CONSTRUCTION AND RF TEST OF THE DEBUNCHER FOR NICA LIGHT ION INJECTOR BEAM LINE

D. A. Zavadtsev, J. Z. Kalinin, L. V. Kravchuk, V. V. Paramonov, D. V. Churanov, Institute for Nuclear Research of RAS, Moscow, Russia
A. A. Zavadtsev†, Nano Invest, LLC, Moscow, Russia
A. V. Butenko, A. V. Smirnov, E. M. Syresin, Joint Institute for Nuclear Research, Dubna, Russia

Abstract

Debuncher is to be installed in the present beam line after the LU-20 linac in the light ion injector of the NICA facility. The purpose of the debuncher is to reduce by a factor of up to ten the ion energy spread in the accelerated beam before injection into the Nuclotron. Relative ion speed is 0.1. Split-ring cavity driven from solid state RF amplifier at 145.25 MHz, should provide effective RF voltage up to 200 kV at 4 kW peak RF power. The RF controller allows adjust effective RF voltage for different ions: 58 kV for *Z/A*=1, 121 kV for *Z/A*=0.5 and 190 kV for *Z/A*=0.3. The debuncher cavity is provided with the stepper-motor driven capacitance tuner with 2 MHz tuning range.

INTRODUCTION

The debuncher has been developed [1] as a prototype for the new light ion injector for the Nuclotron based Ion Collider fAcility and Multi Purpose Detector (NICA/MPD) [2]. The debuncher is intended to reduce the width of the energy spectrum of the accelerated ion beam after the linear accelerator LU-20 and 6 m drift space by a factor up to ten.

The debuncher consists of the cavity, the RF amplifier, the RF controller and the vacuum system.

The present report describes the construction and low power RF test of the debuncher cavity. The high power RF test will be performed some later, when the vacuum system will be ready.

MAIN PARAMETERS

After consideration and simulation of several different cavity types the split-ring has been chosen as an accelerating cavity.

The main specified parameters of the debuncher are

- operating frequency f=145.25 MHz,
- effective accelerating voltage UT=0-200 kV,
- range of the tuning Δf=±250 kHz,
- coupling coefficient of the feeding line and the cavity β=1,
- input power P_m=20-30 dBm,
- pulse length τ=100-300 μsec,
- rise/fall length τ_R=200 μsec,
- repetition rate $F\leq$0.5.

The calculated parameters of the optimized shape of the split-ring cavity are

- shunt impedance $R_{sh.eff}=(UT)^2/P$=11.68 MOhm,
- unloaded Q-factor Q_0=9516,
- effective voltage UT=200 kV,
- power loss P=3.4 kW,
- max electric field E_{max}=8.0 MV/m,
- relative max electric field E_{max}/E_k=0.62.
- multipacting not found.

CAVITY CONSTRUCTION

The debuncher cavity includes following parts: split-ring, case with flanges, input coupler, pick-up antenna, tuner and directional coupler. The design is shown in Fig. 1.

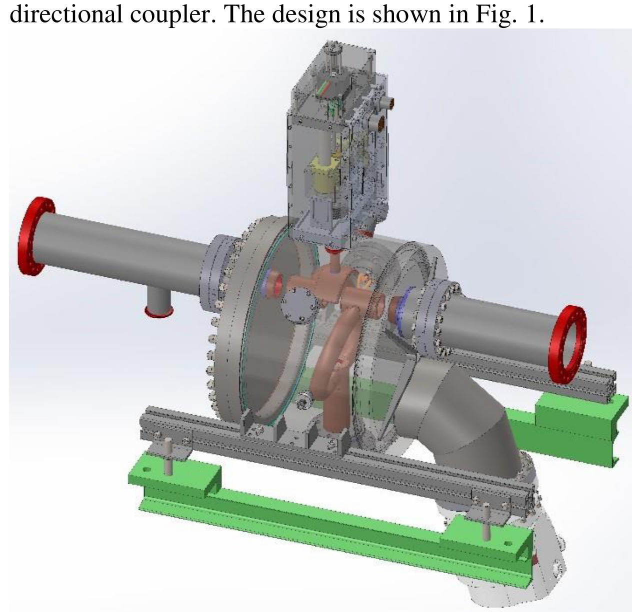

Figure 1: Debuncher cavity design.

Split-ring

The split-ring is a half wave-length vibrator with drift tubes at the ends and cylindrical rod support (Fig. 2). The split-ring is manufactured of Oxygen-free copper and brazed with 72%Ag-28%Cu brazing alloy in special fixture, guaranteed precise designed shape after brazing.

The split-ring is fixed on the special platform in the cavity case. The right position of the split-ring in the cavity is provided by following way. The split-ring was fixed on the platform with the bolt and the pins. Then the half-drift tubes were installed in the case with the bolts and the pins. Then assembled split-ring and platform were installed in the case using special fixture. This special fixture provides precise coaxial position of the split-ring drift tubes and the half-drift tubes of the case. Also the fixture provides precise position of the split-ring drift tubes along the beam line

† azavadtsev@yandex.ru

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axis. When the split-ring drift tubes were in a design position, the platform was welded to the case. So precise manufacture, brazing and welding procedures using special fixtures provide designed position of the split-ring in the case.

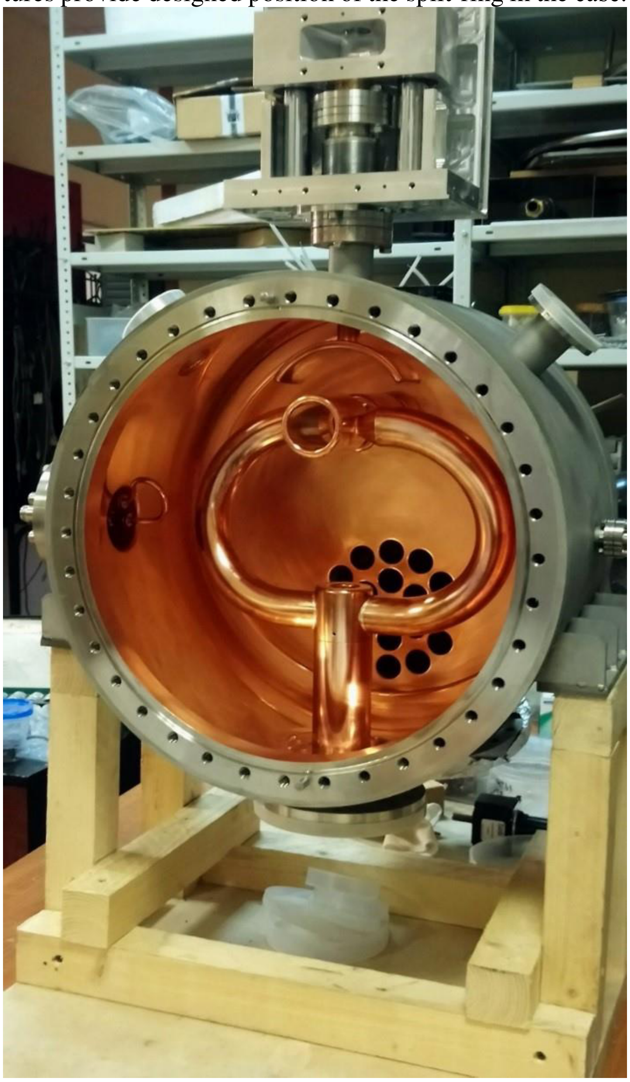

Figure 2: Debuncher cavity.

Cavity Case

The cavity case is made of the stainless steel and welded. After welding the case has been copper-plated galvanically. The copper thickness is 43 µ.

The housing is equipped with several ConFlat flanges: DN350 for the cover of the case, DN160 for the vacuum pumping, DN100 (3 pcs.) for the aperture pipes and for the platform of the split-ring, DN63 for the input coupler, DN35 (3 pcs.) for the tuner and the vacuum sensors, DN16 for the pick-up antenna.

The case is equipped with two copper half-drift tubes, connected with the bolts and the pins, two support plates to install the case on the alignment system and two alignment marks on each aperture flange. The mark is a hole Ø$6^{+0.02}$×10 mm.

Input Coupler

The input coupler includes the coupling loop, the ceramic feed-through with the DN16CF flange and the N-connector and the DN63CF-DN16CF adapter. The loop ends are connected to the inner conductor of the feed-through and to the adapter. The feed-through is specified for operation at up to 1.5 kV. This is good enough for designed power level. The DN63CF flange is rotatable to tune the coupling coefficient via rotating the loop with respect to the cavity.

Pick-up Antenna

The pick-up antenna is the ceramic feed-through with DN16CF flange and N-connector. The pin-antenna is used for monitoring the field level in the cavity.

Tuner

The tuner includes movable bended capacitive coper plate on the cylindrical rod. The plate provides additional capacity between the drift tubes of the split-ring, reducing the resonant frequency of the cavity. So the resonant frequency of the cavity can be changed via changing the distance between the plate and the drift tubes.

The tuner is equipped with the translational motion actuator with the stepper motor and the bellows.

Directional Coupler

The dual coaxial directional coupler has been developed, designed and manufactured. It will be used between RF amplifier and the cavity at full RF power. The directional coupler is shown in Fig. 3.

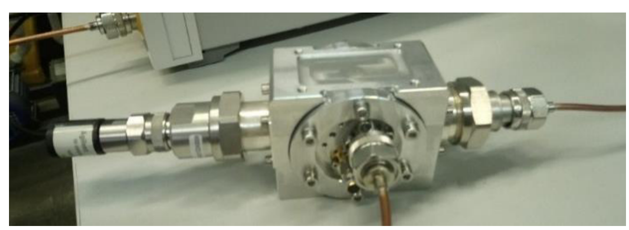

Figure 3: Directional coupler.

The directional coupler is equipped with input and output coaxial 7/16-connectors and two N-connectors for the forward and reflected signals.

RF TEST OF THE CAVITY

Frequency Tuning range

The operating frequency of the debuncher is 145.25 MHz. RF test of the cavity is performed at the air with permittivity of ε=1.00058 inside. It leads to reducing the resonant frequency to the value 145.21 MHz. The measured tuning range is 144.3-146.4 MHz (Fig.4).

Input Coupling

In accordance with the debuncher project the feeding coaxial line is to be matched with the cavity. The input coupler has been tuned via rotating the coupling loop around its flange axis. The measured reflection value is S_{11}=-

36.55 dB at f=145.21 MHz. It means the coupling coefficient β=1 practically. The measured reflection in the frequency range is shown in Fig. 5.

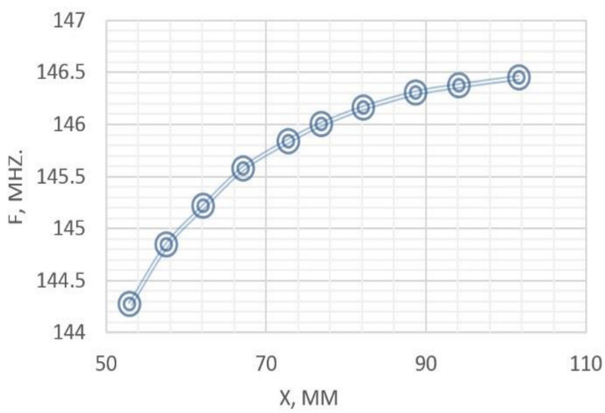

Figure 4: Frequency tuning.

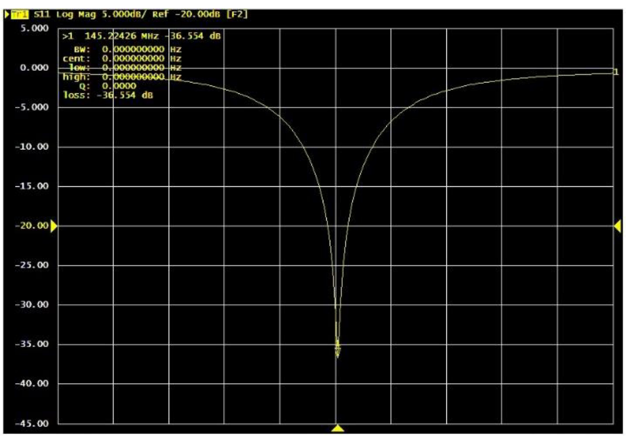

Figure 5: Measured reflection S_{11} in the frequency range.

Pick-up Signal

The measured transmission through the cavity from the input coupler to the pick-up antenna is S_{12}=-35.725 dB. The transmission S_{12} in the frequency range is shown in Fig.6.

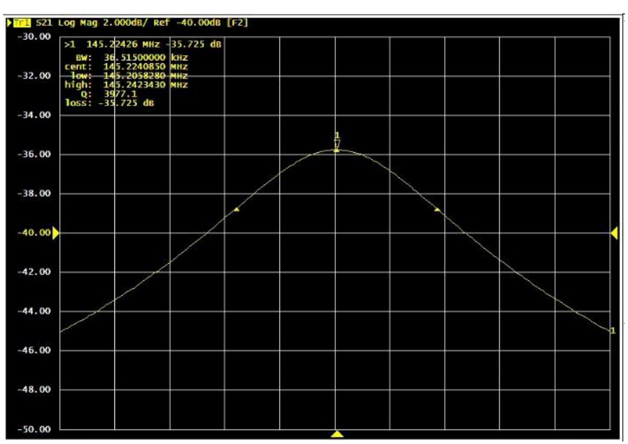

Figure 6: Measured transmission S_{12} in the frequency range.

Q-factor

The measured transmission S_{12} in the frequency range (Fig. 6) allows us to get loaded Q-factor of the cavity equalled to Q_L=3977. It means that unloaded Q-factor is Q_0=2·Q_L=7954, i.e. 83.6% of calculated value. Needed RF power for voltage UT=200 kV is P=3.8 kW at Q_0=7954.

Accelerating Field

The electric accelerating field along the cavity axis has been measured using bead-pull method. Fig. 7 and 8 show calculated and measured field distribution. The measured field corresponds to the calculated one fully.

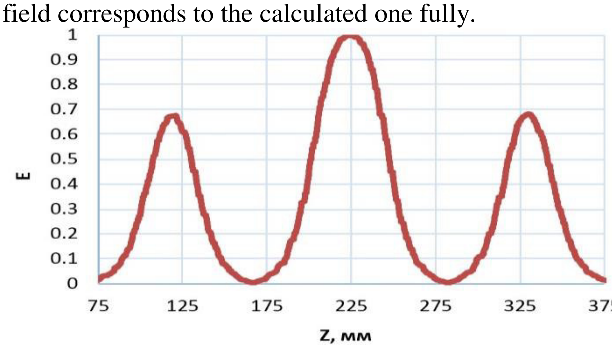

Figure 7: Calculated electric field.

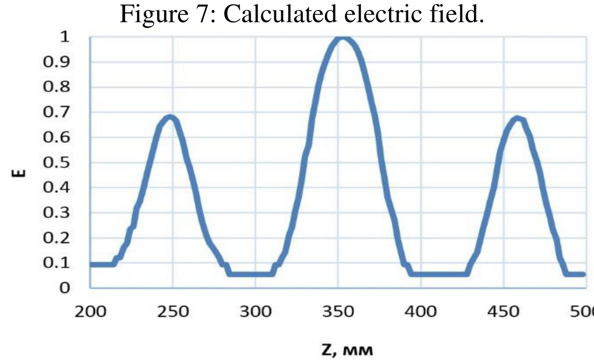

Fig. 8: Measured electric field.

Directional Coupler

The directional coupler has been tuned and tested. The measured parameters are: reflection (F) -47.4 dB, coupling (F/R) -47.4/47.4 dB, directivity (F/R) 43.4/45.6 dB.

CONCLUSION

The debuncher for the light ion injector beam line of NICA facility has been built. The cavity and the directional coupler have been tuned and tested at low RF power level. The measured parameters correspond to the designed parameters fully.

REFERENCES

[1] A A Zavadtsev et al., "Development of the debuncher for the injector part of the accelerator complex NICA". *IV International Conference on Laser and Plasma Researches and Technologie. IOP Conf. Series: Journal of Physics: Conf.* (2017).

[2] Technical Project of the Accelerating Facility NICA. Under general supervision by I.N.Meshkov and G.V.Trubnikov, JINR, Dubna 2015.

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