IMPEDANCE STUDIES FOR BEPC

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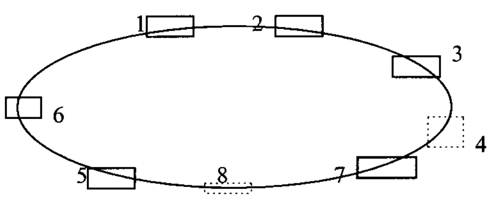
Abstract

This paper focuses on the impedances from various beamline elements in the BEPC with and without vacuum chamber upgrade. We also discuss their power depositions generated by a beam in the form of the High-Order-Mode(HOM) losses by interacting with its surroundings.

1 INTRODUCTION

The high luminosity is the destination of every electron-positron collider, due to which, one can reduce the β functions at the interaction point while shortening the bunch length, especially for the lower RF frequency like 200MHz in BEPC. Small coupling impedances is thus requested in order to shorten the bunch length. Due to this reason, in 1995 we made vacuum upgrade in BEPC while shielding 33 of 40 pairs of the 2-cm-long gaps on both sides of all bellows in the arcs. The impedance sources with and without upgrade in BEPC mainly come from the RF cavities, separators, injection kickers, bellow gaps, gate valves , flanges, all bellows and so on, which is shown in Fig.1, where the dashed line means the elements are completely or partly shielded after upgrade.



1-RF cavities, 2-Separators, 3-kickers, 4-Bellow gaps
5-Bellows, 6-Flanges, 7-Gate valves, 8-IR

Figure 1: Layout of BEPC Vacuum components

2 IMPEDANCES OF COMPONENTS

In this section, we summarize our estimates of impedances and loss factors of main beamlines in the BEPC, respectively.

RF Cavities

Through calculation, the wake of BEPC cavity almost characterizes in capactive, as shown in Fig.2, where we use the 4.2-cm-long bunch length. Using the wake Green functions of four cavities and one cavity respectively, and then solving their Haissinski equation we find that both of their bunch lengths are suppressed, as shown in Fig.3. After comparision, it is shown that the bunch length of four cavities is shortened more than that of one cavity. Next using the perturbation approach to solve the linearized, time independent Vlasov equation, which includes the potential well distortion as zero order effect, we find that there is no microwave instability. From the simulation results, it is shown that these cavities have no contribution to the bunch lengthening in BEPC. However, four cavities contribute to more loss factor, 0.2526V/pC per cavity at 4.2cm bunch length, which corresponds to the 250W HOM loss at I=35mA.

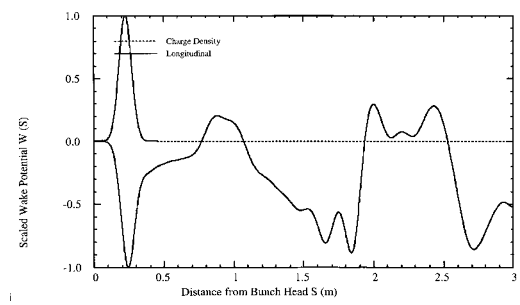


Figure 2: Wake potential of BEPC cavity

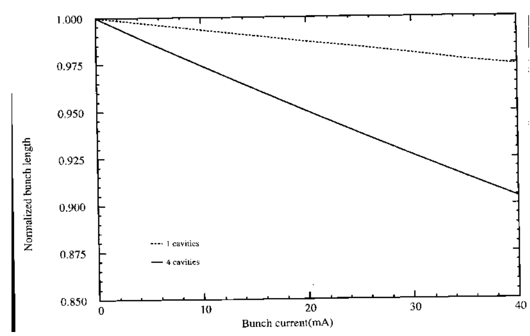


Figure 3: Bunch length with beam current

Bellow Gaps

Before vacuum chamber upgrade in BEPC, there exist 40 pairs of 2-cm-long gaps on both sides of bellows in the arcs as shown in Fig.4. Using the 3-D MAFIA, one can obtain its wakefield as shown in Fig.5. It is shown that its wakefield in inductive and its inductance per pair of gaps is 8.75nH. Its loss factor is 0.0425V/pC and corresponding HOM loss is 70W at 45mA. With the help of temperature probes, it is measured that the temperature rise is near 10 degrees while other temperature rises of other

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vacuum components are below 1 degree. In the view of frequency domain, there exists one trapped mode in the gap, whose frequency is 1.66 GHz through transmission measurements. During vacuum upgrade we shield 33 of 40 pairs of gaps, and then find the 1.6GHz trapped mode has disappeared and its HOM loss is also small, only 0.2 degree with almost the same condition as that of previous measurements. It is much clear that the impedance of bellow gaps are reduced greatly with vacuum chamber upgrade.

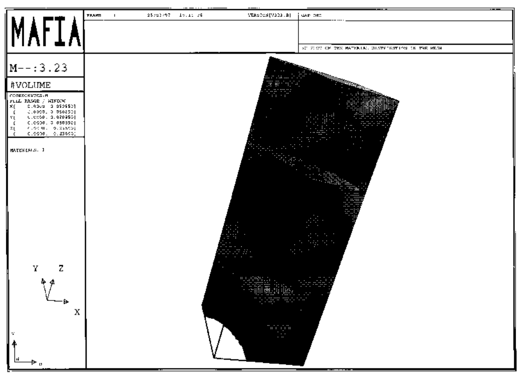

Figure 4: Sketchic map of bellow gaps

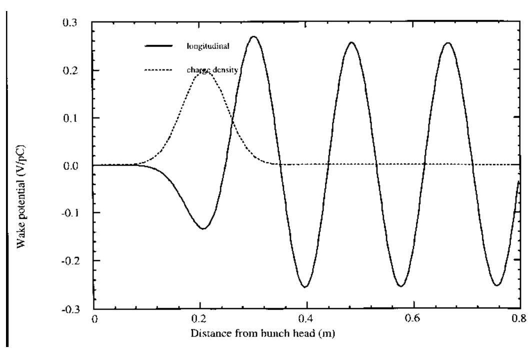

Figure 5: Wake potential of bellow gaps

Injection Kickers

BEPC has four injection kickers, which is the conventional air-coil magnet which has two metallic current plates surrounded by a large vacuum tank. Exprement shows that its impedance comes from the tapers and the two ends of metallic plates. Its wakefield is shown in Fig.6, from which one can obtain that the effective inductance is 10nH, and loss factor is 0.0365V/pC, corresponding to 36W HOM loss at 35mA current. In 1995, we fabricated one slotted-pipe type kicker model[1,2], which has low impedance in two magnitudes than that of the present kicker.The new slotted-pipe kicker model is principally based on the vacuum pipe itself with properly arranged slits as current conductors. Both ends of the vacuum pipe are directly connected with two ends of the external vacuum tank flanges, respectively. These two parallel conductors on both sides of the beam axis form an inductive loop, and the slits between

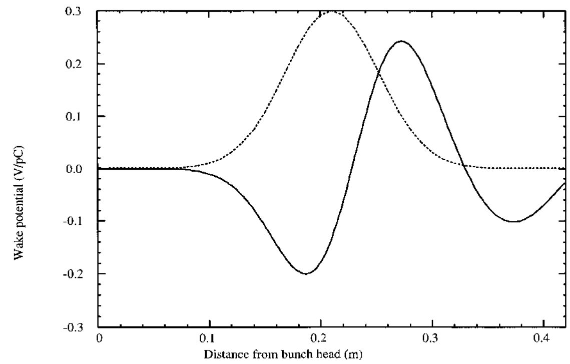

Figure 6: Wake potential of injection kicker

the conductors are connected to ground, which is one of the most important features different from the present one. Due to the racetrack beam pipe, the central metallic plates are the nearest to the moving beam and carry most of the image current. Thus, it is obvious that the impedance of BEPC will be further reduced if we apply the new type of kicker.

Separator

Using the transmission method, one can obtain its transmission spectrum as shown in Fig.7. It is observed that there exist some trapped modes below 1GHz, and their high-order-mode frequencies are intger multipoles of the lowest resonant frequency. In fact, one can consider the separator as the transmission line, where the parallel plates is considered as internal conductor, while external vacuum tank as external one. The relation between the loadings

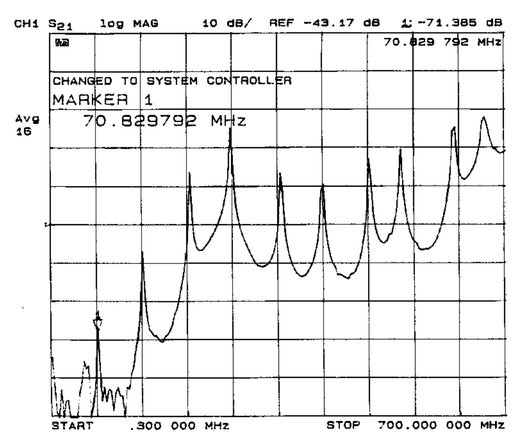

Figure 7: Transmission spectrum without loadings

of the plates and the trapped modes is studied. Results show that some modes are suppressed as shown in Fig.8, while the current plates are connected with the 5-cm-long cables. Analyzing both spectums, one can find that the odd modes are still trapped inside, but even modes are suppressed through the coupling between the cable and the fields of the modes. According to above two plots, one can determine the field directions of the modes. The field distrdibutions of both odd and even modes are analyzed in detail in the thesis[3]. On the basis of the field distributions, one can determine its total shunt impedances of the modes, when the shunt impedances of two ends are measured.Uisng MAFIA, one can obtain that its inductance and loss factor are 9.6nH and 0.0375V/pC, respectively.

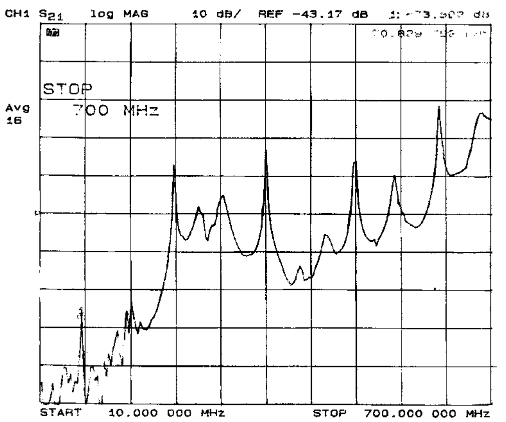

Figure 8: Transmission spectrum with loadings

Others

In addition to the components mentioned above, there are eight flanges, sixteen gate valves and sixty-four bellows in the BEPC. Their structures are small cavity-likes except bellows. The impedances of bellows is almost pure inductive.

3 IMPEDANCE BUDGET

The effective inductances and loss factors of the individual elements in the BEPC are tabulated in Table 1. The total longitudinal wake potentials for the BEPC with and without upgrade are plotted in Fig.9. Using the least-squares fit, the scaling laws of total loss factors of components without and with upgrade vs bunch length are obtained as followings:

$$k_l = 35.0(\sigma(cm))^{-1.45} V/pC, \quad (1)$$

$$k_l = 23.3(\sigma(cm))^{-1.51} V/pC, \quad (2)$$

where equation(1) and equation(2) are the cases without and with upgrade for BEPC vacuum chmabers, respectively. The impedance and loss factor budgets with and without vacuum chamber upgrade are shown in Table 1, where the values in the brackets are the ones with upgrade. From the above plots and data, it is shown that the whole impedance and HOM loss have been decreased greatly after vacuum chamber upgrade.

Table 1 Impedance and loss factor budgets

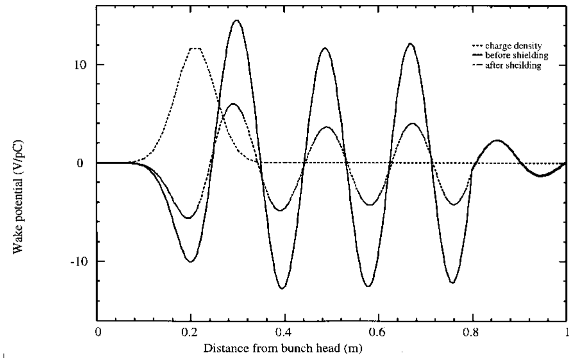

Figure 9: Total wake potential of BEPC

component	inductance(nH)	loss factor (V/pC)
RF cavities	-	1.01
Separators	38	0.15
Kickers	40	0.146
Bellow gaps	350(61.4)	1.7(0.34)
Bellows	63.7	0.019
Gate valve	50	0.218
Flange	31.8	0.205
IR	28.1(0)	0.14(0)
Total	602.5(313.9)	3.6(2.2)

4 REFERENCES

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