SINGLE MODE RF CAVITY FOR VEPP-2000 STORAGE RING BASED COLLIDER

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Abstract

Accelerating cavity 172 MHz with strong damped higher-order modes (HOM) for VEPP-2000 electron-positron collider have been made in Novosibirsk. Resonance frequencies and Q values of cavity HOMs are measured and analyzed. Most of HOMs has Q values less than 100. We compare these results with numerical calculations of HOM.

INTRODUCTION

The VEPP-2000 is a storage ring based e^+e^- collider designed for a target luminosity of $1\cdot10^{32}$ $cm^{-2}s^{-1}$ at the c.m. energy of 2000 MeV [1]. To get the required luminosity both e^- and e^+ high current beam values (2×100 mA) of a single bunches are foreseen.

A charged particle beam is a source of e.m. fields that are excited in the surrounding vacuum chamber of the storage ring. Higher-order modes (HOM) in the RF cavities and resonant modes, trapped in any discontinuities of the pipe cross-section, can drive coupled bunch instabilities and limit the ultimate luminosity.

To prevent the instabilities one should find a combination of conditions such that the net wake force is stabilizing, rather than destabilizing. Typically, this is done by adjusting the frequencies of HOM relative to the harmonics of revolution frequency. We take the cardinal solution – perfectly damping of all HOM in the whole frequency range of the bunch spectrum. Here only single (fundamental) mode yield for its frequency adjusting has been left. Such damping has been obtained by using two special HOM loads made from poorly current-conducting ceramics.

Numerical calculations of HOM coupling impedance was done with CLANS [2] and CLANS2 [3] codes. It is able to model devices containing dispersive materials. CLANS solves the Maxwell equations in the frequency domain on a finite-difference rectangular mesh. The device must be axisymmetric. Both the longitudinal and transverse impedances have been calculated. Materials with complex permeability μ and permittivity ε can be put by a table for each frequencies, usually for the harmonics of revolution frequency and for its side frequencies of coherent synchrotron oscillations. The codes hands either a list of complex coupling impedances on each table frequencies or solution of a complex eigenvalue problem (trapped modes so on).

The e.m. interaction between the beam and RF cavity HOM is studied with MBI cod [4, 5] which calculates longitudinal and transversal current thresholds for the microwave instability. This code is compatible for previous one, uses its list of coupling impedances and storage ring parameters. The calculation has predicted longitudinal and transversal current thresholds as 2×200 mA - in twice large then required.

CAVITY DESIGN

The cavity is made as a half-wave section of a coaxial line (see fig.1). It consists of two coaxial lines, one inserted to in other. Such unusual form of the cavity is made with the purpose of shortening of its length on space of 92 см. Furthermore it transforms the voltage of accelerating gap (120 kV) to the choke gap as 3:1.

At the one cavity side, where the accelerating gap is placed, a large diameter beam pipe having the cutoff frequency of 1200 MHz is connected. A part of the monopole and dipole HOMs being above the cutoff frequencies propagates into the beam tube via waveguide modes. To produce a low *Q* in the propagating modes, a section of beam tube with a set of microwave-absorbing ceramic elements (waveguide HOM load) is placed nearby.

At the other cavity side the choke filter (having 6.5 mm gap) prevents the leakage of RF power of fundamental frequency to second (coaxial) HOM load. The monopole and dipole HOMs freely passes the choke and then dissipates in coaxial HOM load.

The resonant frequency of Choke is adjusted by tuners in a range of ±150 кГц. For this purpose the internal cavity part can slide on ball-bearings and can be moved by a reducer in an axial direction within of ±2.5 mm. Large diameter bellow connects it with the cavity body. The filter is adjusted by three rods (symmetrically disposed around of cavity axis). The length of rods can be changed by heating (within of ±20ºC), it changes the 6.5 mm gap of the filter within of ±0.05 mm.

The main cavity characteristics are shown in table 1.

Table 1: Cavity RF fundamental mode characteristics.

Frequency, MHz	172.09
Accelerating voltage, kV	120
RF input power, kW	60
Unloaded quality factor	8194
Shunt impedance, kOhm	230

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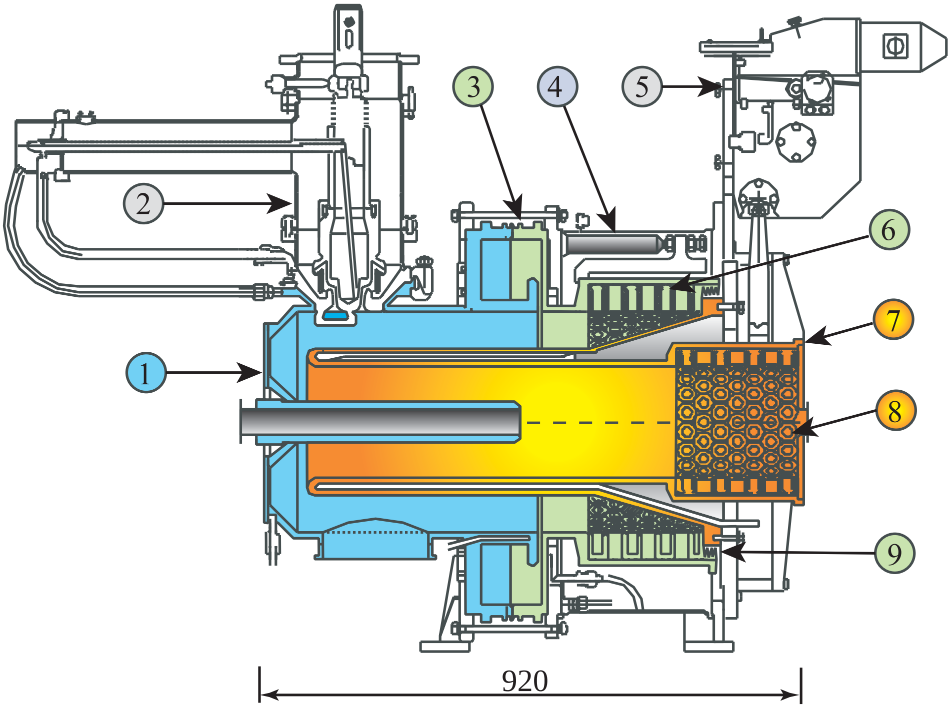

Figure 1**:** Sketch of VEPP-2000 cavity: 1-Left side of cavity, 2- Power input, 3-Choke filter with a flexible right wall, 4-Thermal adjuster, 5-Mechanical adjuster, 6-Coaxial HOM load, 7-Internal cavity part moved by mechanical adjuster, 8- Waveguide HOM load, 9- Bellow (color picture).

HOM loads

The damping scheme developed for the VEPP-2000 cavity uses two different HOM loads, one is waveguide load and other is coaxial load. Those HOM modes which are being trapped for one load, are being damped in other load.

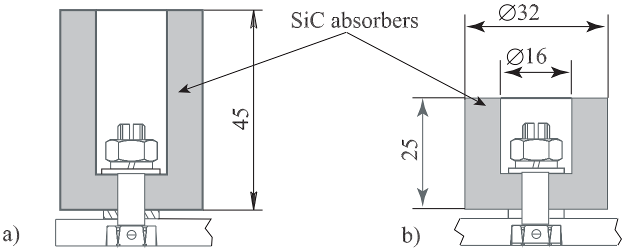

Figure 2: View of ceramic elements what HOM loads consists from, a) for coaxial HOM load, b) for waveguide HOM load.

The poorly conducting ceramics (KT-30) produced in Russia is used for loads material. It has a volume conductivity 1.67 $\mathrm{Ohm}^{-1}\cdot\mathrm{m}^{-1}$ and dielectric constant 15. The thermal conductivity (of 5 $\mathrm{W}\cdot\mathrm{m}^{-1}\cdot\mathrm{K}^{-1}$) is perfectly sufficient for the loads if to take into account, that the full damped HOM power does not exceed 150÷200 W. The loads consist of separate elements as is shown in figure 2. Total number of elements in both loads is 400. Each element is fixed inside the water-cooled cylinder by a bolted connection, as shown in a fig. 3.

Average density of load material is twice less after the free space between the elements. It was meant in numerical simulations, that the loads are continuous, so magnitude of conductivity and permeability also are accepted twice less.

Figure 3: Coaxial load during assembly (color picture).

Choke Filter close to Fundamental Frequency

In order to prevent RF power leakage to the coaxial load, the choke with R_{shunt}=73 kOhm is applied. In coaxial load having resistance of 8 Ohms if the frequencies of the cavity and filter are adjusted equally the power of 1 Watt dissipates. If these frequencies are unadjusted on ±100 kHz, only 150 Watts dissipates (the filter pass-band is 16 kHz). Measured ratio between a maximum H field in the cavity and H field behind of the filter (70 db) and cavity quality (Q=8194) well agree with the calculations.

HOM MEASUREMENT

In the first HOM measurement with a network analyzer, the HOM spectrum is obtained in the frequency band up to 4000 MHz (see fig.4). Antenna type field probes mounted in both beam tubes close to the cavity axis (and also the main power input) were used for this purpose.

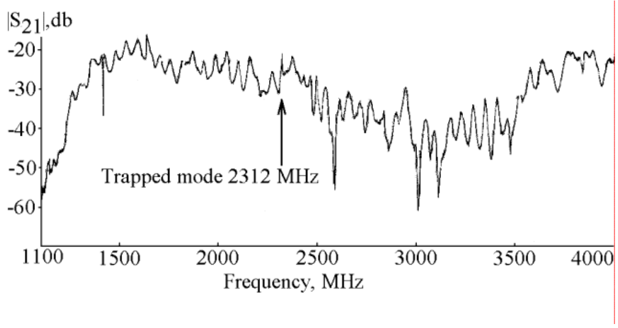

Figure 4: Measured HOM spectra of VEPP-2000 cavity.

The measured signal clearly shows the cutoff of the beam pipe waveguide at 1200 MHz. There are a difficulty in finding low Q modes (Q<100). Their peaks are very wide; they overlap and actually form a common background.

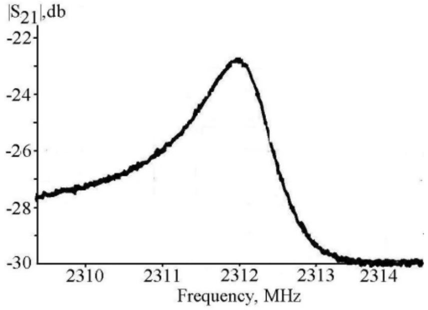

Figure 5: The view of trapped mode scaled from fig.4.

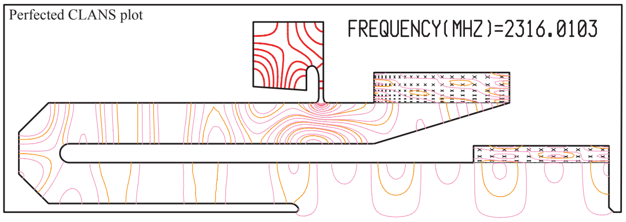

Figure 6: The trapped mode having Q=2063 and R/Q=0.0458 Ohm predicted by calculation (color picture).

Only one relatively high Q mode with measured Q=1777, that was predicted by calculation [6], was actually found here (see fig.5, 6). As calculation with MBI code has shown, it does not any influence on stability of phase motion in the storage ring perfectly, because of its low (81 Ohm) coupling impedance.

Other some relatively high Q modes (Q~500) that were predicted by calculations were not found. Apparently, it was due to very low field level in the antenna probe area for those trapped modes.

SUMMARY

The first measurements of the new cavity with strong damping of HOM have shown the correctness of the numerical simulations and of applied codes. It also has confirmed a high performance of HOM damping by two different loads, and justified application of poorly conducting ceramics for this purpose. At the same time it has assured us in reliability of operation of a new type of the accelerating cavity combined with choke filter.

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