PRESENT STATUS OF THE TEST RF SYSTEM FOR THE KEK PS BOOSTER

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ABSTRACT

Since 1988 we have been constructing a new accelerating system for the KEK PS Booster. The system cancels the beam loading effect[1] by itself. The construction of the ferrite stacks and the system test operation are reported.

THE TEST RF SYSTEM FOR THE PS BOOSTER

The test rf system picks up the wall current at the upstream of the accelerating cavity and the current is fed into the accelerating cavity via the cathodes of the final vacuum tubes installed near the cavity(Fig.1). Since the current has the opposite polarity to the loading current, the loading effect at the cavity is cancelled.The main parameters of the system are listed in Table 1.

The power dissipated at the anodes of the final tubes is the same value as that of feed-forward compensation[3]. The maximum beam current accelerated by this system is determined by the specification of the the final tubes.In our case the final tubes are two 4CW50000E (Eimac) connected in parallel. The parallel connection is employed because of its higher maximum current and transconductance. A circulating beam current of 3A will be accelerated by this system without an influence of the beam loading.

CAVITY

The 24 ferrite rings with outer and inner diameters of 620mm, and 350mm respectively, and with the thickness 25mm are installed in the accelerating cavity. The permeability of the ferrite is 250. The estimated shunt impedance of the cavity is 1.5kΩ at an accelerating voltage of 15kV.However,the measured impedance is only 1.2kΩ at 4kV. The impedance is calculated from the measured cathode current[4]. The quality factor of the ferrite is far less than the expected value. The equivalent circuit of the cavity is shown in Fig. 2. The Q-value of a ferrite changes with magnetic flux density in the ferrite.

$$Q = \frac{Q_0}{1 + \eta \cdot B_{rf}},$$

where, for our ferrite $\eta \sim 0.027[\text{gauss}^{-1}]$, B_{rf} the average flux density in the ferrite, and $Q_0 \simeq 50$ is the value at $B_{rf} \sim 0$. By using this equation the shunt impedance of the cavity at 15 kV is estimated to be 500Ω.

If we remove the 200pF capacitance at the gap(see Fig. 2), the shunt impedance of the cavity at 15kV will increase to ~ 800Ω, which is nearly one half of what is expected. The peak power in the ferrite amounts to 140kW at 15kV. The average power and the power density in the ferrite are less than 70kW and 0.56 W/cm³ respectively.

The permissible power density is determined by the tensile strength of the ferrite and its thickness[5]. If we assume that the temperature at the surface of the ferrite is 30°C, the maximum temperature at the center of the ferrite is ~ 50°C. The maximum tensile stress in the ferrite is ~ 1.7kg/mm². The permissible tensile stress of ferrite is said to be ~ 2kg/mm². It means that the accelerating voltage of 15kV is nearly the limit for this cavity.

COOLING OF THE FERRITE RINGS

Because of the large power in the ferrite, the cooling system of the ferrite must be designed carefully.The ferrite rings are sandwiched between cooling disks with 5mm thickness.The cooling disk is made of copper hollow conductor. The water flows with a speed of ~ 2 liters/min. at a inlet pressure of 8.8kgf/cm^2.

The ferrite stack is supported with FRP disks with thickness 20mm. They are fixed with 12 pieces of FRP rods. Because the support mechanism is not tight, there exist the air gaps between cooling disks and ferrite rings. In order to fill the gap with the compound, we started with the selection of the compound. A silicon compound grease with a conductivity of 0.8W/m˚C was selected because of its low viscosity. To decrease the viscosity further, we mixed the solvent silicon oil to the compound.

The working stand having an oil hydraulic press mechanism is used to construct the ferrite stack(Fig. 3). The surface of the cooling disk placed on the stand are painted with the thermal compound and the ferrite ring is mounted on it. After the stacking is completed, the stack is pressed at a pressure of 2kg/mm^2. By this process the air is removed out from the gap. Final thickness of the compound is ~ 200μm. The thermal resistance at the gap filled with the compound is nearly $1.3 \cdot 10^{-3}$ ˚C/W. The power flows through a surface of the cooling disk is ~1.5kW, therefore, the temperature increase at the compound gap is 2˚C, which is far less than the temperature increase of the cooling water flowing through the disk.

BEAM LOADING CURRENT PICKUP

The gap which picks up the circulating beam current is loaded with amorphous core having a large permeability. Because of the large imaginary part of permeability, for a frequency above 500kHz, the amorphous core behaves as a 100Ω resistor. The input impedance of the final tube cathodes is 10 Ω. Therefore, neary 90% of the wall current at the pickup gap flows into the cathodes. The equivalent circuit of the pickup is shown in Fig.4.

THE TEST OPERATION

The leakage inductance of anode windings on the ferrite and the gap capacitance had resonated at 10MHz. To reduce this resonance to a frequency far lower than the accelerating frequency range, two 0.01μF capacitors, which connect the anodes of the final tubes and the accelerating gap, are installed at the accelerating gap.

The test operation of the cavity voltage is limited to 4kV, because of the discharge at the ferrite support mechanism made of FRP. The rf voltage at the accelerating gap, the ferrite bias current, and the phase error of the tuning system are shown in Fig.5. The setup of the test system is shown in Fig. 6. The bandwidth of the automatic tuning system is ~ 1kHz.

CONCLUSION

The improvement of the cooling system in the ferrite stack has been finished in August 1991. In order to increase the shunt impedance, the 200pF fixed capacitor at the accelerating gap has to be removed. Further experiments are necessary to increase the accelerating voltage.

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REFERENCES

1) S.Ninomiya et al, Particle Accelerators, Vol.32, 1990, p.1511
2) F.Pedersen, IEEE Trans. Nucl. Sci. NS-22, 1975, p.1906
3) S.Ninomiya, Beam Loading Effect on RF System in PS(in Japanese), KEK Report 1989-18
4) S.Ninomiya and T.Katori, ASN-309(KEK-PS Internal Report) Sept,1990
5) S. Ninomiya 高周波加速の問題点 TARN II 拡充計画検討報告書 1990

Table 1 Basic parameters of the test rf system.

Repetition rate	20 Hz
Frequency range	2.2 ~ 6.02 MHz
Max. acc. voltage	15 kV
Length of the system	1.75 m
Anode voltage(4cx50,000E)	17.5 kV
Max. bias current	3000 A
Max. power in ferrite	70 kW
Max. beam current	3 A

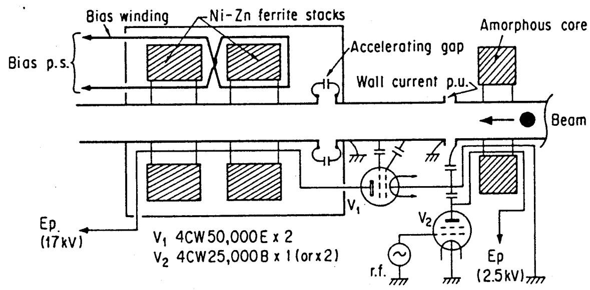

Fig. 1 Schematic diagram of the test system

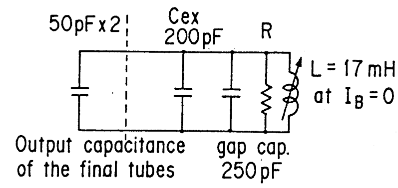

Fig. 2 Equivalent circuit of the cavity

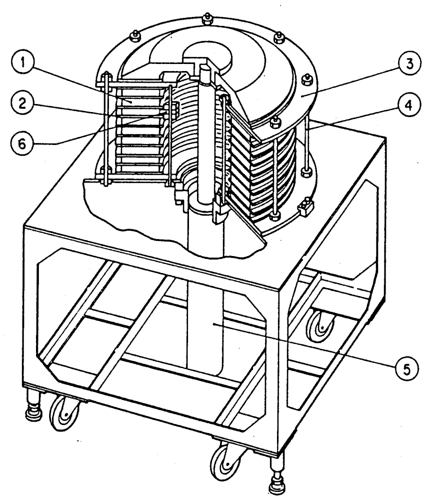

Fig.3 Sketch of the working stand for ferrite stack assembly; 1. Ferrite ring, 2. Copper cooling disk, 3. FRP disk (20mm thickness), 4. FRP rod (ø20mm), 5. Oil hydraulic press and 6. Alignment mechanism.

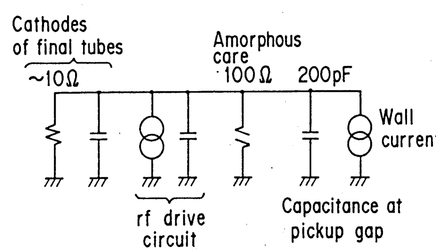

Fig. 4 Equivalent circuit of wall current pick-up

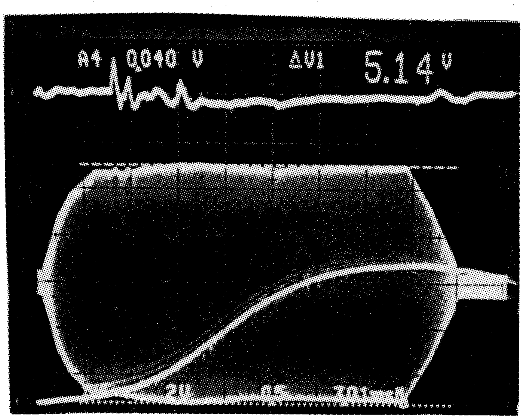

Fig. 5 Monitor signals at test operation; phase error signal of tuning system(Top), RF voltage envelope($8kV_{pp}$, Middle) and ferrite bias current(Bottom)

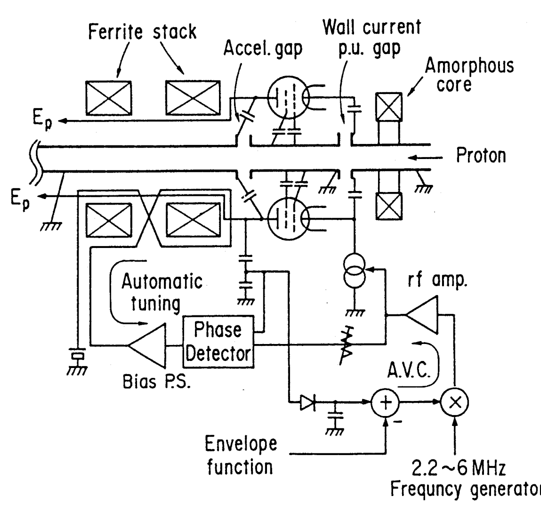

Fig. 6 Setup of the system with feedback loops