RF Cavity for the Medium Energy Booster for SSCL

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Abstract

The RF cavity for the Medium Energy Booster (MEB) is required to accept beam from the low energy booster (LEB) at a momentum of 12 GeV/c (possibly 10 GeV/c) and accelerate it to 200 GeV/c. Each cavity must provide a maximum gap voltage of 250 kV, and must be tunable from 59.7 MHz to 59.96 MHz with a maximum sweep rate of 450 kHz/s. This requires a ferrite-tuned cavity with a high quality factor. A quarter-wave cavity was designed which meets these requirements while minimizing beam-loading problems (minimizes R/Q). This paper describes the design of this cavity, results from measurements of a corresponding cold model, and several proposed Higher Order Mode (HOM) damping system designs.

I. INTRODUCTION

During each accelerating cycle the RF system of the MEB must overcome heavy static and dynamic beam loading effects. These effects are most pronounced in the high current mode of operation of the MEB, when the dc component of the beam current reaches 500 mA. Difficulty in achieving acceptable beam-dynamic phase, and amplitude stability of the gap voltage at this current required careful design of the RF system. The calculations and the simulations show that it will be necessary to cancel bunch-to-bunch beam loading. Both feedforward and fast-feedback systems will be required to accomplish this. The growth rate of the couple bunch mode instabilities for the existing lattice and the accelerating scenario depends on the frequencies, R/Q values, and shunt impedances of the HOM spectrum. Low R/Q values of the HOM is been achieved by shaping the inner and outer conductors of the cavity in the accelerating gap region. Shunt impedances of the parasitic resonances will be lowered by applying HOM dampers (two types of HOM dampers are being considered for use and will be discussed in Section 4). The power amplifier using a 4CW150000 EIMAC tetrode will be mounted on the top of the cavity and capacitively coupled via a 14 pF capacity. The cavity will be tuned with an off-axis, conductively-coupled tuner. The tuner will employ perpendicular biasing of annular, yttrium-iron garnet rings for its tuning.

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II. MECHANICAL DESIGN

As shown in Figure 1 the cavity is a simple, quarter-wave structure. Except for the stainless steel beam pipe it will be made from oxygen free copper.

The maximum power density in the inner conductor of the cavity will reach 8 W/cm^2, so the cooling system of this unit has been carefully designed. The cross-section of the inner conductor is shown in Figure 2. The copper cooling tubes will be brazed in place between the inner conductor and the supporting tube. The outer conductor of the cavity will be cooled by 3/8 inch copper cooling tubing soldered to its outer skin.

Power dissipated in the power tube section is only few hundred watts and should therefore require no additional cooling. The vacuum window in this already-fabricated section is made from Rexolite 2200 (Q_e = 2000 @ 10 MHz).

A prototype of the cavity is being built for us by INP (Novosibirsk, Russia), and will be delivered to SSC by the end of August 1993. The nearly-complete tuner design is similar to that of the LEB cavity except the tuner is off axis rather than on axis. The magnet core is mechanically isolated from the tuner housing and is independently attached to the supporting frame of the cavity. Two ferrite rings with an inner diameter of 10 cm and an outer diameter of 16 cm are epoxied to the copper walls of the tuner shell. A one cm thick Rexolite 2200 spacer holds the ferrite rings apart. The vacuum window is made out of 99.8% pure Alumina. The power dissipated in the tuner will be about 8.5 kW.

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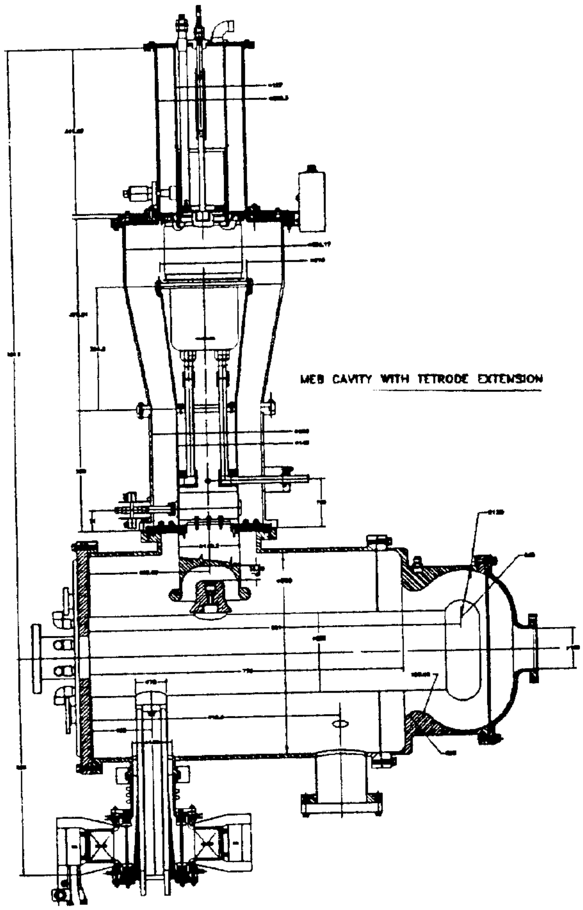

Figure 1. MEB RF cavity.

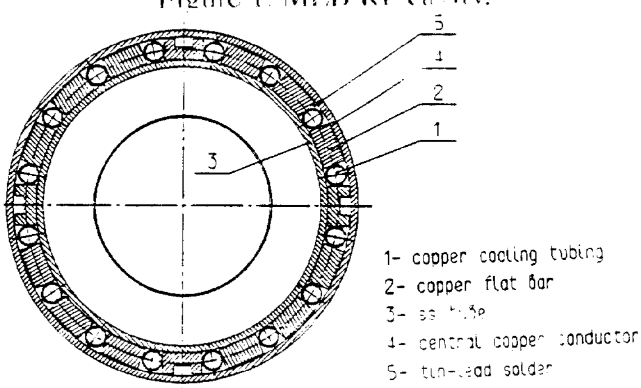

Figure 2. Cross section of the inner conductor.

III. ELECTRICAL DESIGN

A.Cavity

The maximum gap voltage in the MEB cavity in the presence of the high power feedforward system is limited to 250 kV by the power dissipated on the anode of the power tube (4CW150000 tetrode). The final dimensions of the cavity were determined based on calculations (Superfish and MAFIA), and the cold model measurements. The maximum electric field in the accelerating gap region will be 67 kV/cm, the shunt impedance at the fundamental frequency will be 650 kΩ and R/Q 51 Ω. Total power dissipation in the cavity including the tuner and tube sections was estimated using Mafia to be 48 kW. The actual value will likely be 10-15% larger due to imperfect surface finishes and the resistance of the RF joints.

B. Power tube section

The power amplifier configuration for the MEB cavity will be similar to that used in the LEB. For a large-gain, fast-feedback system this configuration is optimum. If we use a long transmission line system to feed power to the cavity, stability could be effected by transmission line resonances. Sudden changes of the dc component of the tube current creates oscillations of the anode network at its natural resonant frequencies (feedforward system creates this problem). The most important of these is the lowest one, the frequency of which is determined mainly by the rf choke inductance, output capacity of the power tube, and the coupling capacity. The amplitude of this effect is determined by the characteristic impedance of the parasitic resonance and the tube current. By decreasing the self inductance of the rf choke we can decrease the amplitude of this phenomenon. SABER simulations show the optimum value of the RF choke inductance to be about 150 nH (choke placed in the voltage node). The gap- to-anode voltage transformation ratio was chosen to be 14 (coupling capacity ~ 14 pF).

C. Tuner

The total power dissipated in the tuner at 250 kV continuous wave (CW) will be about 8.5 kW. The tuner has been carefully designed in order to avoid the multipactoring problems and to minimize electrical stresses. The Poisson software was used to determine the main parameters of the tuner magnet. The main parameters of the tuner are given in Tab.

TABLE 1.

MEB Tuner Parameters

MAGNETIC PERMEABILITY AT	59.96 MHz		1.4
MAGNETIC PERMEABILITY AT	59.7 MHz		3.0
TUNER REACTANCE AT	59.96 MHz	[OHM]	32.4
TUNER REACTANCE AT	59.7 MHz	[OHM]	38.1
POWER LOSSES IN COPPER	59.96 MHz	[kW]	8.2
LOSSES IN THE FERRITE	59.96 MHz	[kW]	0.3
VACUUM WINDOW VOLTAGE	59.96 MHz	[kV]	13.2
MAX. E-FIELD ON WINDOW	59.96 MHz	[kV/cm]	2.3
VOLUME OF FERRITE		[dcm3]	3.0
NUMBERS OF AMPERE-TURNS			12000
MAXIMUM CURRENT		[A]	300
COIL RESISTANCE		[mOHM]	27
DC POWER		[kW]	2.4

VI. HOM DAMPERS

A simple, aluminum, cold model of the MEB cavity has been built with three main purposes:

a. Determination final dimensions MEB cavity.

b. Determination of the HOM frequencies and their R/Q values

c. Testing different types of HOM dampers.

The cold model is shown in Figure 3. The measured and calculated (MAFIA-3D code) longitudinal modes are given in Table 2. Simple non-inductive resistors connected at the voltage node in the tube section of the cavity provide a very effective HOM damping tool. Two 50 W carbon resistors have been used in our cold model (see Figure 3). All longitudinal modes except those with the frequencies near multiples of 500 MHz were damped to less than 300 Ω. For high power operation it will be necessary to isolate the d.c. voltage and the fundamental frequency using blocking capacitor and a band stop filter.

Also being considered is a variation of the coupled line damper that has been investigated at TRIUMF[2]. For the MEB cavity the damper is located at the rear of the cavity as is shown in Figure 4. Inductive tuning provided by the short-circuited transmission line is used to minimize the voltage developed on the damping resistor at the fundamental frequency.

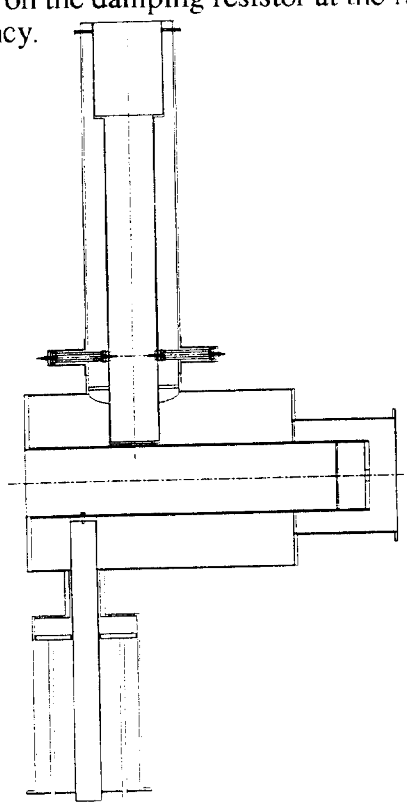

Figure 3. Cold model of the MEB cavity

Table 2.
Measured and calculated longitudinal modes of the MEB cavity.

LONGITUDINAL MODES

	MAFIA RESULTS				COLD MODEL MEASUREMENTS			
MODE NR.	F [MHz]	Rsh [kOHM]	Qo [ ]	R/Q [OHM]	F [MHz]	Rsh [kOHM]	Qo [ ]	R/Q [OHM]
1	60.0	650	12750	51	60.0	285	5600	51
2	93.0	14	9600	1.4	91.8	3.1	1100	2.8
3	168.0	53	12800	4.2	163.8	8.8	2000	4.4
4	183.4	12	11400	1	179.6	1	1000	1
5	230.0	47	15800	3	246.8	3.5	1060	3.3
6	292.2	74	22400	3.3	298.5	2.3	880	2.6
7	357.3	47	25600	1.9	369.3	4.2	2500	1.7
8	392.6	135	21500	6.3	395.8	3	630	4.8
9	459.3	95	23400	4.1	420.0	1.6	400	4
10	471.4	16	14100	1.2	470.0	1.2	480	2.5
11	491.5	164	22650	7.2	509.6	14.6	1350	10.8
12	561.8	7	11700	0.6	544.6	0.6	230	2.6
13	597.8	53	33300	1.6	569.0	0.7	780	0.9
14	611.4	9	16000	0.6	611.0	0.8	800	1

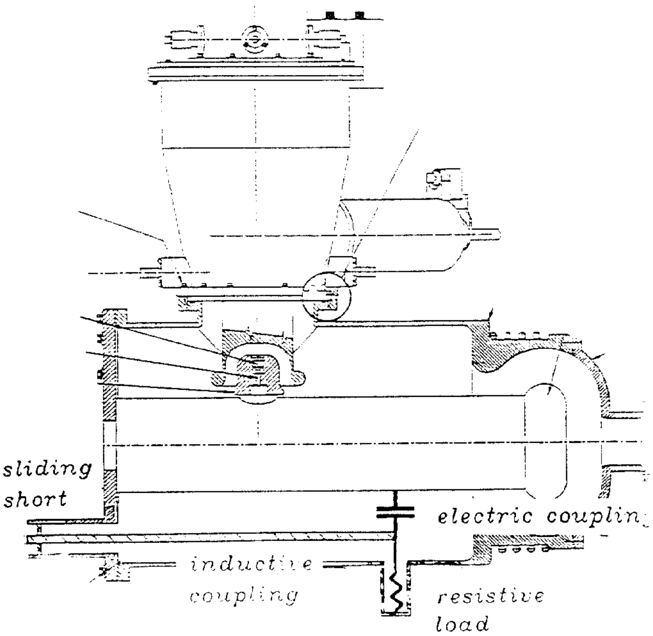

Figure.4 Coupled Line HOM Damper.

V. CONCLUSIONS

The mechanical and electrical designs for the MEB cavity have been discussed. The main body of the cavity is currently being fabricated and the tuner should be completed in December, 1993

VI. REFERENCES

[1] S.Kwiatkowski, "MEB cavity and power amplifier" KAON/SSCL Workshop, March 4-5, 1993

[2] T.A. Enegren, "Coupled Transmission Line Higher Mode Damper." TRIUMF design note TRI-DN-89-K105, June, 1990