PRESENT STATUS AND PROGRESSES OF RFQ OF IFMIF/EVEDA

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Abstract

The IFMIF project aims to produce an intense neutron flux (14.4 MeV) to test and qualify materials suitable for the construction of fusion power plants. The DEMO project will be the first plant for civil and industrial power production.

The neutron flux is obtained by impacting two 125 mA deuteron beams, produced by two parallel LINACs, onto a liquid Lithium target.

We are working on the engineering validation phase of the project (IFMIF-EVEDA) [1], which consists on the construction of a linear accelerator prototype (LIPAC) to be installed and commissioned in Rokkasho (Japan).

The RFQ of IFMIF/EVEDA is composed of 18 modules flanged together for a total length of 9.8 m designed to accelerate the 125 mA D+ beam from 0.1 MeV to 5 MeV at a frequency of 175 MHz [2]. This accelerator will be the longest RFQ in the world with the highest beam power. The mechanical specifications are very challenging, tight tolerances are required on the machining and on the brazing process. The first two modules (16 and 17) were produced adopting two brazing steps. A single brazing step was tested on Module 15 to confirm the advantages described in [3,4,5]. In this paper the production status as well as the development of the brazing procedure design will be described.

MODULE 17

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. We already reported on the test performed and on the applied solutions adopted on the Module 17 [3, 4].

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[1];

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 1). 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 [6] have been performed on Module 17 before brazing and after each brazing step. The results with wave guide (WG) terminations are listed in Table 1. The extrapolation for the measured sensitivity gives a final average value of $\Delta R0 = +13$ µm (mean tips displacement), which is in fair agreement with CMM scan (Figure 2).

Table 1: RF Measurements on Module 17

Step	Freq. with WG [MHz]	Quad. Freq. [MHz]	ΔR0 [µm]
Pre-braze	187.015	173.738	-
After 1st braze	186.820	173.540	-25
After 2nd braze	187.115	173.839	+13
Sensitivity = 7.7 MHz/mm (with WG)			

The final vacuum and hydraulic (cooling lines) test was successfully.

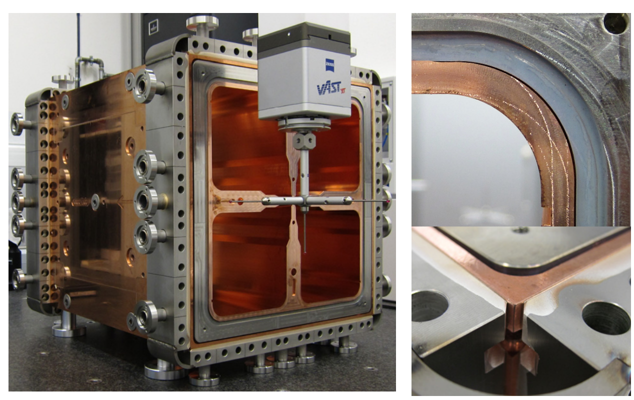

Figure 1: Module 17 under the final metrology survey (left); the coupling constraints of the front flange (top right) and the excellent quality of the AISI-Cu brazed joints (bottom right).

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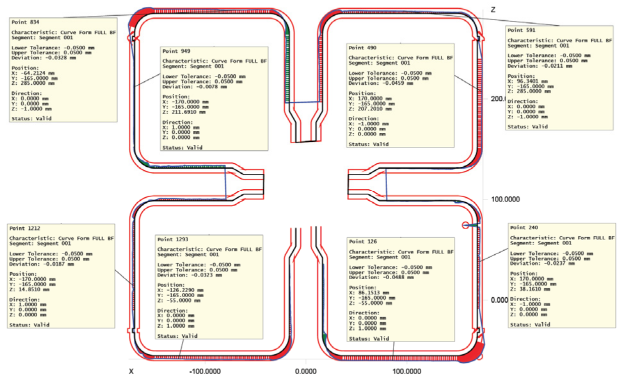

Figure 2: Transversal scan of the M_17 quadrupole after the second step brazing.

MODULE 15

A single brazing step was adopted for Module 15 (figure 3) using Palcusil 10^2 as brazing filler. Unfortunately some problems occurred. A longitudinal relative displacement of about 0.1 mm was measured on one side (on the contact surface between T and E elements, figure 4), resulting on a transversal shift on the opposite side. One of the AISI sealing rings detached from copper giving a very poor brazed joint: we decided to remove it completely. The unpredictable deformation looks not related to the single brazing approach, but likely to an unexpected collision of the brazing tooling (long molybdenum longitudinal rods) during the handling of the module inside the furnace. Nevertheless the CMM scan showed small displacements of the pole tips of the brazed module.

RF tests have been performed on Module 15 before brazing and after brazing. The results are listed in Table 2. The extrapolation for the measured sensitivity gives a final average value of $\Delta R0 = +22\ \mu m$ (mean tips displacement), which is in fair agreement with CMM scan (Figure 4).

Table 2: RF Measurements on Module 15

Step	Freq. with WG [MHz]	Quad. Freq. [MHz]	ΔR0 [μm]
Pre-braze	187.207	173.972	-
After braze	187.359	174.126	+22
Sensitivity = 6.94 MHz/mm (with WG)			

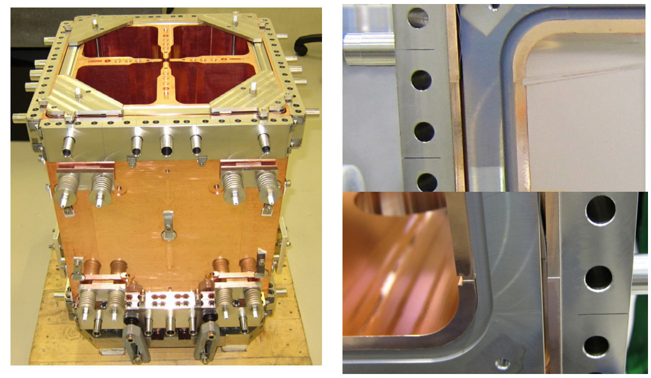

Figure 3: Module 15 assembly before the single brazing step brazing (left); the longitudinal shift of CuC2 copper elements (bottom right); the tilting of the T profile on the opposite side (top right).

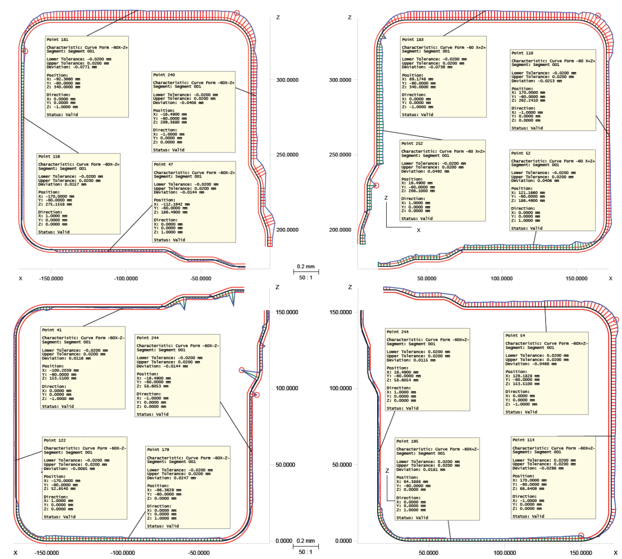

Figure 4: Transversal scan of the M_15 quadrupole after the single step brazing.

The vacuum test on the copper joint surfaces and on the undamaged AISI ring results positive while we noticed a poor contact of the side flanges on the damaged side. The vacuum test on the AISI cooling tubes revealed some gross leaks on the whole F22 lines and on several F18 lines. The ultrasonic scan of the side flanges showed also extended glued surfaces even though the witness mark was plainly visible on all the side flanges sides (figure 3). We assume there had been a problem on the cleaning procedure of the AISI cooling ducts and we decided the nickel plating of AISI components will become mandatory with any brazing material adopted (as stated for the brazing procedures and tooling in the tender specifications). The Module 15 will be repaired soon.

MODULE 18

A single brazing step will be adopted for module 18 using Palcusil 10 as brazing filler: all the AISI parts have been Nickel plated. The assembly of the components is ongoing and the Module will be ready to be assembled for the RFQ power test by mid June. We'll maintain all the tooling components and assembly procedure adopted for the Module 15 brazing while introducing some TZM[3] "C" profiled springs to widely increase the amount of coupling constraints of the AISI side flanges. Their effectiveness induced us to progressively substitute the Nymonic springs whereas possible. An even more careful quality check has been agreed accordingly to the experience on Module 15.

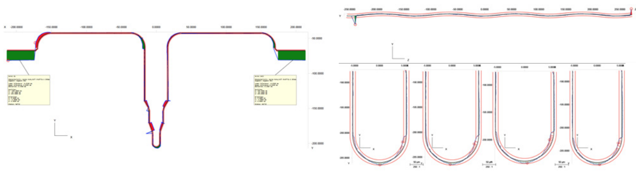

Figure 5: Transversal scan (left), tip scan (bottom right) and modulation (top right) of an M_18 E.

MODULE 2

The production of SM_I was commissioned to RI-Research Instruments Gmbh Company (Koln, Germany) and started on September 2012 with Module 2. There was a long period devoted to the define to tooling and the milling procedures of components with an effective exchange of qualified experience. After having successfully passed the CMM qualification on an aluminum mockup of an E profile RI started the final milling of all the CuC2 components (figure 6) and completed the milling of the common planes of Module 2.

They decided to adopt the two steps brazing to get fully experienced on the brazing steps, nonetheless they assume they will probably perform single step brazing for the whole remaining production. The completion of Module 2 is foreseen for July 2013 and the planning agreed for the compleation of the six modules is compleant with the overall RFQ realization schedule.

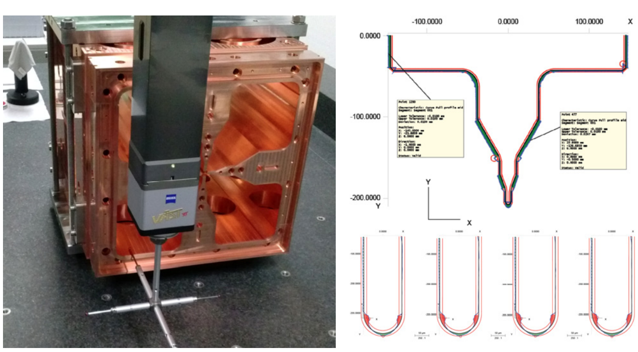

Figure 6: Module 2 assembly before the common planes milling (left); transversal scans of a profile tip (bottom right); the transversal scan of a T profile (top right).

CONCLUSIONS

The last part of the RFQ, where the RF power density is maximum, will be tested in Europe up to the operating field and duty cycle. A new test stand has been built at LNL, based on a 220 kW RF transmitter ; 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 used.

This RF test is very important to verify the functionality of the 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 RFQ team will try to identify all possible issues before the end of the module construction and before the transportation to Japan.

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