ISBN: 978-3-95450-240-0 ISSN: 2673-5539 doi:10.18429/JACoW-RuPAC2021-WEPSC12

PRELIMINARY CALCULATION OF THE POWER COUPLER FOR THE SYLA STORAGE RING RF CAVITY

S. V. Matsievskiy*, M. A. Gusarova, M. V. Lalayan, Ya. V. Shashkov
NRNU MEPhI, Moscow, Russia and NRC KI, Moscow, Russia

Abstract

Several new accelerator facilities will be built in Russia in the next few years. One of those facilities is a 6 GeV storage ring light source, the Ultimate Source of Synchrotron Radiation to be built in Protvino, near Moscow.

This paper considers storage ring RF cavity power coupler design issues and provides preliminary calculations of the device.

INTRODUCTION

6 GeV Ultimate Source of Synchrotron Radiation is planned to be built in Protvino, Russia. Storage ring scheme is based on the ESRF-EBS design [1]. Thus, many design patterns are copied from the aforementioned project, including the RF system, consisting of a number of a mono-cell normally conducting HOM-damped cavities (HOM mitigation is discussed in other paper in this conference) [2].

Cavity properties are presented in Table 1. Continuations were carried out for the accelerating voltage value for all cavities $V_{cav\ all} = 3\,\mathrm{MV}$.

Table 1: RF Cavity Properties

Property	Value
f, MHz	357
Q, $\times 10^3$	41
$R_{sh\ eff}$, MΩ	10
W_{rad}, MeV turn^{-1}	3
I_{beam}, A	0.25

POWER COUPLER

RF cavity with the attached magnetic loop is presented in Fig. 1.

Calculation of the generator power P_g and coupling coefficient β was done by using conventional equations for cavity voltage [3]

$$V_{cav} = \frac{2\sqrt{P_g}\sqrt{R_{sh\ eff}}\sqrt{\beta}\left(-\frac{I_{beam}\sqrt{R_{sh\ eff}}}{2\sqrt{P_g}\sqrt{\beta}} + 1\right)}{\beta + 1} \qquad (1)$$

and optimal coupling [4]

$$\beta = \left(\frac{I_{beam}\sqrt{R_{sh\ eff}}}{2\sqrt{P_g}} + \sqrt{\frac{I_{beam}^2 R_{sh\ eff}}{4P_g} + 1}\right)^2. \qquad (2)$$

* svmatsiyevskij@mephi.ru

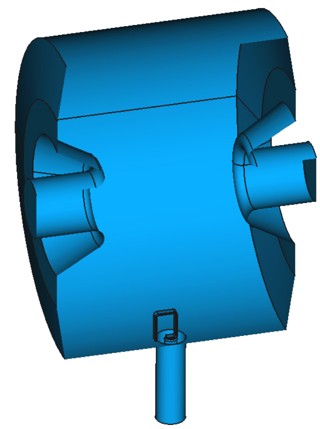

Figure 1: RF cavity with coupling loop.

Substituting Eq. (2) into (1) yields a simple equation for the optimally coupled cavity supply power

$$P_g = \frac{V_{cav}\left(I_{beam}R_{sh\ eff} + V_{cav}\right)}{R_{sh\ eff}}. \qquad (3)$$

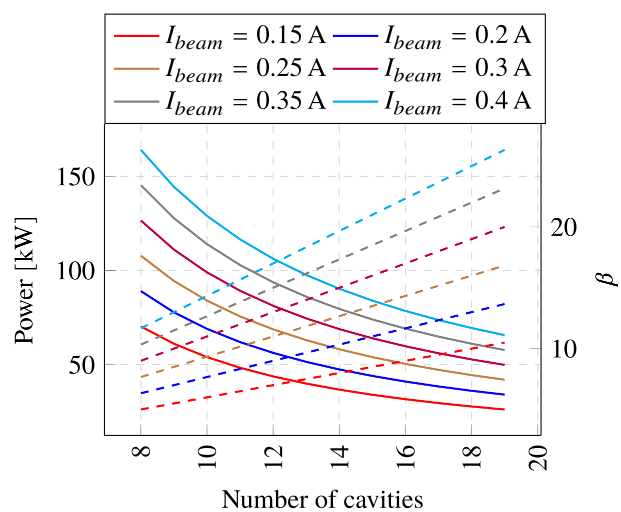

Figure 2: Optimal supply power (solid lines) and coupling coefficient (dashed lines) for different number of cavities.

Equation (3) was used in calculation of Fig. 2. For the operation under 100 kW number of cavities should be greater then 9. Considering a possible cavity failure and operation under higher current a number of cavities in the ring was chosen $N = 14$. Further calculations were done for the constant coupling coefficient value β corresponding to the beam current $I_{beam} = 0.25$ A.

ISBN: 978-3-95450-240-0 ISSN: 2673-5539 doi:10.18429/JACoW-RuPAC2021-WEPSC12

Solving Eq. (1) for P_g yields the equation for the cavity supply power with the fixed coupling coefficient

$$P_g = \frac{I_{beam} V_{cav}}{4\beta} \left(\frac{I_{beam} R_{sh\,eff}}{V_{cav}} + 2\beta + 2 \right) + \\ + \frac{V_{cav}^2}{4 R_{sh\,eff}} \left(\frac{1}{\beta} + \beta + 2 \right). \quad (4)$$

Using this equation cavity power balance was calculated (Fig. 3). In this figure RF cavity power loss was determined using the conventional shunt impedance equation $R_{sh\,eff} = V_{cav}^2 / P_{loss}$ and the conservative one $R_{sh\,eff} = V_g^2 / P_{loss}^*$. Filled regions on the plot represent difference between the two. Based on the obtained value of generator power P_g standard CF50 flange was chosen as a power coupler interface.

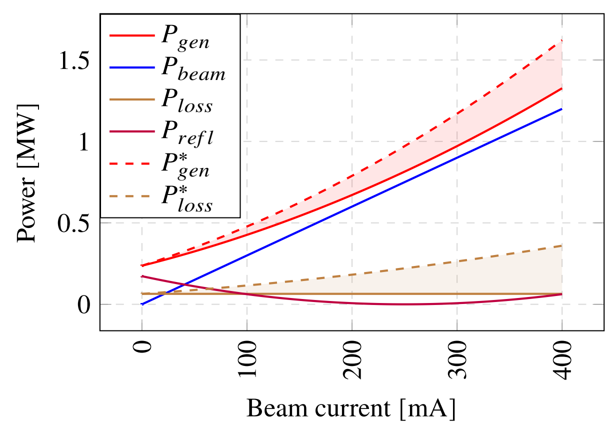

Figure 3: Cavity power balance. Filled regions represent difference between precise values of P_g and P_{loss} and the conservative ones P_g^* and P_{loss}^*.

For the model presented in Fig. 1 dependence of the coupling coefficient β on the magnetic loop immersion depth is shown in Fig. 4.

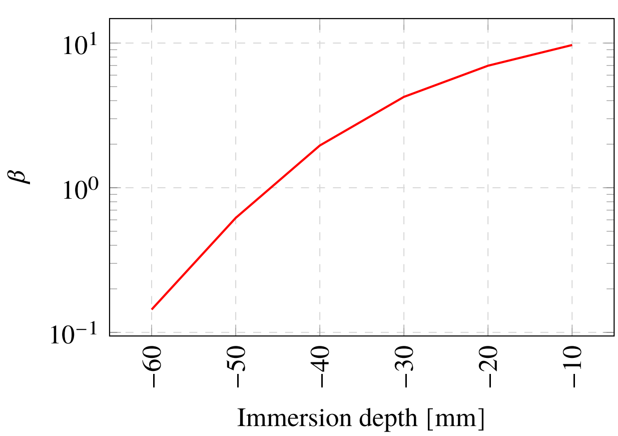

Figure 4: Coupling coefficient over the magnetic loop immersion depth.

RF WINDOW

One of the big concerns for the power supply system is the ceramic RF window. Such a window with a 6 mm alumina ceramic disc was designed and matched. Reflection from the device in frequency range is shown in Fig. 5.

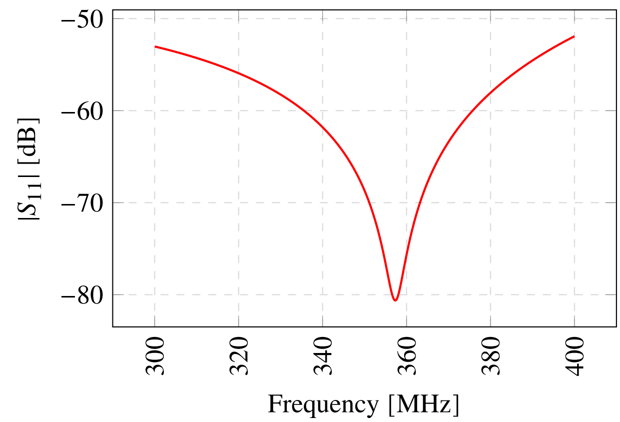

Figure 5: RF window reflection coefficient.

Temperature in the ceramic window was calculated for the CW operational regime with the 140 kW of the transmitted power (Fig. 6). For the simulation temperatures of the inner and outer conductors of the regular line were fixed. Convectional cooling from the atmosphere side was assumed. Even in this case the temperature of the ceramic window is quite large and exceed 380 K.

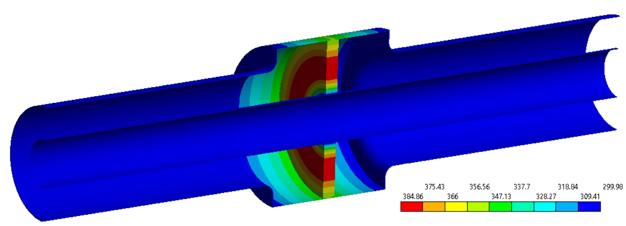

Figure 6: RF window temperature.

Not surprisingly, high temperature gradient lead to the high mechanical stress in the ceramics. It is shown in Fig. 7.

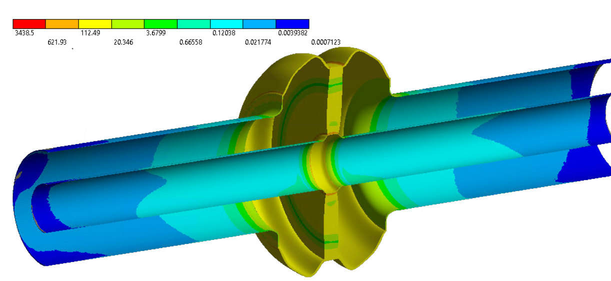

Figure 7: RF window mechanical stress.

For the alumina ceramics mechanical safety factor is shown in Fig. 8. The dangerous values of $f_S < 5$ may be observed on the ceramics inner connection ring, which has high probability of failure. Therefore, lowering the ceramics

ISBN: 978-3-95450-240-0 ISSN: 2673-5539 doi:10.18429/JACoW-RuPAC2021-WEPSC12

temperature is necessary. One of the possible solutions is to use beryllium based ceramics, which has lower RF losses and higher heating transfer coefficient, but is very toxic.

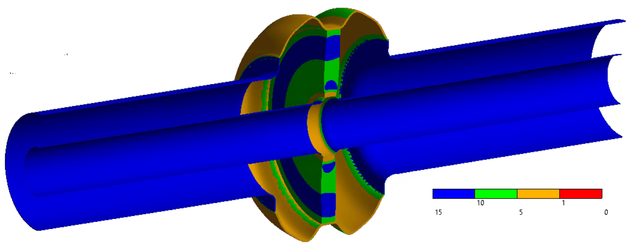

Figure 8: RF window safety margin.

CONCLUSION

In this paper power coupler preliminary calculations were carried out. Number of RF cavities was chosen $N = 14$, CF50 vacuum flange was selected as an RF coupler interface.

Simulation of the simplified RF window model was done. It showed an excessive temperature on the ceramics window, which lead to the unacceptably large mechanical stress in the copper to ceramics brazing region. Usage of the beryllium based ceramics is currently under consideration.

REFERENCES

[1] L. Hoummi *et al.*, "Optimization and error studies for the USSR HMBA lattice," in *Proc. IPAC'21*, (Campinas, SP, Brazil), paper MOPAB224, May 2021 DOI: 10.18429/JACoW-IPAC2021-MOPAB224.

[2] L. Farvacque, Ed., *ESRF-EBS design report*, 2018.

[3] P. V. Wilson, "High energy electron linacs: Applications to storage ring RF systems and linear colliders," SLAC, Accelerator Center, SLAC, 2575 Sand Hill Rd., Menlo Park, CA 94025, USA, Nov. 1991. https://www.slac.stanford.edu/pubs/slacpubs/2750/slac-pub-2884.pdf

[4] V. I. Kaminskii, N. P. Sobenin, and M. V. Lalayan, *Uskoryayushchiye struktury*. 2005, 294 pp., (in Russian), ISBN: 5-7262-0588-X.