CONSTRUCTION of an RF CAVITY for the LNLS SYNCHROTRON

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Abstract

A construction program for an RF cavity for the LNLS storage ring is under development. The cavity main frequency is 476 MHz, and should operate with 60 kW CW. The cavity design is based on the development made for the proposed PEP II B factory[1]. Special wave guide dampers are used in order to reduce HOM instabilities. In order to get the precise mechanical dimensions of the 476 MHz cavity, a scalled prototype (approximately 1200 MHz) was built based on the results of numerical simulation. Low power tests were used to fully characterize the HOM spectrum. Using the measured values, couple-bunch instabilities are studied.

I. INTRODUCTION

The synchrotron light source under construction at the LNLS requires an RF system operating with a CW RF power of 56 kW at the input coupler of the cavity. Construction of the RF transmitter, coaxial and wave line system and cavity control system has been completed. A 3 cell RF cavity resonating at 499 MHz is available at the LNLS. Different tests performed with this cavity however indicated that it would be desirable to develop a new one that should include several improvements. The new cavity's main characteristics should be:

- Fundamental frequency: 476 MHz (linac sub-harmonic).
- 60 kW CW.
- Single cell.
- Standard conflat vacuum seals.
- 500 kV gap voltage.
- Coupling factor: 1.4
- Tuning range: ± 150 kHz.

II. CAVITY DESIGN

The cavity geometry is similar to that proposed for the PEP II B factory [1]. It is a reentrant type cavity with 3 ports located around the equatorial plane to accommodate for a mechanical tuner, a 45 dB RF monitor and an RF input aperture coupler. Three wave guides, symmetrically located around the axis, are used to damp the HOM. The wave guide is dimensioned so that the fundamental frequency is about 200 MHz below cut off. Figure 1 gives a general view of the cavity.

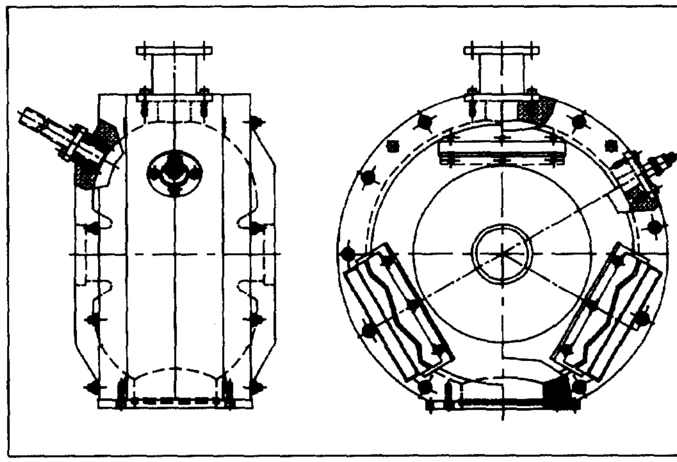

FIG 1
Schematic design of the RF cavity.

Considering the cavity's narrow range of tuning, the final shape, after assembling all ports and couplers, should give a fundamental resonant frequency within $2\ 10^{-4}$ of the desired value. Thus it was decided to construct a small model with a fundamental frequency at 1200 MHz, 2.5 times smaller. Dimensional measurements were performed on the constructed model. Also measurement of the resonant frequency, coupling factor and other parameters was done with the model. Finally the exact scaling geometrical factor for the real-size prototype was determined. A prototype, made of aluminum is shown in Figure 2. The picture shows the 3 damping wave guides with adjustable broad band loads inside, a step motor driven-plunger, an RF monitor and the wave guide coupler that communicates with the cavity through a ceramic disk located some distance away from the cavity's standing wave fields. The fundamental frequency was measured to be 476 MHz at room temperature and normal pressure. The plunger's tuning range is 350 kHz, enough to compensate for the frequency shift due to vacuum, cavity operating temperature and beam loading.

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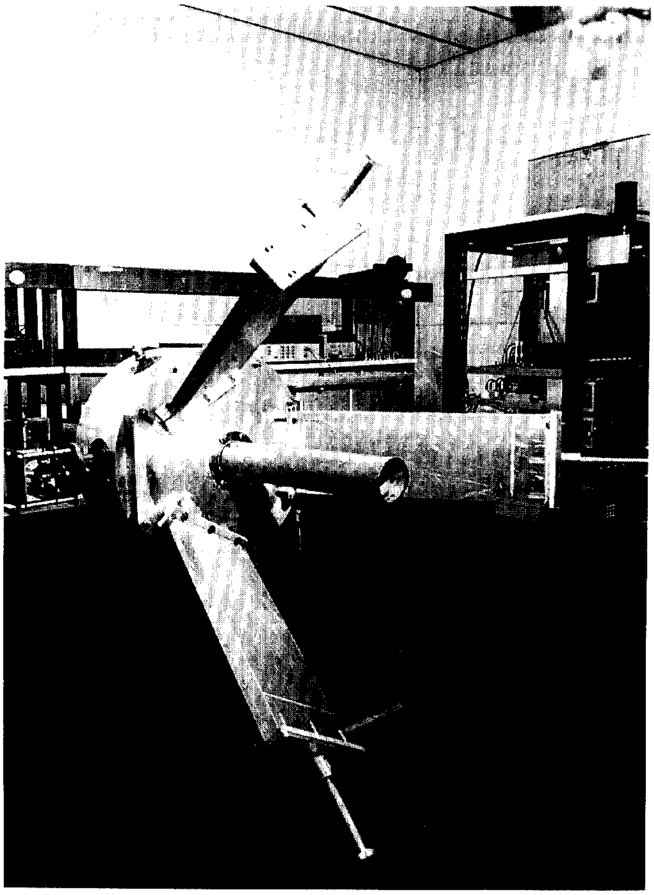

FIG 2

III. HOM CONFIGURATION

HOM were calculated using URMEL-T code[2]. In multibunch instabilities study, monopole and dipole modes are the most interesting. In order to identify these modes a computer simulation of the aluminum cavity was performed using URMEL-T code. Table 1 gives the result of the calculation up to the beam pipes cut off frequency.

TM MONOPOLE MODES			
Mode	Freq.(MHz)	Q	R/Q ($M\Omega$)
0-EE-1	484.2	37600	110.8
0-ME-1	763.6	32600	47.5
0-EE-2	1003.9	33700	0.9E-5
0-EE-3	1275.3	73000	7.69
0-ME-2	1282.9	33200	7.02
0-EE-4	1564.5	34500	6.68
0-ME-3	1693.5	69000	3.30
0-EE-5	1798.5	87000	.85E-1
0-ME-4	1869.2	36700	3.32
0-EE-6	2075.3	52000	0.74
0-ME-5	2136.7	67000	O.12
0-EE-7	2224.6	47000	1.27
0-EE-8	2331.4	71000	2.37

DIPOLE MODES			
Mode	Freq.(MHz)	Q	R/Q $M\Omega/m$
1-ME-1	670.9	38500	.28E-3
1-EE-1	785.7	48600	15.2
1-ME-2	1055,1	40600	27.1
1-EE-2	1121.5	40900	0.25
1-ME-3	1190.4	73000	0.32
1-EE-3	1301.9	42000	5.64
1-ME-4	1421.1	32200	2.74
1-EE-4	1521.9	82000	1.05
1-EE-5	1575.0	68400	1.42
1-EE-6	1667.6	31000	6.17
1-ME-5	1701.5	59900	.21E-1
1-ME-6	1745.4	82500	.73E-1
1-ME-7	1913.6	38800	.97E-1
1-ME-8	1947.3	56000	1.49
1-ME-9	2001.7	71600	2.00
1-EE-7	2048.4	78900	.25E-2
1-EE-8	2057.5	101100	.68E-1
1-EE-9	2152.2	56400	.31E-1
1-EE10	2223.7	36600	.17E-1
1-ME10	2296.1	93900	.31E-2
1-EE11	2371.9	88700	0.39
1-EE12	2388.3	86600	1.00

TABLE 1

IV.HOM MEASUREMENTS

Different measurements of the HOM spectrum were performed using several antennas at different locations in order to correctly identify the resonances. The cavity modes were first measured with all ports closed and Q_0 was determined. This allowed a comparison to be made with the theoretical values. Next, the ceramic window, all 3 damping wave guides and the tuner were mounted and mode parameters were measured for different plunger positions. The results are condensed in table 2. Six columns of the table show the measured frequency and Q value for 3 different positions of the plunger: maximum, middle and minimum course with the 3 loaded wave guides, the wave guide coupler and 2 pipes simulating the vacuum chamber. It can be noticed that for the fundamental mode there is a 20% decrease in the value of Q when the wave guide couplers are added. The Q expected for a copper cavity properly machined and brased should go up to about 30000. The reduction in Q is much stronger for all HOM, showing the strong damping effect produced by the wave guides. A study of multibunch stability was performed using ZAP[3] for the parameters given in table 2 and a beam energy and current of 1.15 GeV, 200 mA. The results are shown in the last column of table 2, which gives the ratio of the growth time of instability for the mode relative to the synchrotron damping time for the longitudinal modes and betatron damping time for the transverse dipole modes.

TM MONOPOLE MODES

Mode	Closed cavity		Cavity with dampers Plunger position						relat. growth
			out		middle		in		
	Freq.	Q_0	Freq.	Q	Freq.	Q	Freq.	Q	
0-EE-1	481.7	20000			476.1	15500			
0-ME-1	760.8	18100	--	--	--	--	--	--	--
0-EE-2	--	--	--	--	--	--	--	--	--
0-EE-3	1270.9	31900	--	--	--	--	--	--	--
0-ME-2	1281.6	5800	1280.5	450	1279.9	500	1277.5	680	0.37
0-EE-4	1558.4	14100	1566.0	200	--	--	--	--	0.51
0-ME-3	1691.0	11200	1685	200	1684.8	200	1683.8	250	0.97
0-EE-5	1798.3	37400	1797.2	200	1798	150	1798.4	500	37.8
0-ME-4	1863.9	4200	1867.3	300	1867.3	350	1867	450	0.58
0-EE-6	2067.9	10000	2077.9	200	2077.9	200	--	--	3.91
0-ME-5	2130.7	2300	--	--	--	--	--	--	--
0-EE-7	2219.8	10100	2224.5	400	--	--	--	--	1.02
0-EE-8	2327.4	17900	2334	100	2332.7	800	2333.1	650	2.12

DIPOLE MODES

Mode	Closed cavity		Cavity with dampers Plunger position						relat. growth
			out		middle		in		
	Freq.	Q_0	Freq.	Q	Freq.	Q	Freq.	Q	
1-ME-1	668.1	24700	646.5	50	646.5	100	646.7	100	1.23
1-EE-1	784.8	24900	788.5	120	788.1	150	788.4	150	1.18
1-ME-2	1118.9	27600	--	--	--	--	--	--	--
1-ME-3	1189.2	44000	1189.2	1564	1188.9	1300	1188.3	550	1.22
1-EE-3	1289.2	19000	--	--	1291.8	580	--	--	--
1-ME-4	1417.7	7900	1418.5	950	1418.4	750	1418.7	800	1.19
1-EE-4	1518.4	25300	--	--	--	--	--	--	--
1-EE-5	1567.1	12800	1560.5	300	--	--	--	--	--
1-EE-6	1663.1	9200	1653	1460	1651.2	500	1652.3	1400	0.75
1-ME-5	1704.4	2800	1698.9	250	1700.9	300	1699.7	260	1.22
1-ME-6	1737.5	26000	1738.5	350	1738.0	360	1738.0	350	1.22
1-ME-7	1905.6	4010	--	--	--	--	--	--	--
1-ME-8	1940.6	3800	1944	290	1943.8	280	1944.1	240	1,17
1-ME-9	1998.1	1500	--	--	--	--	--	--	--
1-EE-7	2042.3	14500	--	--	--	--	--	--	--
1-EE-8	2054.7	4030	2056.9	780	2056.7	1000	2056.7	780	1.22
1-EE-9	2150.0	1020	--	--	--	--	--	--	--
1-EE10	2214.4	2170	2219.5	350	2219.7	340	--	--	1.22
1-ME10	2298.2	17700	--	--	--	--	--	--	--
1-EE11	2368.9	26030	2371.4	650	2371.8	980	--	--	1.18
1-EE12	2381.9	66000	2379.6	540	2379.9	560	2380.0	260	1.15

TABLE 2

V. CONCLUSIONS

A 476 MHz aluminum prototype RF cavity was built using computer simulation and a 1200 MHz model. The cavity has 3 wave guides which couple the high order modes to broad band load termination. Measurements of the Q values of the HOM for the cavity, with and without the wave guides, were performed. The results show that there is a strong damping effect due to the loading. Multibunch instabilities calculations were done using the LNLS storage ring parameters and the cavity HOM impedances. All transverse modes, except one, are stable for beam currents up to 200 mA.

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