Higher Order Mode Damping System in the UNK RF Cavity.

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I. INTRODUCTION

The accelerating structure of the UNK consists of two cavities, working at 200 MHz and fed by an RF power generator via a 3dB hybrid [1]. The UNK bunched proton beam will have an extremely high intensity ($6 \cdot 10^{14} ppp$) and therefore the problem of acceleration stability is a paramount one. One of the causes of instability is known to be higher order modes (HOM) excited by the beam itself in the accelerating structure. In order to eliminate the beam instability the HOM coupling impedances must be reduced to a certain threshold level. A threshold value of the coupling impedance for the first ring of the UNK is $Z_c/n = 6 - 16\ \Omega$ [2] (the first ring contains 16 accelerating cavities). Here n is the HOM frequency - revolution frequency ratio. In this report the damping system reducing the cavity HOM impedances to the threshold level is described.

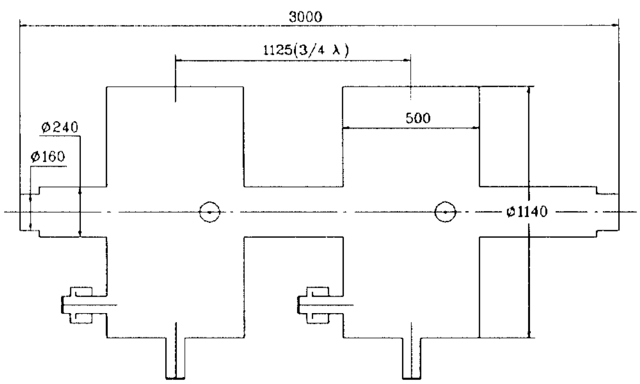

Figure 1: RF unit geometry

For the accelerating system of the UNK the cylinder-shaped single-cell cavity was chosen as the simplest in production and analysis of HOM, e.g. identification, computations (see fig.1). The beam-tube diameter of the cavities is fairly large, 240 mm. As a result, the number of the HOM localized in the cavity are limited and there is the possibility to suppress a HOM propagated in the beam-tube by special ferrite absorbers. The parameters of an azimuthal-homogeneous E modes were calculated with the help of the standard code PRUD-0 [3] in the frequency range to 1500 MHz that is cutoff frequency for 160 mm OD vacuum chamber. For each mode the following parameters were computed: frequency, shunt impedance Rs, Q-factor, transit-time factor T (max. value), the longitudinal coupling impedance:

$$Zc = Rs \cdot T^2$$

The analysis of the computations shows that in this frequency range the accelerating structure has about 15 modes whose coupling impedance exceeds the threshold values. Some modes require a high degree of damping, e.g. E_{011} by 120 times, E_{021} by 70 times, and E_{022} by 30 times, etc. Accordingly, a high coupling between the absorbers and the HOM fields and a high cutoff of the fundamental mode are needed.

II. DESIGN OF MODE DAMPERS

Each cavity has three suppressors, one placed on the plate and two others on the shell(see fig.1) . Each suppressor has a coupling probe.

On the plane wall a "rejection" damper is placed (see fig.2a) [4]. It is coupled with all E modes, but it is needed primarily to suppress HOM which do not have field variations over the cavity length (E_{ono} modes).

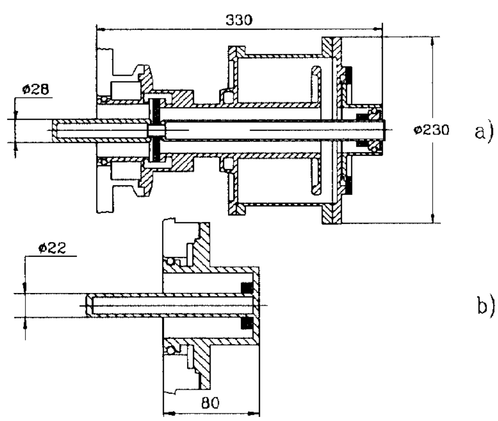

Figure 2: Rejection(a) and radial(b) dampers

To cut off the current of the fundamental frequency, the coaxial cavity loaded on the capacity is used. The fundamental frequency attenuation is about 60 dB whereas in the bandwidth for HOM it does not exceed 2 dB.

The RF loss in this damper on the fundamental frequency is about 500 W, that is less than 2% of the total loss in the accelerating cavity. About 50% of it dissipates

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in the coupling probe, 30% - in the coaxial cavity and the remaining in the coaxial line and ceramic window.

The coupling probe and central conductor of the line are cooled by water. The gap voltage of the coaxial cavity is about 6 kV under an accelerating voltage 0.8 MV.

Two other suppressors coupled with the radial field component of HOM are placed on the cylindrical shell of the cavity. One of them is placed in the middle and another one at a quarter of the cavity length from the plate. This arrangement allows one to achieve the maximum coupling with the HOM having a different number of fields variations over the length. In order to dump the dipole (φ-dependence) modes, these suppressors are shifted by 90^0 in the azimuth. The coupling between "radial" dampers and the fundamental mode field is almost absent. Therefore these dampers contain only coaxial line terminating with a matched load (see fig.2b). The RF loss depends on the eddy currents of the fundamental frequency in the coupling probe and is about 200 W. The probe is cooled by water.

The absorbing load in each damper is a ferrite ring. VSWR of such loads does not exceed 2 in the 300-1500 MHz frequency range.

In the damped structure almost the whole power at HOM frequency dissipates in the damper loads. Because of a great difference between the frequencies of HOM and RF harmonics of the beam currents ($f_k = 200 \cdot k, k = 1, 2, \dots$) this loss is not greater than several Watts.

III. MEASUREMENTS

In a frequency range of 300-1500 MHz the azimuthal-homogeneous E-modes with the E-field longitudinal component on the axis were investigated.

Higher-order mode resonances were computed by the PRUD-0 [3] code and then identified using a perturbation method. These experiments include a comparison of the computed and measured distributions of HOM E - field longitudinal components and R_s/Q values accordingly. The measured R_s/Q values coincide with computed ones to an accuracy of 10-15%. Then the influence of all three dampers on the HOM was determined. The damping degree of each mode was estimated by comparing their Q-factors with and without dampers. In this experiment we assumed R_s/Q to be constant and the coupling impedance to be defined by the formula

$$Z_c = (\frac{R_s}{Q}) \cdot Q T^2$$

The results of the damping are shown by the diagram in fig.3, where the frequency dependence of the threshold impedance for one cavity [2] is shown by the dashed line. It is seen that all HOM in this frequency range are damped to the degree required.

The possibility of damping HOM by means of the absorber placed in the beam-tube is investigated too. Ferrite rings were placed in the beam-tube at a rather long distance from the cavity so that the fundamental mode has no additional loss. This experiment showed that this method provides the required reduction impedances of the majority of HOM modes in a frequency range of 960-1500 MHz.

IV. CONCLUSIONS.

The performed measurements showed the possibility of using 3 dampers on each accelerating cavity for reducing the HOM coupling impedances to a threshold level of 300-1500 MHz. If required, the damping degree can be increased by optimizing the shape and dimensions of the coupling probe. HOM the frequency range 960-1500 MHz are damped effectively by the ferrite absorber placed in the beam-tube.

V. REFERENCES

[1] Katalev V.V. et al. The 200 MHz Accelerating Structure for the UNK. EPAC, 1992, Vol.2, p.1197.

[2] Balbekov V.I.,Ivanov S.V. Atomnaya Energiya, 1986, V.60, N1, p.45-51.

[3] Abramov A.G et al. PRUD0 Program Package for Computing Accelerating Structures, Preprint IHEP 83-3.

[4] Shembel B.K. et al. Authors Certificate 984077, 1981, USSR.

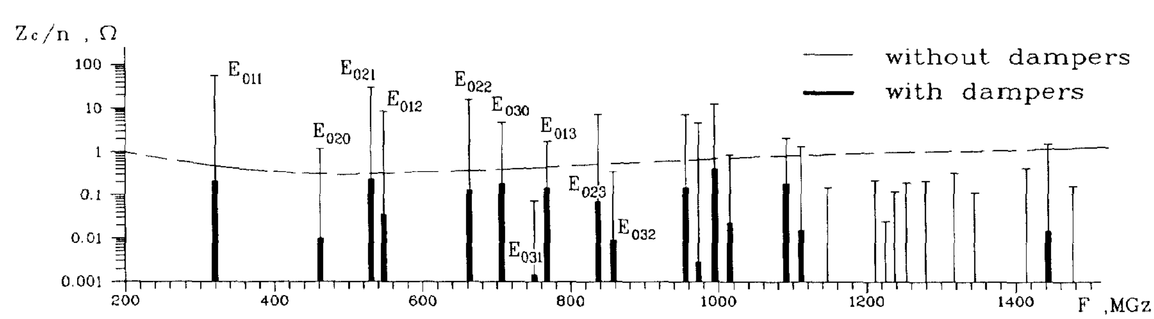

Figure 3: HOM coupling impedances