DESIGN OF 4-VANE RFQ WITH MAGNETIC COUPLING WINDOWS FOR NUCLOTRON INJECTOR LU-20

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Abstract

Alvarez-type linac LU-20 is used as Nuclotron injector. In the framework of NICA project the high voltage electrostatic pre-injector for LU-20 has been replaced by RFQ linac. The RFQ was designed by the team of ITEP and MEPhI (Moscow, Russia) and was manufactured in VNIITF (Sneginsk, Russia). The engineering design of the 4-vane RFQ linac with magnetic coupling windows and details of its manufacturing are presented and discussed.

INTRODUCTION

The new accelerator complex Nuclotron-based Ion Collider fAcility (NICA) is under development and construction at Joint Institute for Nuclear Research [1]. New complex is assumed to operate with two injectors: Alvarez-type DTL LU-20 as injector for light ions (mainly polarized deuterons) and new linac HILAc for heavy ions. To provide polarized deuterons acceleration, the modernization of LU-20 was carried out. The old 700 kV electrostatic for-injector was replaced by an RFQ with coupling windows (see Fig.1) [2]. The RFQ has been developed by a team of specialists from Institute for Theoretical and Experimental Physics (ITEP) and Moscow Engineering-Physics Institute (MEPhI). The RFQ was designed to accelerate ion beams with charge -to-mass ratio ≥ 0.3. It has to accelerate polarized deuteron beam with current up to 15 mA. The RFQ injects beam into Alvarez-type DTL LU-20 for following acceleration. The RFQ resonant frequency is 145.2 MHz, the same as LU-20 one. The RFQ has to provide the operation mode with RF pulse length of 150 µs and pulse repetition rate not higher than 1 pps. The RFQ was fabricated, assembled and aligned at Zababakhin All-Russian Scientific Research Institute of Techinical Physics (VNIITF). The design of the RFQ as well as the fabrication procedures are presented and discussed.

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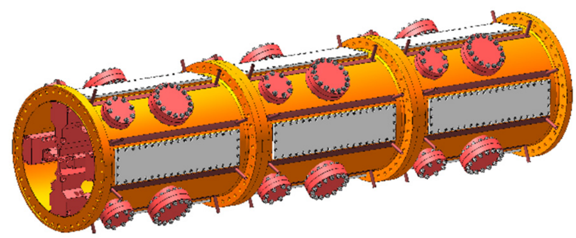
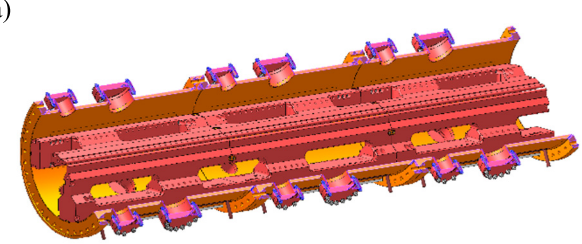
RFQ DESIGN

The RFQ cavity has a length of 2230 mm and consists of three nearly identical segments of 695 mm length and input/output flanges. A complete design of the central segment as well as the cutaway view showing the relative location of electrodes is given in Fig. 1.



a)



b)

Figure 1: Design of RFQ tanks.

Electrodes

Each electrode line is divided into three sections, therefore twelve electrode units were fabricated for the RFQ. Eight of them have the identical design (except modulation at the tip). Two pairs of electrodes differ from each other in geometry of open half-windows at front and rear end of the resonator. The adjacent electrodes are installed in the tank as it is shown in Fig. 1b. One can see that their half windows are located at the opposite ends of the tank.

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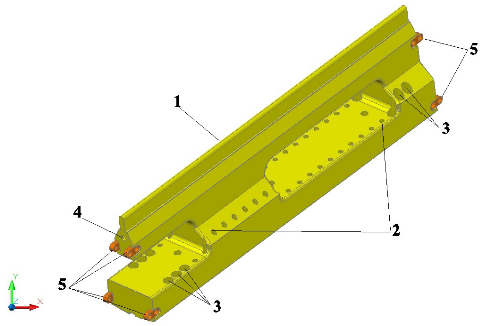

Figure 2: Electrode (1) with set of through threaded holes (2) and non threaded holes (3) for electrode installation, base aperture (4), copper inter electrode joint plugs (5).

The electrodes are fabricated from carbon steel and plated with copper. The depth of electrode modulation at the initial part of the RFQ is about of 10-20 µm, which is in the range of the thickness tolerance for the copper layer. It forces us to keep electrode tip surfaces copper-free. This reduced a shunt impedance of the RFQ and rise the power required for the C^{4+} ion beam acceleration up to 460 kW. Nevertheless the small duty factor and available RF power allow this solution.

Each electrode has one full "coupling window" and one 1/2 window (see Fig. 2). There are blind holes at both ends of section (item 4) used for the base line definition. This line is used as a reference for electrode tip modulation milling. During resonator assembling special pins are installed in the base holes to guarantee accurate alignment of the electrodes.

Each electrode has a set of threaded (item 2) and non-threaded (item 3) holes. All of them are used for electrode mounting to the segment tank. To simplify the assembling, most of the bolt heads remain accessible from outside of the tank (Fig. 3). After electrode assembling and alignment the bolts are covered by the stainless steel plate sealed by the Viton (Figure 4). Axial holes in bolts enable the pumping of the volume under the covering flange.

The aluminum wires are used for electrical contact between electrodes and the tank surface. The copper joints (item 5 in Fig. 2) provide electrical contact between neighboring electrode units.

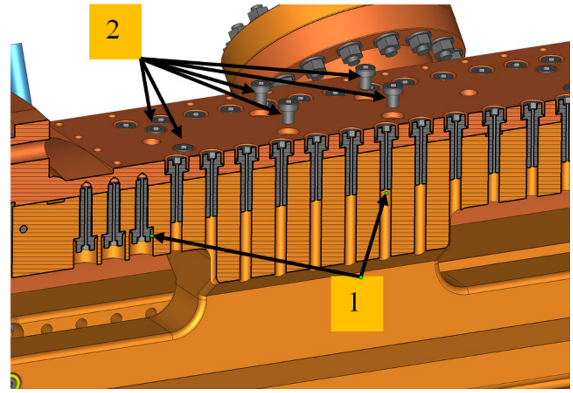

Figure 3: Electrodes installation. 1-bolts for electrode installation, 2- alignment bolts.

Cavity Tank

The segment tank with inner diameter of 400 mm is fabricated from stainless steel. The inner surface of the tank is coated with copper layer of 50 µm thickness. The tank has a set of holes for electrode installation and alignment (Fig. 4).

Side pipes with flanges CF100 are used for turbo pumps, driving loops and frequency tuners. Side pipes with flanges CF63 are used for pick-up loops, vacuum detectors and bypass pumping line.

Front and rear segment tank flanges have plug-socket geometry. The copper wire ring is used for both vacuum sealing and intersegment electrical connection.

Each tank equipped with water flow channels (Fig. 4) which allows thermo-stabilized operation.

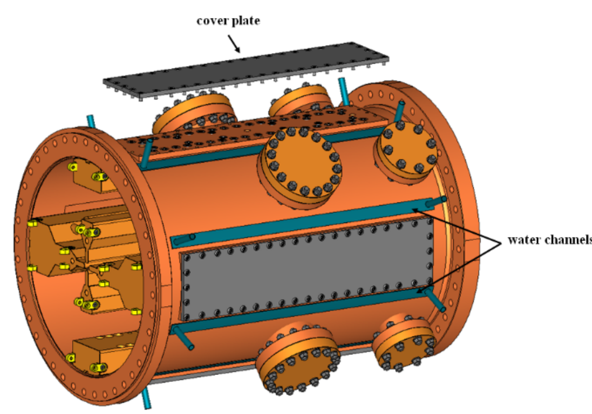

Figure 4: Tank assembling.

FABRICATION

RFQ was fabricated by VNIITF (Sneginsk, Russia). The fabrication procedure passed the following steps:

1. The complete set of segment tanks, edge flanges and electrodes was produced. The electrodes were fabricated with modulation.
2. The RFQ was assembled with properly adjusted electrodes (Fig. 5).
3. The coupling windows correction was calculated according to the measured resonance frequency of the RFQ.

4. The coupling window was enlarged to the final dimension by milling of surfaces marked in red in Fig.6. The design allows the milling up to 20 mm.
5. The whole RFQ was copper plated except electrode tips (Fig.7).
6. The RFQ was reassembled and aligned one more time with contact wires between electrodes and segment tank.
7. Inter electrode contact joints were installed.
8. End flanges as well as bolts covering plates were installed.

Figure 5: RFQ segment after first assembling and alignment.

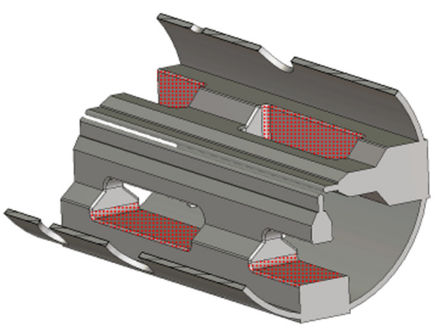

Figure 6: The cut view of the RFQ segment.

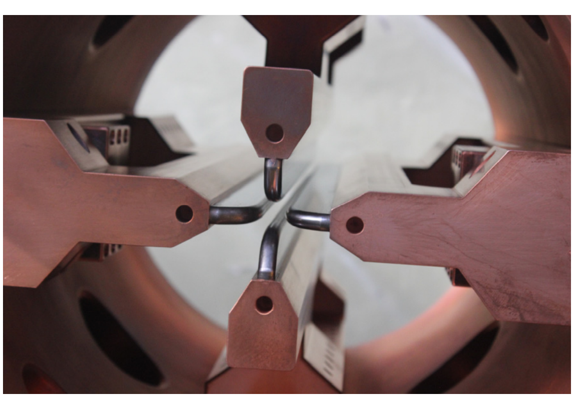

Figure 7: Copper-plated RFQ segment.

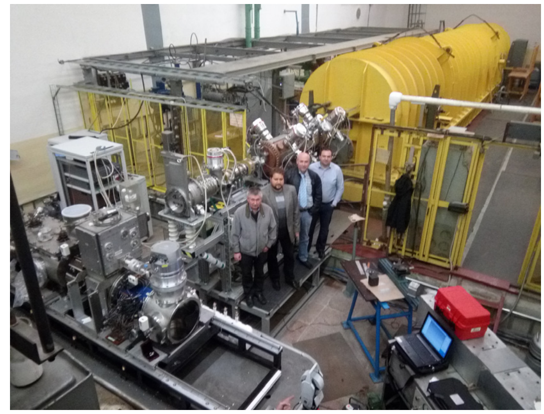

Figure 8: RFQ at LU-20.

After all the RFQ was filled by nitrogen gas and moved by truck to ITEP.

CONCLUSION

The RFQ was delivered to ITEP for vacuum test and RF parameters tuning. The full set of work starting form RF tuning and up to high power commissioning was carried out successfully. Then the RFQ was moved to JINR where it was commissioned with deuteron and C^{4+} ion beams from the laser ion source [3]. In May-June 2016 the session of Nuclotron operation with the RFQ was successfully carried out (Fig. 8).

ACKNOWLEDGES

We dedicate the work in memory of Victor Koshelev who designed this RFQ and left us one month after the linac successful operation for Nuclotron.

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REFERENCES.

[1] G. Trubnikov, A. Butenko, V. Kekelidze *et al.*, in *Proc. of IPAC2016,* pp. 2061-2065
[2] V.A. Andreev, G. Parisi, in *Proc. PAC'93,* p. 3124.
[3] V.S. Aleksandrov, A.V. Butenko, *et al* in *Proc. of IPAC2016*, pp.941-943

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