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ACCELERATING CAVITIES WITH HOM DAMPING FOR USSR-4 STORAGE RING

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Abstract

Preliminary results on accelerating cavities for USSR-4 facility (also known as SYLA - SYnchrotron and free-electron LAser) project are presented. This facility is under development by collaboration hosted by National Research Center "Kurchatov Institute". SYLA is synchrotron radiation facility based on injector linac and 6 GeV storage ring. Beam energy loss in storage ring is to be compensated by several modified pillbox cavities. Cavity geometry features, its operation frequency choice and induced HOM parameters are discussed. HOM damping technique using corrugated cylindrical waveguides were studied. Longitudinal impedance values of HOM are presented for initial accelerating cavity and structure with waveguides.

INTRODUCTION

6 GeV Ultimate Source of Synchrotron Radiation is planned to be built in Russia. Storage ring scheme is based on the ESRF-EBS design [1-3]. For sources of synchrotron radiation, large values of beam currents are required. Excitation of Higher order modes (HOM) can lead to multi-bunch instabilities, emittance growth, beam breakup, etc. [4,5].

The general view of the accelerating cavity with an operating frequency of 357 MHz is shown in Fig. 1.

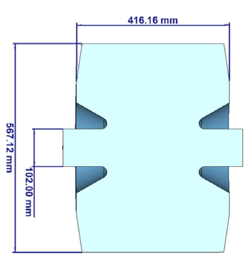

Figure 1: General view of an accelerating cavity at 357 MHz.

For an accelerating cavity the electrodynamic characteristics (EDC) [6] of the fundamental mode (Table 1) and HOM were carried out [7].

Table 1: EDC of Accelerating Cavity

EDC	Values
f, MHz	357
Q, $\times 10^3$	41
$R_{sh\ eff}$, MΩ	10

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The frequency dependence of the longitudinal shunt impedance for monopole HOMs is shown in Fig. 2.

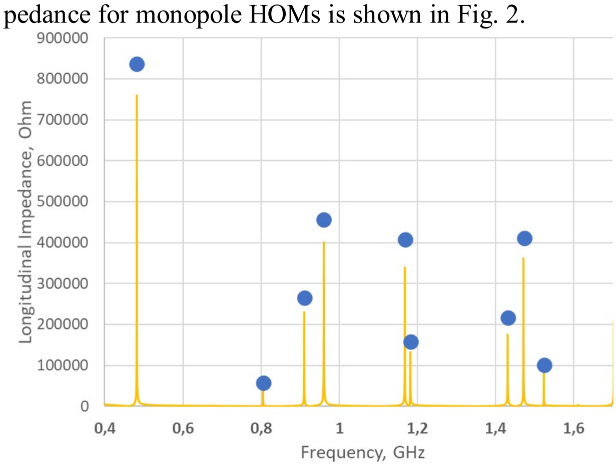

Figure 2: Frequency dependence of the longitudinal shunt impedance for monopole modes for an accelerating cavity at 357 MHz. Graph – result of wakefield simulations, dots – results of eigenmode simulations.

From Fig. 2 one could see that that the shunt impedance of parasitic HOMs accelerating cavity can reach values of up to 10^6 Ohm.

One of the requirements for EBS-ESRF cavity design was to ensure unconditional beam stability up to currents of 1000 mA. For EBS-ESRF longitudinal coupled bunch instability threshold at 200 mA is $R_{HOM} \cdot f_{HOM} = 16$ kW·GHz (Fig. 3) [4].

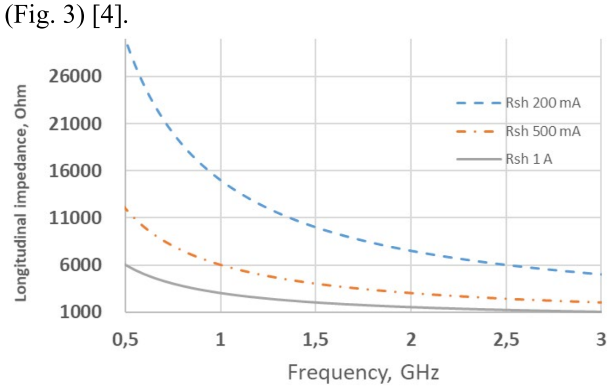

Figure 3: Threshold for longitudinal impedance necessary for unconditional beam stability for 200, 500 and 1000 mA beam current.

From Fig. 2 and 3 we can see that it is necessary to significantly decrease the shunt impedance values of HOMs. To reduce these values, it is proposed to add HOM couplers to the system.

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HOM DAMPING USING CORRUGATED WAVEGUIDES

As a baseline design for HOM damping it is proposed to use the design options applied in BESSY and ESRF (Fig. 4) [8]. This design assumes three corrugated waveguides for power output, located at an angle of 120 degrees with respect to each other. The presence of three waveguides is a prerequisite for damping all polarizations of higher order modes [9,10].

Figure 4: Accelerating cavity of the BESSY accelerator (left) and ESRF (right).

In such systems, dipole and parasitic monopole mode will excite an TE11-type mode in the waveguide (Fig. 5). The cutoff frequency should be above 357 MHz (to prevent fundamental mode damping) but below 442 MHz (first monopole frequency). The height of the corrugation ribs and the diameter of the waveguide will determine the cut-off frequency of the TE11 mode (the rest of the parameters have no significant effect on this parameter).

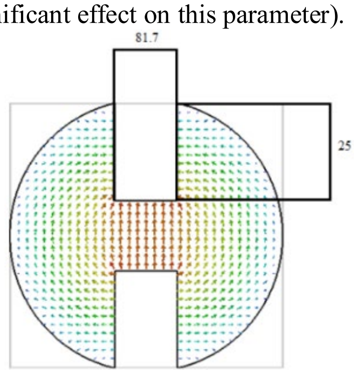

Figure 5: Distribution of TE11 mode electric field in a corrugated cylindrical waveguide.

The graph of the dependence of the cutoff frequency of the TE11 mode on the outer radius of the waveguide, as well as the height and width of the corrugation, is shown in Fig. 6.

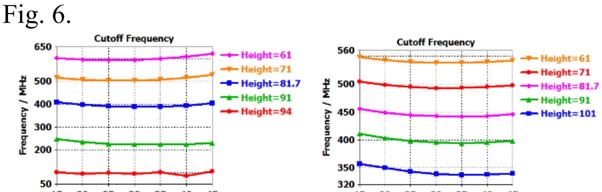

Figure 6: Dependence of the cutoff frequency of the TE11 mode on the outer radius of the waveguide, as well as the height and width of the corrugation.

The waveguide diameter is 220 mm, the corrugation height is 81.7 mm, and their thickness is 25 mm, since with these parameters the cutoff frequency is 437 MHz.

The lengths of the HOM dampers are dimensioned such that the non-propagating decaying fields at 357 MHz are sufficiently low at the HOM absorbers not to affect the quality factor of the accelerating mode (Fig. 7).

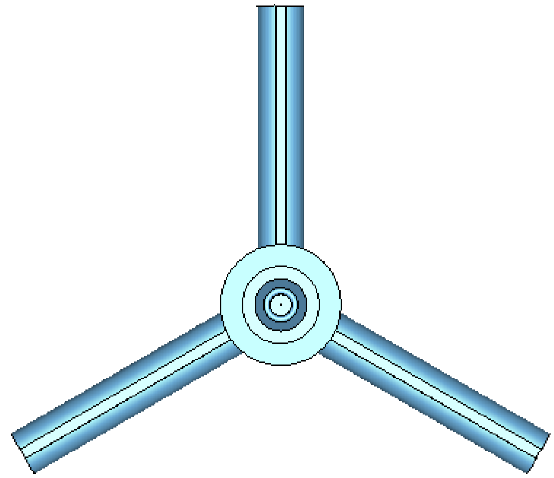

Figure 7: General view of an accelerating cavity with three HOM output devices.

The dependence of the longitudinal and transverse shunt impedance for monopole and transverse modes of oscillations on frequency for an accelerating cavity at 357 MHz with HOM waveguides and a comparison of the damping results are presented in Fig. 8.

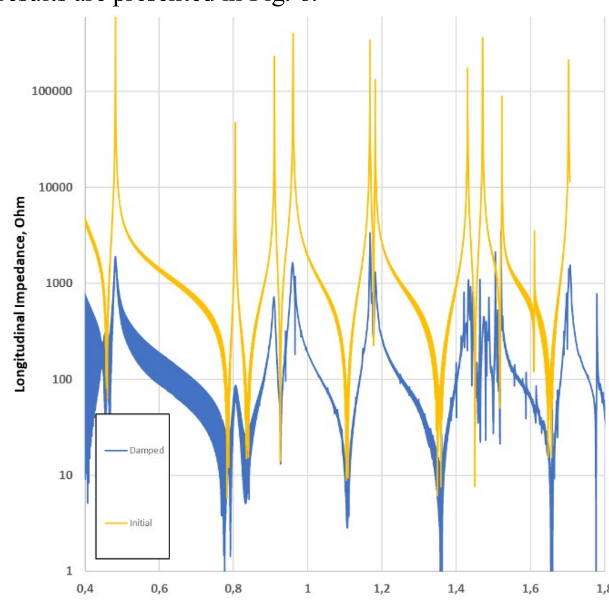

Figure 8: Comparison of the longitudinal shunt impedance for monopole HOMs for an initial accelerating cavity and with HOM waveguides.

From Fig. 8 we can see that longitudinal impedance values of HOMs were reduces by 2-3 orders of magnitude.

Comparison of longitudinal shunt impedance for monopole HOMs for accelerating cavity with HOM waveguides

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with threshold longitudinal shunt impedance values necessary for unconditional beam stability for 200, 500 and 1000 mA presented on Fig. 9.

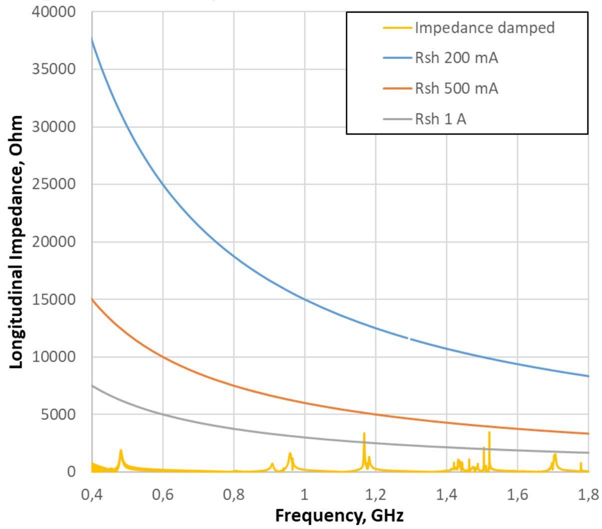

Figure 9: Longitudinal shunt impedance for monopole HOMs for accelerating cavity with HOM waveguides and threshold longitudinal shunt impedance values necessary for unconditional beam stability for 200, 500 and 1000 mA.

From Fig. 9 we can see that achieved impedance values satisfy conditions for unconditional beam stability for currents up to 500 mA. However, it is necessary to conduct further studies in order to achieve stability up to 1000 mA. Field distributions of HOMs that exceed 1000 mA threshold are presented on Fig. 10.

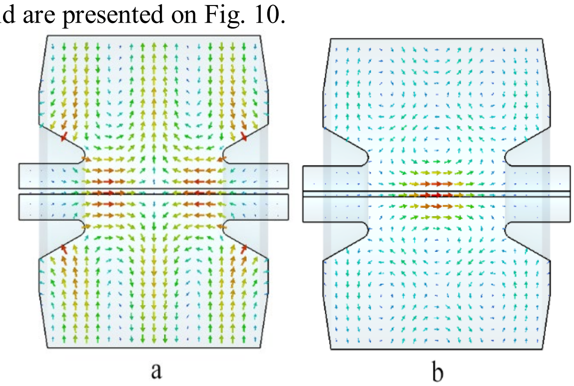

Figure 10: Electromagnetic field distribution of HOMs. (a) – 1168 MHz mode, (b) – 1528 MHz mode.

CONCLUSION

Achieved impedance values satisfy requirements for unconditional beam stability for currents up to 500 mA. However, it is necessary to conduct further studies in order to achieve stability up to 1000 mA. Further research is currently underway.

REFERENCES

[1] L. Hoummi *et al.*, “Optimization and error studies for the USSR HMBA lattice,” in Proc. IPAC’21, (Campinas, SP, Brazil), ser. International Particle Accelerator Conference, Aug. 2021, MOPAB224, pp. 730–733, doi:10.18429/JACoW-IPAC2021-MOPAB224.

[2] S.M. Polozov *et al.*, “Current Results of the 4th Generation Light Source USSR (Former SSRS4) Development”, presented at the *26th Russian Particle Accelerator Conf. (RUPAC'18)*, Protvino, Russia, Oct 2018, paper MOXMH04.

[3] T.A. Lozeeva, A.S. Fomichev, L.V. Grigorenko, T. Kulevoy, S.M. Polozov, and A.V. Samoshin, “Beam Dynamics Simulation for LINAC-100 - Heavy Ion "Driver" for DERICA Project”, presented at the *26th Russian Particle Accelerator Conf. (RUPAC'18),* Protvino, Russia, Oct 2018, paper WEPSB03.

[4] L. Farvacque, Ed., *EBS Storage Ring Technical Report*, 2018

[5] Ya.V. Shashkov *et al.* “Comparison of Higher Order Modes Damping Techniques for 800 MHz Single Cell Superconducting Cavities”, *Nucl. Instr. Meth.* A, v. 767, p 271–280, 2014.

[6] N.Sobenin and B.Zverev, “Electrodynamic Characteristics of Accelerating Cavities”, Foundation for International Scientific and Education Cooperation. Gordon and Breach Science Publishers S.A. 1999.

[7] S.V. Matsievskiy *et al.,* “Preliminary calculation of the power coupler for the SYLA storage ring RF cavity”, presented at the 27th Russian Particle Accelerator Conference (RuPAC 2021), September 2021, paper WEPSC12, this conference.

[8] E. Weihreter, “Status of the European HOM Damped Normal Conducting Cavity”, in *Proc. 11th European Particle Accelerator Conf. (EPAC'08),* Genoa, Italy, Jun. 2008, paper THXM03, pp. 2932-2936.

[9] Ya.V. Shashkov *et al*., “Suppression of higher order modes in an array of cavities using waveguides”, *Journal of Physics: Conference Series,* Volume 74, p. 116-123, 2016.

[10] Ya. V. Shashkov, A.A. Mitrofanov, N.P. Sobenin, V.L. Zvyagintsev, “Analysis of higher order modes damping techniques in 9 cell cavity with modified drift tubes”, *Journal of Physics: Conference Series,* Volume 74, p. 124-131.