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INPUT POWER COUPLER FOR NICA INJECTOR COAXIAL QUARTER WAVE SC CAVITY

T. A. Bakhareva*, M. A. Gusarova, M. V. Lalayan, S. V. Matsievskiy,
National Research Nuclear University MEPhI , Moscow, Russia
V. Zvyagintsev, TRIUMF, Vancouver, Canada

Abstract

Nuclotron-based Ion Collider fAcility (NICA) is being built in Dubna, Russian Federation [1]. Usage of the accelerator superconducting QWR cavities for the proposed injector part of the accelerator upgrade is considered. These cavities along with auxiliary RF systems are under development by collaboration of Russian and Belorussian research institutions. In this paper the results on power coupler R&D for the 162 MHz QWR are presented and discussed. According to technical requirements power coupler should be able to transmit 20 kW of RF power. Additionally, external Q-factor tuning in small range should be possible.

DESIGN OVERVIEW

Nuclotron-based Ion Collider fAcility (NICA) injector upgrade plans comprise superconductintg QWR cavities (Fig. 1) for the acceleration of particles at velocity about 0.12 c. These cavities will operate in the pulsed mode [2, 3].

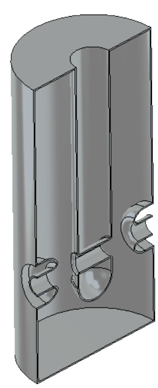

Figure 1: QWR cell.

Size of the 162 MHz rectangular waveguide is unacceptably big so the coaxial power input type was chosen. Outer and inner conductors of the coupler will be made of steel. Optional thin layer of plated copper is considered for better electrical and thermal conductivity. Accelerating system layout consists of 5 identical QWRs having the same beta value. This design was chosen because of low overall cost and cavity production capabilities despite the phase slipping occurred. It was decided to develop one power coupler suitable for all cavities. It require cavity external Q-factor value to be varied for different cavities in string. Power coupler antenna is of cylindrical shape and it couples to electric field in cavity. The required external Q-factor tuning range was calculated to be covered by the antenna with total tip penetration is varied within ±10 mm (Fig. 2).

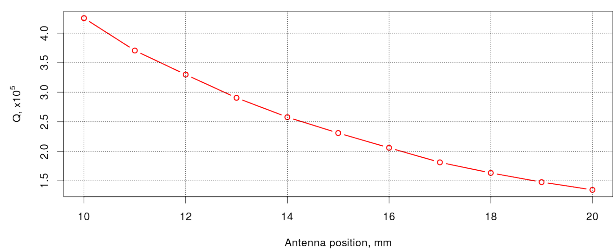

Figure 2: External Q-factor of the cell vs antenna position.

RF WINDOW

Conventional two-window power input design was chosen. It provides some protection from cavity contamination in case of mechanical failures and is not too complicated. First window isolates the high-vacuum cavity volume and contacts to the 70 K heat sink. Second window operates at higher temperatures. Usually, these windows would be half of the wavelength apart, but in this case it is unpractical. Both windows have the similar design providing them to be matched with reflection less than -45dB. Overview of the RF window design is shown in Figure 3.

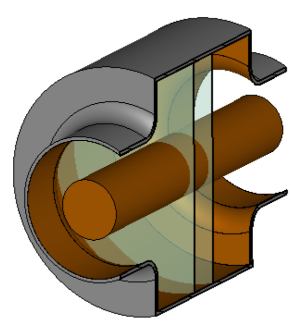

Figure 3: RF window overview.

In simulations 95% alumina ceramics was used. It is frequent to be employed in this kind of applications because of its good loss to cost ratio. Windows were tuned to achieve low reflection at operating frequency and in broad frequency range (Fig. 4).

In order to decrease the possibility of the breakdown, some rough window edges were smoothed. Due to rounded edges in transition from cylinder coax to pillbox volume the overvoltage factor is 1.3. (It equals to the maximal surface

* tatyanabasha@gmail.com

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fields ratio – one found on the window unit and on regular coax line).

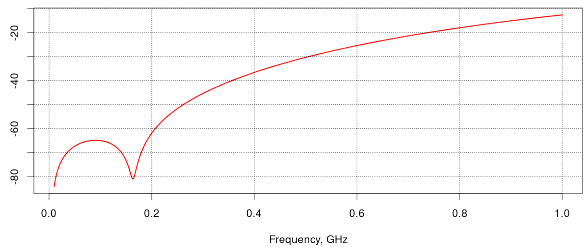

Figure 4: RF window reflection.

One of the most problematic parts of the design are window ceramics heating and mechanical stress caused by thermal deformations. These calculations were carried out for the RF window.

Temperature maps of the 70 K RF window without and with transmitting power are presented in Figure 5. Mechanical tensions in the ceramic window are presented in Figure 6.

It should be noted that these simulations are preliminary and will be reviewed after the decision about manufacturer will be made.

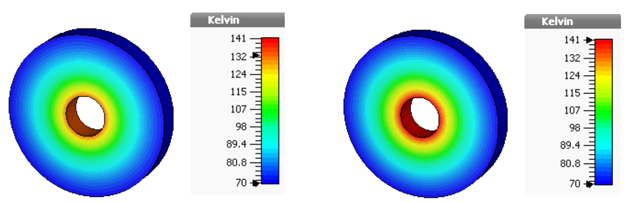

Figure 5: Thermal maps of the 70 K RF window without (left) and with (right) transmitting power.

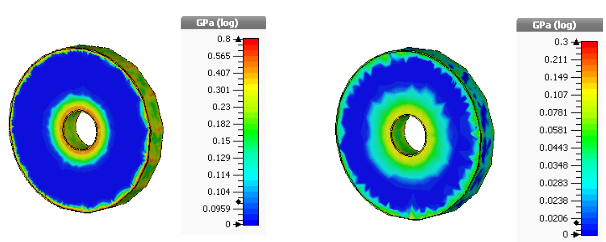

Figure 6: Mechanical maps of the RF window without (left) and with (right) transmitting power.

BELLOWS

In order for antenna to move, bellows were introduced in the coupler design (Fig. 7). Thin copper plating is considered optional and will be involved only if bellows heating caused by RF losses became intolerable. Choice of bellows corrugation number and the copper layer thickness were carried out in order to ensure mechanical reliability and achieve minimal thermal load for the QWR cryogenic system. Reflection of the bellows was estimated and appears to be low enough for any parameters combination at operating frequency (Fig. 8).

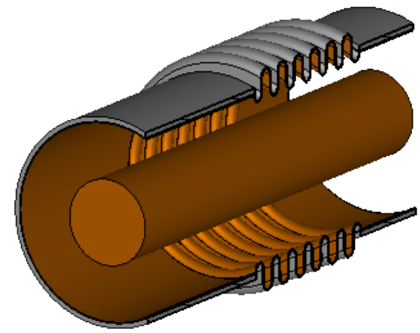

Figure 7: Bellows overview.

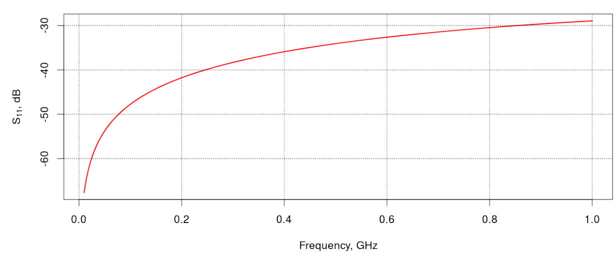

Figure 8: Bellows reflection.

FULL ASSEMBLY

After the coupler parts optimization, calculations of the full assembly were done.

Reflection for the whole model appeared to be satisfactory (Fig. 9).

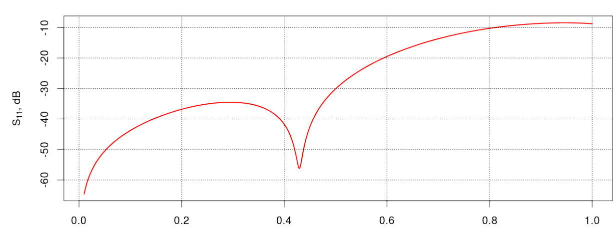

Figure 9: Full assembly reflection.

For the full assembly temperature distribution was calculated. Cold RF window was set to be in contact with 70 K temperature sink. Surface of the cavity was set to 4 K. Temperature distribution in the coupler is shown in Figure 10.

In Figure 11 approximate assembly drawing is shown. Outer cryostat is not shown and its final design is under consideration.

MULTIPACTING CALCULATIONS

Multipactor is often observed in the power couplers and can cause significant problems with the cavity operation,

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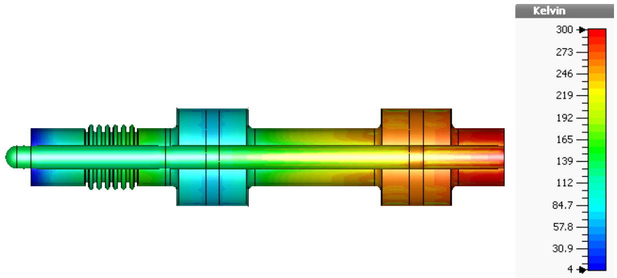

Figure 10: Temperature distribution in the coupler.

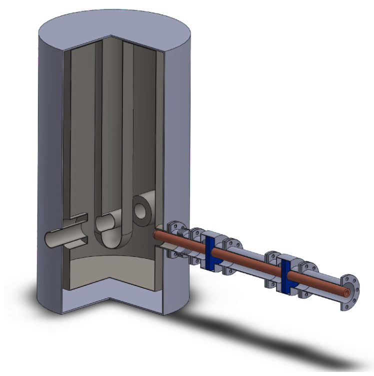

Figure 11: Assembly of the coupler.

power source etc. Additionally, excessive heat can significantly reduce superconducting properties of the accelerating cavities and causes an additional load on the cryogenic systems. herefore it is very important to check each component of the possibility of multipacting. In a coaxial waveguide, multipactor phenomenon depends mainly on the operation frequency, the power coupler sizes, the impedance of it and the RF power [4]. This relation is expressed in following formulas:

$$P_{one-point} \propto (fd)^4 Z$$
$$P_{two-point} \propto (fd)^4 Z^2$$

Examining these formulas and correlating them to the experimental data showed that multipacting phenomena will not be observed in the coupler.

CONCLUSION

Steps of designing initial model of the NICA low-beta input power coupler were discussed in this paper. Parts of the coupler – RF windows and bellows – were optimized to achieve minimal RF reflection. Thermal and mechanical tasks were solved to ensure stable coupler operation. Multipacting possibility was estimated.

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