The RFQ delivered for the IFMIF prototype accelerator in Japan

INTRODUCTION

IFMIF EVEDA (International Fusion Material Irradiation Facility-Engineering Validation and Design Activity) is part of the international program for the test of the materials for the reactors based on Nuclear Fusion. Within this project INFN has in charge the construction of a linear structure of RFQ kind (Radio Frequency Quadrupole) able to accelerate 130 mA of deuterons up to 5 MeV [1]; Padova, Torino and Bologna sections are together with LNL in charge of this realization. This structure is part of a prototype accelerator (named LIPAc, linear IFMIF prototype accelerator) to be installed in the Broader Approach site in Rokkasho (north of Japan).

The components of the RFQ were completed, the preassembly in three super-modules realized. The transportation of the RFQ to Japan happened in February 2016.

RFQ DEVELOPMENT

The main components of the RFQ are the 18 modules, produced in three sets: the high energy supermodule, commissioned to the Italian industry Cinel, completed in 2014, the intermediate energy supermodule, produced entirely in INFN workshops, and the low energy supermodule, commissioned to the German industry RI. In all cases the copper procurement, the deep drilling of the cooling channels and the EDM cut is INFN responsibility.

Concerning the intermediate energy supermodule, during 2015 was brazed the last module, M_7, and all the modules underwent final machining. Dimensional and RF characteristics are in specs for all the modules.

The low energy supermodule SM_I (M_1÷M_6) was commissioned on the base of an International Tender to the company RI. The construction started on October 2012 with M_2, that has successfully overcome the first brazing, but an error has occurred in the final machining with a damage of the bottom electrode; such an error was corrected with a brazed insert, but at the end the module was out of frequency and the module could not be accepted.

M_4, M_5 and M_6 were brazed, but resulted to be out of frequency. M_5 needed a reparation of a leak on the cooling tubes. For M_1 and M_3 the electrodes were machined up to the brazing step excluded.

At the end, also due to the unavailability of the vacuum oven of the company on the short time, it was decided to stop the contract and to perform the remaining brazing, repairing and machining under INFN responsibility. The eigen frequency of the modules were recovered (when needed) with additional openings closed with indium sealed copper plugs.

In September the assembly of the supermodules has started. The original plan was to assemble at LNL the entire RFQ, measure the field, tune the RFQ with temporary tuners, machine ad assembly the fix tuners, separate the three supermodules and send them to Japan.

In the assembly started with the high energy supermodule, and various problems were found in the procedure closing the metallic spring gaskets in the proper way. It is indeed necessary to guarantee the perfect contact of the reference planes, a relative positioning of the electrode modulation in the two next modules better then 0.1 mm and a vacuum tightness better than x10^{-9} mbar-l/s.

Few modules required remachining of sealing groove, and new gaskets softer, with more accurate geometry and with larger diameter were ordered and used.

The experience of high energy supermodule was successfully applied to the others. In Fig.1 the first supermodule completed and assembled is shown.

Concerning ancillaries a first delivery from LNL to Rokkasho took place in Nov 2015. Mainly the cooling skid and other components of the cooling circuit were sent by boat to Rokkasho.

Fig. 1: The first of the three RFQ super-modules after assembly and vacuum test
**HIGH POWER TEST**

Figure 2: on 27 February the RFQ remains 4 hours at nominal field level

The high power test stand at LNL has been used in two steps, for the conditioning and tests of the INFN power couplers, and for the test of the RFQ structure, using the three highest energy modules and the RFQ prototype 2 as RF termination.

Just after coupler assembly, vacuum pumping started. After reaching 1x10^{-6} mbar vacuum level, RFQ modules experienced baking at 100 °C for 1 week using an ad hoc thermal shielding jacket. After baking, RF line and RF cables were mounted and test structure was finalized. The RFQ was conditioned up to 178 kW in CW and up to 190 kW at 50 % duty cycle; therefore operation at nominal power (178 kW, 1.8 Kilpatrick field) is no more critical for the cavity. After some hours at this power, vacuum level is at 6x10^{-8} mbar, no arc phenomena are detectable and thermal stability, reached after some minutes, is maintained.

After that residual multipacting phenomena were conditioned and a complete characterization of the cavity frequency control took place. In Fig.2 the RFQ module assembled and the result of four our at nominal RF level is shown.

**RFQ DELIVERY TO ROKKASHO AND NEXT STEPS**

In November is was agreed with the collaboration to proceed as follows. The three supermodules, assembled and vacuum tested at LNL (fig. 3), will be sent rapidly to Japan. The entire RFQ will be assembled there to the total length, for the first time. Will then follow the same procedure done for the high power test: the RFQ will be tuned with temporary tuners, and then final plungers, couplers, vacuum system and cooling will be installed. The main advantage of this procedure is to eliminate the risk to tune twice the RFQ due geometry deformation during the overseas transportation.

[1] A. Pisent et al “IFMIF-EVEDA RFQ design” Proceedings of EPAC08, Genoa, Italy

Fig. 3: The three supermodules assembled and a representative photo the group, sez. Padova, Bologna Torino and LNL, involved in IFMIF-RFQ development, at the end of the assembly work in Italy.