Status of the RFQ for IFMIF Prototype Accelerator

A. Pisent¹, E. Fagotti¹, L. Antoniazzi¹, M. Comunian¹, J. Esposito¹, M. Giacchini¹, F. Grespan¹, M. Montis¹, A. Palmieri¹, M. Poggi¹, C. Roncolato¹, F. Stivanello¹, A. Colombo², A. Pepato², R. Dima², F. Scantamburlo², E. Udup², P. Mereu³, D. Dattola³, G. Giraudo³, A. Margotti⁴

¹ INFN, Laboratori Nazionali di Legnaro, Legnaro (Padova), Italy, ² INFN, Sezione di Padova, Padova, Italy, ³ INFN, Sezione di Torino, Torino, Italy, ⁴ INFN, Sezione di Bologna, Bologna, Italy.

INTRODUCTION

Within IFMIF/EVEDA 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 with LNL in charge of this realization. This structure is part of a prototype accelerator (recently named LIPAc, linear IFMIF prototype accelerator) that will be installed in the Broader Approach site in Rokkasho (Japan). The building is ready, the injector is in phase of installation, various part of the accelerator are under construction in Europe. The RFQ delivery date is fall '14.

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.

RFQ DEVELOPMENT

The 2012 has been a construction year for the RFQ modules both in Industry and in INFN.

The updated lay out of the RFQ is shown in fig. 1. The RFQ structure, divided in three super-modules (SM), each composed by 6 modules, the vacuum system manifolds and pumps, the cooling water distribution and the fixed tuners can be seen. The mutual integration of those systems, and the integration with the building services has progressed very significantly during this year.

The production of the 18 modules is divided as follows: High energy SM in construction at Cinel, Padua (Italy), Intermediate energy in INFN, Low energy by RIKoln (Germany).

Two modules have been completed and accepted up to now (M16 and M17, Fig. 2); M15 has been brazed but requires a reparation. Some issues have been solved and the production is proceeding regularly, with a solid system of mechanical measurements and quality verification [2].

Fig. 2. Module 17 under the final metrology survey (left); the coupling constraints of the front flange (top right) and the excellent quality of the AISI-Cu brazed joints (bottom right).

Fig. 1. CAD mock up of the 10 m long RFQ, with the integration of support, vacuum system and cooling distribution.
In particular, the module 16 production pointed out problems on the stability of the AISI 316 LN side flanges and on the proper estimate of the differential thermal expansion coefficient of AISI 316 LN and CuC2 copper parts. The Module prototype 2 production showed the poor coupling of the Copper-AISI parts when avoiding the Nickel plating of the AISI components. The choice of two brazing steps was due to verify the effectiveness of the modifications: a) gap between copper and the sealing AISI ring on the T’s side; b) passing through incisions on the AISI side flanges; c) Nickel plating of all the AISI parts when using Cusil; d) introduction of TZM springs to allow for a more effective and well distributed coupling of parts.

On the 1st brazing step we confirmed point a) successfully: we noticed any relative displacement between T’s and E’s. On the 2nd brazing step we confirmed point c) and d) obtaining an excellent quality of the brazing by visual inspection. The witness mark was plainly visible on all the brazing interfaces (see figure 2). An extensive UT scan showed an excellent and uniform contact surface between copper and AISI parts, with clear evidence of empty brazing grooves. The point b) effectiveness was measured by the CMM scan.

RF tests have been performed on Module 17 before brazing and after each brazing step. The results with wave guide (WG) terminations show quadrupole frequency shifts of about 100 kHz. The extrapolation for the measured sensitivity gives a final average value of $\Delta R_0 = +13 \mu m$ (mean tips displacement), which is in fair agreement with CMM scan.

Two important components of the beam instrumentation are developed at LNL (Fig.3). The low power beam dump, able to withstand beam power (650kW) with 1 mA 1 Hz duty cycle, will be used during the RFQ beam commissioning. This device is realized in Al to avoid activation and follows the same cooling circuit scheme as the main beam dump. The bunch length detector has been successfully tested with a low intensity PIAVE beam [3].

![Fig. 3. Low power beam dump (necessary for pulsed beam RFQ commissioning), left, and residual gas beam bunch length detector (right).](image)

For the other aspects of the project, the development of the control system is proceeding, both for EPICS and PLC parts [4]. Concerning the Cu blocks, the delivery has been completed. The cooling system procurement has been launched. All the vacuum system components have been ordered.

### HIGH POWER TESTS

A very important activity completed this year is the TRASCO RFQ high power test at CEA Saclay [5]; with these tests the main design criteria used in IFMIF RFQ for cw operation (like the surface 1.8 EKP field or the eigen-frequency tuning with water cooling temperature) have been proven; beside the test allowed to gain experience with the main RFQ subsystems and their integration up to the RF commissioning. This experience is also important for IFMF RFQ tests that will take place at LNL in 2013.

The last part of the RFQ, where the RF power density is maximum, will be tested up to the operating field and duty cycle. A new test stand has been built at LNL, based on a 220 kW RF transmitter (developed in Italy making use of the same TH781 tube as for the Ciemat RF system) and of a dedicated cooling system (with separate circuits for vanes and external walls) for the control of the resonating frequency. The modules M_18, M_17 and M_16, together with prototype 2 (used as end cell to close the RF field), for an approximate length of 2m, will be fed by one coupler, realized by JAEA (Fig. 4). One of the ten pumping units based on cryogenic pump will be used, and one RF circulator will be provided by Ciemat.

This RF test is very important to verify the functionality of RFQ, the alignment, the low power field tuning, the assembly, and the ability to reach the peak RF field, to master the RF power and to tune the resonant frequency. The aim is to identify all possible issues before the end of the module construction and before the transportation to Japan.

![Fig. 4. The mockup of the Power Test RFQ line (left); laser tracker in use for the alignment of two modules (right).](image)

[1] A. Pisent et al “IFMIF-EVEDA RFQ design” Proceedings of EPAC08, Genoa, Italy
[3] M. Poggi this AR
[4] [M. Giacchini et al.” this AR
[5] E. Fagotti et al. this A.R.