COMMISSIONING OF NEW PROTON AND LIGHT ION INJECTOR FOR NUCLOTRON-NICA

V.S. Aleksandrov, A.V. Butenko, B.V. Golovenskiy, A.I. Govorov, V.V. Kobets, A.D. Kovalenko, K.A. Levterov, V.A. Monchinsky, V.V. Seleznev, A.O. Sidorin[1], G.V. Trubnikov[1], Joint Institute for Nuclear Research, Dubna, Moscow Region, Russia
V.S. Dyubkov, M.A. Gusarova, A.A. Martynov[2], S.M. Polozov, A.V. Samoshin, National Research Nuclear University – Moscow Engineering Physics Institute, Moscow, Russia
V.A. Andreev, A.I. Balabin, S.V. Barabin, V.A. Koshelev, A.V. Kozlov, G.N. Kropachev, R.P. Kuibeda, T.V. Kulevoy[3], V.G. Kuzmichev, D.A. Liakin, A.Yu. Orlov, A.S. Plastun[3], D.N. Selesnev, A.L. Sitnikov,
Yu.B. Stasevich, Institute of Theoretical and Experimental Physics NRC "Kurchatov Institute", Moscow, Russia
S.V. Vinogradov, Moscow Institute of Physics and Technology, Dolgoprudniy, Russia
A.P. Durkin, Moscow Radiotechnical Institute of RAS, Moscow, Russia
[1] also at Saint-Petersburg State University, Saint-Petersburg, Russia
[2] also at Institute of Theoretical and Experimental Physics NRC "Kurchatov Institute", Moscow, Russia
[3] also at National Research Nuclear University – Moscow Engineering Physics Institute, Moscow, Russia

Abstract

The new accelerator complex Nuclotron-based Ion Collider fAcility (NICA) is now under development and construction at JINR. New complex is assumed to operate using two injectors: the Alvarez-type DTL linac LU-20 as injector for light ions, polarized deuterons and a new linac HILAc for heavy ions. Now the modernization of LU-20 is also realized and old electrostatic injector is planning to replace by RFQ linac. New RFQ linac has been developed and manufactured and is now it is under commissioning at Nuclotron injectors hall. New results of RFQ linac resonator test and measurements, RF power load and linac testing with deuterium and carbon beams are discussed in this report.

INTRODUCTION

Nuclotron-based Ion Collider fAcility (NICA, Fig. 1) is new accelerator complex constructing at JINR [1-4]. The injection system of operating Nuclotron and new NICA is under upgrade now. Reconstruction is includes the replacement of old pulse DC injector by new RFQ linac. New RFQ linac parameters are presented in Table 1, the project is performed in collaboration of JINR, MEPhI and ITEP. The beam dynamics simulation, RFQ resonator simulation and design as well as RF system development were carried outin 2011-2013 [5]. The accelerator's resonator was manufactured in VNIITP (Snezhinsk). The main results of RFQ tuning and power loading at ITEP and linac commissioning at JINR in Nuclotron injector's hall are presented and discussed.

RESONATOR TUNING AND POWER LOAD

The four-vane resonator with displaced magnetic coupling windows was chosen for the NICA RFQ design. It should operate at frequency of 145.2 MHz. Such frequency is defined by the LU-20 main resonator operating frequency.

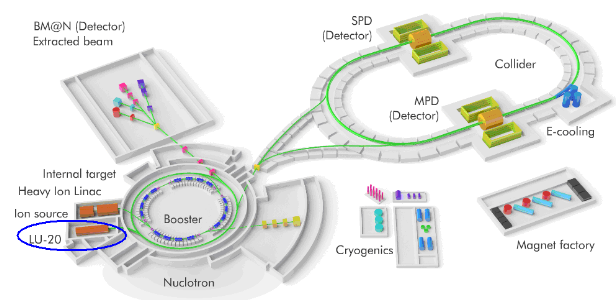

Figure 1: NICA complex. Proton, light and polarized ion linac LU-20 with new RFQ injector is marked.

Table 1: The Forinjector Design Parameters

Z/*A*	0.5	0.3
RFQ input		
Injection energy, keV	61.8	103.0
Maximum current, mA	20	10
Normalized trans. emittance, π·cm·mrad	0.2	0.15
Operating frequency, MHz	145.2	
Output		
Output energy, MeV/u	0.156	0.156
Transmission RFQ, %	≥85	≥90
$\Delta p/p$, %	≤ 4	≤ 4
Normalized trans. emittance, π·cm·mrad	≤0.5	≤ 0.5
Resonator length, m	≤ 3	≤ 3
Voltage at electrodes, kV	84	140

After manufacturing (see Fig.2) and preliminary vacuum and low-power RF tests done at VNIITP the resonator

ISBN 978-3-95450-147-2

was moved at ITEP and installed in tuning hall in March, 2015. First low power RF tests was carried out. Resonator was tuned on operating frequency (see Fig. 3) and RF required field distribution in four quarters was measured. It is clear form Fig. 4 that the RF field amplitude deviation is not more than 2 %. Interesting that we don't observe any appreciable changes in resonator mechanics and no any mechanical tuning of electrodes was necessary after automobile transportation at distance of 2000 km.

Figure 2: New RFQ resonator before coppering.

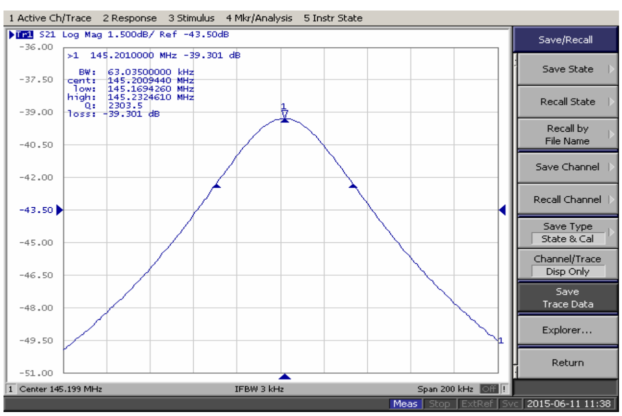

Figure 3: The operating frequency of 145.2 MHz is tuned.

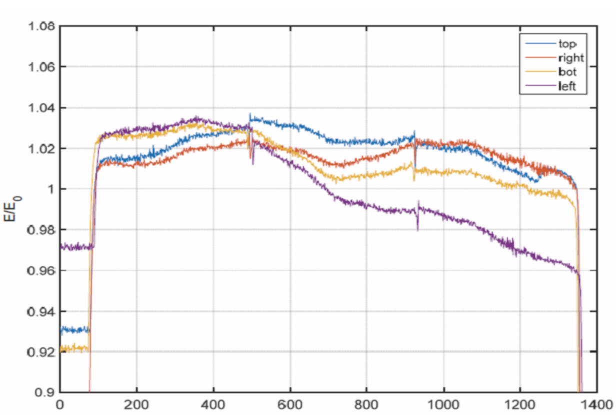

Figure 4: RF field amplitude deviation (< 2%) in four quarters of RFQ resonator.

After transportation the resonator was equipped by RF coupling loops and tuning plungers (see Fig. 5), vacuum pumps and other sub-systems and tuning was started. Vacuum of $1\cdot10^{-7}$ torr was achieved.

RF power load was the next step in tuning. In was realized easily and about 380 kW was feed into RFQ resonator (~340 kW is necessary for carbon ions C^{4+} acceleration). Multiple RF discharges on the same place were not observed but training of multipactor was necessary and it was done. Vacuum of $(8\text{-}9)\cdot10^{-8}$ torr was achieved after RF tests. The resonator was filled by dry nitrogen, moved to JINR and installed in Nuclotron injector's hall.

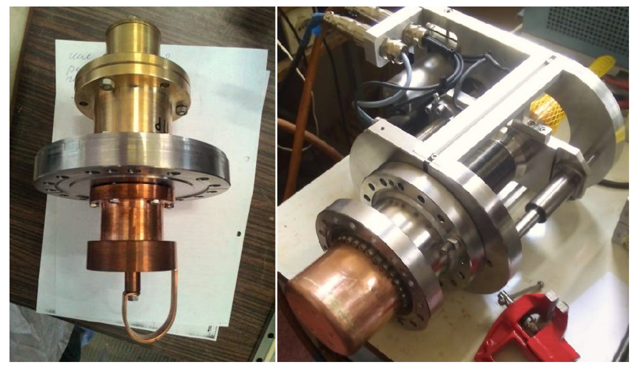

Figure 5: RF coupling loop (left) and tuning plunger.

COMMISSIONING AT JINR

In injectors hall RFQ resonator was equipped by all RF, tuning and vacuum components which were uninstalled for the transportation. High power RF system was also installed in injector's hall. The resonator was vacuumed and RF power was loaded. All operations took two weeks. Photos of RFQ with RF and vacuum components installed on the resonator are presented in Fig. 6.

Further laser ion source and LEBT (two focusing solenoids and two steerers) were mounted to linac support, tested and the deuterium beam was injected in RFQ. The magnet separator was installed on the RFQ output to measure the beam spectrum. The system was calibrated using two non-accelerated beams of D^+ and H^+ which were generated by laser ion source using deuterated/non-deuterated polyethylene target. After magnet separator calibration the RF power was on, deuterium beam was accelerated and its spectrum was measured. The new RFQ linac was successfully commissioned 11-12 Dec. 2015 due to (see Fig. 7). The spectrum of accelerated deuterium beam was measured using magnet separator (Fig. 8). It was compared with beam dynamics simulation results. Such simulations were provided for real channel, including lased ion source, LEBT, RFQ and separator. Excellent agreement of simulation and experimental results is observed for accelerated/non-accelerated carbon and deuterium beams. Measured spectrums for both deuterium and carbon ion beams are presented in Fig. 8, the beam current is equal to ~10 mA for the deuterium beam and ~5 mA for the carbon one. The current transmission coefficient is close to 80 % that agreed with projected value.

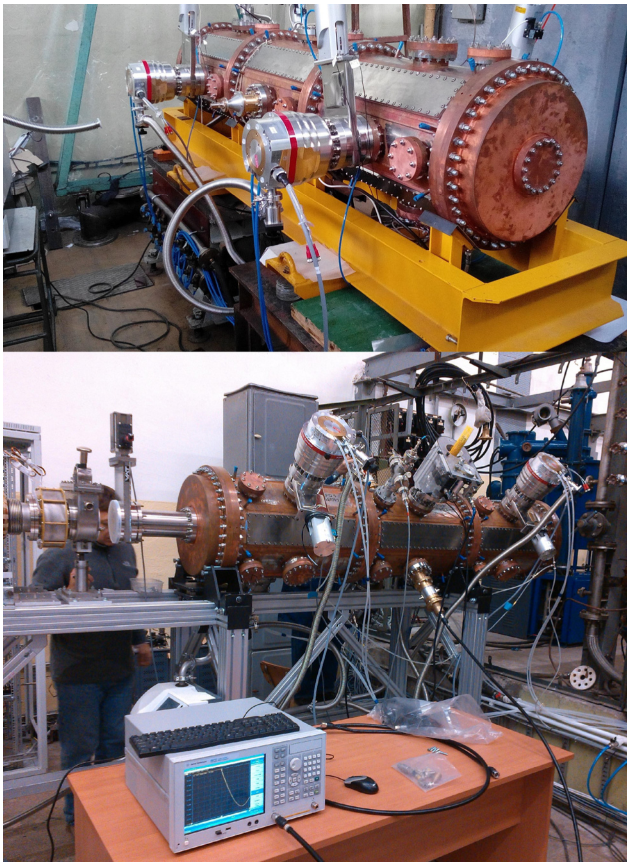

Figure 6: RFQ linac with RF and vacuum components installed on resonator in tuning area at ITEP (top) and linac with laser ion source in Nuclotron injector's hall at JINR.

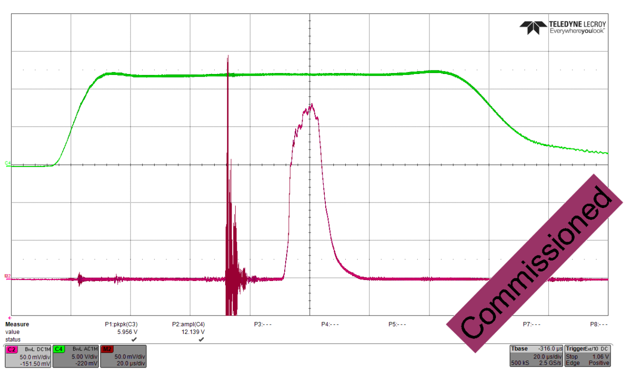

Figure 7: First accelerated deuterium beam was provided 11-12 Dec. 2015.

CONCLUSION

After four years of intensive discussions, simulations, construction and manufacturing new RFQ linac for LU-20 injection complex upgrade was installed in Nuclotron injector's hall at JINR and commissioned. Deuterium and carbon beams were successfully accelerated. Now the operation of LU-20 and Nuclotron with beam from new RFQ is under preparation. The commissioning is planned for May 2016.

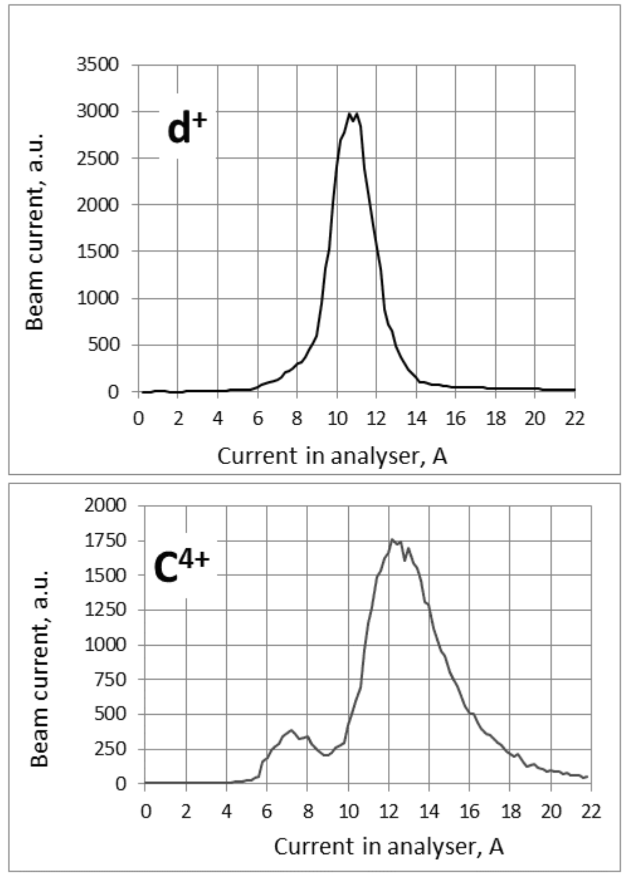

Figure 8: Measured spectrums for accelerated deuterium (top) and carbon C^{4+} beams.

ACKNOWLEDGEMENTS

We would like to thank all Institute of Technical Physics (Snezhinsk) specialists which are take part in resonator manufacturing and personally I.V. Mamaev, K.A. Klykov, M.Yu. Naumenko and G.N. Ostashkov.

We also would like to thank MEPhI TechnoPark and personally A.N. Petrovsky, A.P. Korotkova and S.S. Korotkov for the organization support.

REFERENCES

[1] G. Trubnikov, N. Agapov, V. Alexandrov et al., Proc. of IPAC'10, 693-695 (2010).
[2] O. Kozlov, H. Khodzhibagiyan, S. Kostromin et al., Proc. of IPAC'11, 1108-1110 (2011).
[3] A.V. Butenko, E.E. Donets, E.D. Donets et al., Proc. of IPAC'13, 3915-3917 (2013).
[4] A.V.Butenko, E.E.Donets, E.D.Donets et al., Proc. of IPAC'14, 2103-2105 (2014).
[5] V.A. Andreev, A.I. Balabin, A.V. Butenko et al., Problems of Atomic Science and Technology. Series: Nuclear Physics Investigations, 6 (88), 8-12 (2013).

ISBN 978-3-95450-147-2