBT, RFQ/building), as well as to define the details of the various conventional services such as the piping, the manifolds, either for the cooling water and for the He lines, and the grounding lines, inside the different areas of the building (accelerator vault, heat exchange and cooling water area and the RF area).

Water Cooling Sub-System

The water cooling subsystem is made of the water manifolds, integrated inside the RFQ mechanical frame, the pipes in the vault and the water treatment system in the heat exchange room.

Vacuum Sub-System

The vacuum pumps are placed on supports which are mechanically independent from the RFQ frames, thus avoiding vibrations and de-tuning of the RFQ induced by the operation of the pumps. The Helium compressors are placed on a rack in the RF area; the pipes from the compressors to the pumps are integrated in the passage dedicated for services and routed to the accelerator vault. integrated in the passage dedicated for services routed to the accelerator

RadioFrequency Couplers and Lines

The RF couplers, under QST responsibility, are coupled to the central RFQ SuperModule; they are individually supported by a frame, which is fixed to the RFQ structure. The RF lines are routed from the RF couplers to the RF area, under the RFQ structure. The design of the RFQ structure, as well as the position water flanges, has been checked in order to have sufficient clearance for the installation of the RF lines and their assembly with the RF couplers.

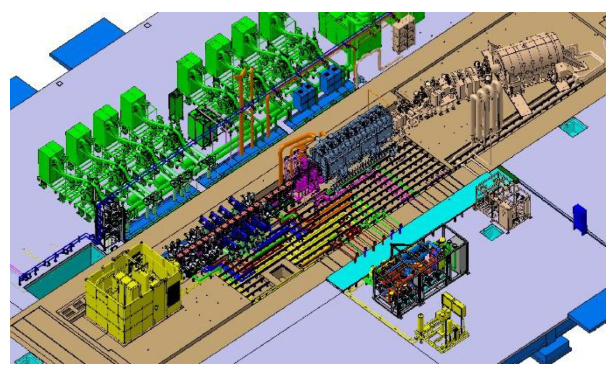

Figure 4: RFQ system integration inside the LIPAc.

SEISMIC ANALYSIS

An RS (response spectrum) analysis was performed with the software Ansys v14.5–workbench to check the behaviour of the RFQ in case of a seismic event. During the preparation of the FEM (Finite Element Method) model, a static analysis was used to determine the best choice between two options for the module/RFQ frame connection. Furthermore, a particular care was given to the simplification of the adjusting system included in the feet of the RFQ. Concerning the boundary conditions, the bottom faces of the thirty feet were considered as fixed. The other interfaces were left free in order to evaluate their maximum displacements during earthquake. The modal analysis showed that no natural modes are located in the maximum acceleration range (2-10 Hz) of the excitation spectrum, the first natural mode having a frequency of 12.8

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Hz and corresponding to the deformation of ion pump supports.

The RS analysis showed that the most important deformations (2.4 mm in longitudinal and 3 mm in transversal directions) are observed at the top of the ion pumps, mainly because of their lever arms. Nevertheless, they are not critical considering that they will be absorbed by the bellows located between the valves and the modules.

The displacements of the modules themselves are uniform along the RFQ length and remain very limited (0.5 mm longitudinally, 0.4 mm transversally, less than 0.1 mm vertically) (Fig. 5).

From a seismic point of view, this RS analysis validates the choices made for the design of the RFQ.

Another seismic analysis has been performed on the welded structure of the mechanical supporting frame of the RFQ, and on the interface with the floor to check the resistance to seismic load of the adjusting feet and the anchoring points.

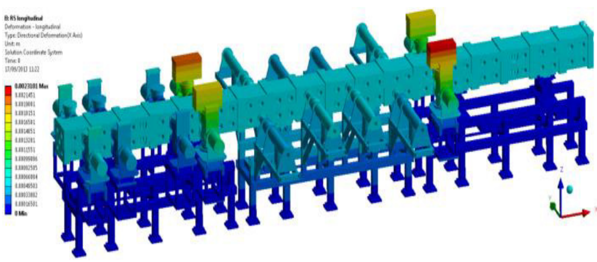

Figure 5: RS analysis longitudinal deformation.

RESULTS

The assembly of the SuperModules in Italy has been successfully completed within the schedule and in the 50 μm required tolerance of the positioning of the geometrical axis of two adjacent RFQ modules. It has to be mentioned the fact that the assembly procedure and tooling of the RFQ modules has undergone a series of solutions of technical issues, mostly during the first phase, which required modifications and implementation of mechanical components, that would have been very difficult, if not impossible, at the IFERC site.

The shipment of the three SuperModules has been done using a tailored set of shock and vibration absorber cushions, at the interface between the RFQ mechanical support frame and the transport box; a 3-axis acceleration log has been installed on each SuperModule and a post-shipment analysis has been carried out without revealing any particular issue.

The vacuum tightness of the energized metallic gaskets between the RFQ modules has been checked after the transportation to Japan and no leak has been encountered.

The assembly of the RFQ in the IFERC site has been done within the foreseen time schedule (Fig. 6).

The alignment inside the accelerator vault at IFERC site, as well as the relative alignment of the RFQ SuperModules has been completed within the required nominal tolerances (100 μm).

The coupling and the sealing with energized metallic gaskets of the RFQ SuperModules has been successfully done with the leak test.

It is worth to be mentioned that the choice to design the RFQ in three SuperModules, already pre-assembled in Europe, aligned and vacuum tested and easy to handle with the proper tooling has been proven strategically important since it has made possible the installation of the RFQ in a temporary position, with a proper clearance from the Injector. Therefore, the following activities on the RFQ (i.e. bead-pulling, tuner final machining, installation of the tuners, vacuum check) can be carried out with the concurrent commissioning of the Injector, presently ongoing. The repositioning of the RFQ in its nominal position inside the LIPAc will be done by disassembling the RFQ in the three SuperModules.

Figure 6: The RFQ installed in the IFERC site.

ACKNOWLEDGMENT

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