ISBN: 978-3-95450-197-7 doi:10.18429/JACoW-RUPAC2018-TUPSA24

TEST BENCH MEASUREMENTS FOR THE NICA STOCHASTIC COOLING PICKUP AND KICKER*

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Abstract

A new test bench for measurements of Nuclotron-based Ion Collider fAcility (NICA) stochastic cooling elements has been created at Joint Institute for Nuclear Research (JINR). The following measurements for NICA stochastic cooling pickups/kickers based on Ring-slot coupler structure has been provided: impedance dependence on azimuthal and longitudinal loop positions, electrical center position behavior as a function of frequency and standing wave ratio (SWR) of the kicker. The results of the listed measurements are given.

INTRODUCTION

Stochastic cooling system (SCS) for NICA collider is under development in JINR. It is required for beam accumulation and luminosity preservation of the collider. Stochastic cooling system it is a microwave broadband system with feedback via the beam that leads to a decrease in the amplitudes of the betatron oscillations and the energy spread of the beam particles. This system consists of pickup and kicker, amplifiers, electrical delay elements and other optional characteristic elements.

Since JINR had no experience with the stochastic cooling, in 2008 it was decided to develop a test channel at Nuclotron before the implementation at NICA. Test channel has bandwidth 2-4 GHz and 60W output power. Pickup and kicker for the test channel were manufactured in FZJ (Juelich, Germany) on the basis of design proposed for HESR of the FAIR project [1]. During experiments at the Nuclotron performed in close cooperation with FZJ personnel the kicker was tested at the design power and the beam cooling was demonstrated for coasting and bunched beams [2]. However the initial design does not satisfy exactly to the NICA requirements. First of all it does not guarantee obtaining of residual gas pressure at the level of 10^{-11} Torr necessary for the collider operation. A few important characteristics of the structures were not measured during the first experiments. In the last run of the Nuclotron operation (spring 2018) the structures were tested with low intensive heavy ion beams. Measurements of the beam transfer functions (BTF, see Fig. 1-2) demonstrated excellent sensitivity of the structure (stable signal of sufficient amplitude was measured at intensity down to 10^5 of the circulating particles). However the maximum of the amplitude response is displaced from the middle of the band (3 GHz) to about 2 GHz (see Fig. 2).

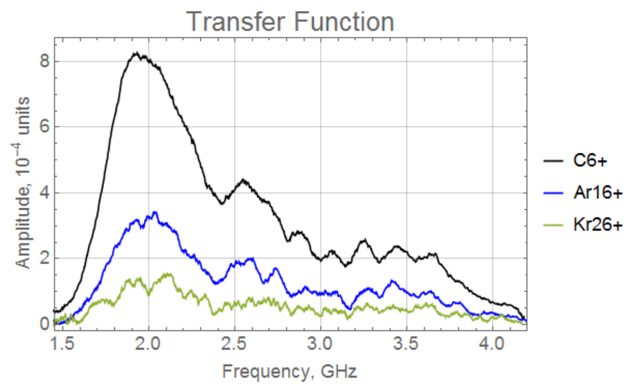

Figure 1: Plot of BTF amplitude. The intensity of carbon beam is $3\cdot10^8$ elem. charges, argon – $1.5\cdot10^7$, krypton – $2\cdot10^6$.

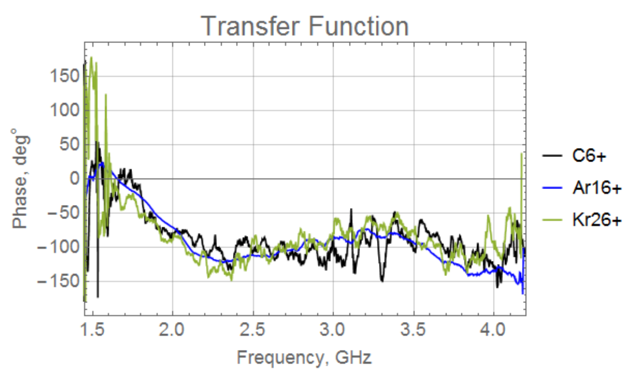

Figure 2: Plot of BTF phase for the same intensities of corresponding particles.

To avoid the mentioned disadvantages modifications of the initial design were proposed and for test of an improved structure specialized test bench has been constructed at JINR.

PICKUP AND KICKER DESIGN

The HESR type design of the pickup and kicker is based on Ring slot couplers proposed by R.Stassen (see Fig. 3). 8 loops distributed uniformly along the azimuth are used to measure or apply a signal.

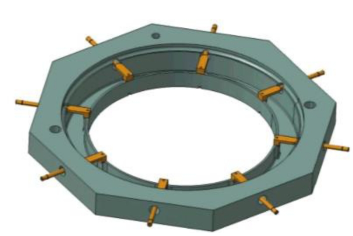

Figure 3: Ring-slot coupler design.

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Basic structure consists of 16 rings combined together with a combiner boards (see Fig. 4).

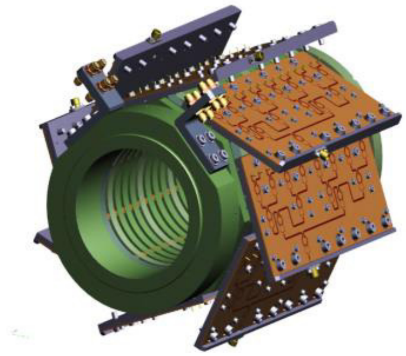

Figure 4: Pickup/kicker structure by FZ Julich.

The whole structure is assumed to be installed in a vacuum chamber. Due to a presence of large number of small elements in a complex design it is complicated to obtain ultra-high vacuum. Radical solution of this problem is to use ceramic vacuum chamber and assembly the structure cut along a median plane around the chamber (Fig. 5).

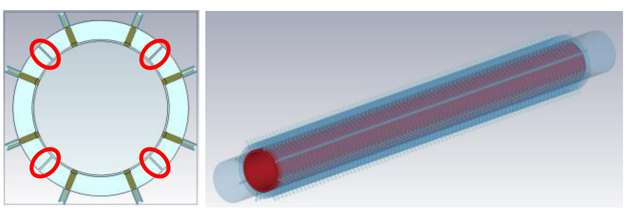

Figure 5: Cut structure with ceramic vacuum chamber inside rings.

Preliminary estimations show that the change in structure does not affect dramatically on the sensitivity and distribution of fields. The original structure and an improved one without ceramic chamber have similar behavior.

Prototype of cut structure was constructed by JINR in 2018. Geometry of the rings was kept identical to the initial design. The assembly prepared for measurements (see Fig. 6) consist of 16 rings in the center, magnetic High-Order Mode suppressors are outside the rings and on the edges there are conical 50Ω matchers from N-type connector to the inner cylindrical conductor.

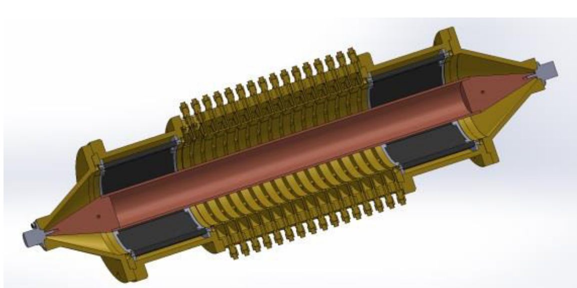

Figure 6: Prototype to Test.

Together with a support (see Fig. 7) the structure was included into test-bench developed for test of the stochastic cooling system elements [3].

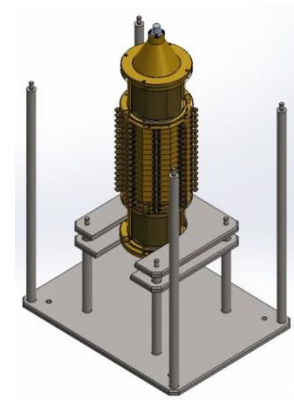

Figure 7: Test bench.

TEST BENCH MEASUREMENTS

To control a quality of the structure the following main parameters have to be measured:

- Impedance dependence on the loop azimuthal and longitudinal position,
- Electrical center position as a function of frequency,
- Kicker SWR

The results of the measurements with cut structure without ceramic chamber inside are presented below.

Impedance

The signal is applied to the input of the structure; the signal is read at the output of the loop at the corresponding azimuth. On Fig. 8-9 the yellow curve detects a defective connection of loop on 10th ring.

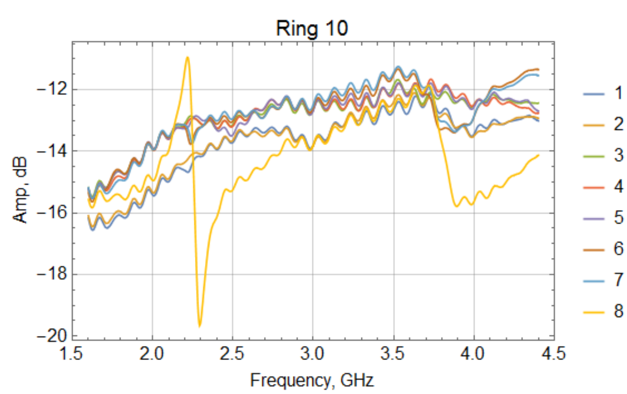

Figure 8: Plot of amplitude for rings.

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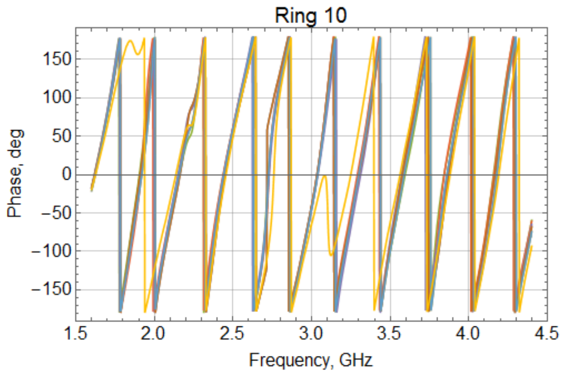

Figure 9: Plot of phase for rings.

Electrical center

The signal is applied to the input of the structure; the signal is read as the difference between outputs from the opposite loops along the azimuths on the corresponding rings. The signal is read at the output of the loop at the corresponding azimuth.

Electrical center position behavior as a function of frequency is presented by plots on Fig. 10-11. Measurement data is being processed.

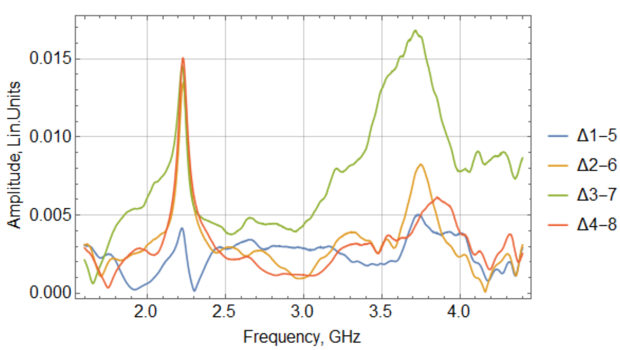

Figure 10: Amplitude of the difference signal from the corresponding azimuths.

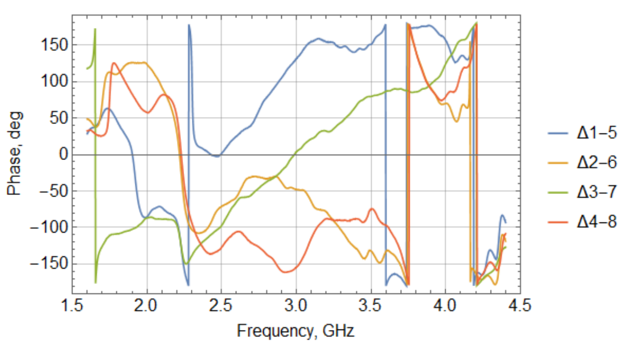

Figure 11: Phase of the difference signal from the corresponding azimuths.

Kicker SWR

The amplifiers are to power the kicker distributed: by a 30 W amplifier for every two radial azimuth directions of the loops as shown on Figure 12.

In order to estimate the reflected power in each direction, the measurements of the kicker SWR were conducted on them.

According to the measurements (see Fig. 13), it turned out to be less than 1.3. Back Reflected Power is 4,76%, that is about 1.5 W. This result is acceptable.

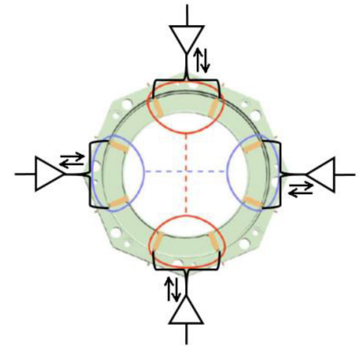

Figure 12: Kicker power feed scheme.

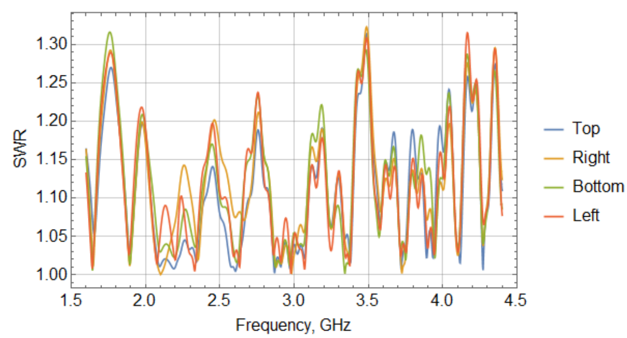

Figure 13: Plot of kicker SWR.

CONCLUSION

The test bench for investigation pickup and kicker structures for stochastic cooling system at NICA collider in JINR has been created and first measurements with cut structure have already provided. That has involved following points:

- Pickup Manufacturing Technology has been tested,
- Pickup prototype has been produced,
- Test Bench has been created,
- Measurement method has been developed,
- Measurements has been started with impedance dependence on azimuthal and longitudinal loop positions, electrical center position behavior as a function of frequency and SWR of the kicker.

The results of the measurements are processed. Preliminary conclusions were made in satisfying the new design to the ultimate goal.

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