MA CAVITY FOR HIRFL-CSR*

Lirong Mei#, Zhe Xu, Youjin Yuan, Peng Jin, Zhibin Bian, Hongwei Zhao,
IMPCAS, Lanzhou 730000, China
Lirong Mei, GUCAS, Beijing 100049, China

Abstract

To meet the requirements of conducting high energy density physics and plasma physics research at HIRFL-CSR. The higher accelerating gap voltage was required. A magnetic alloy (MA) core loaded radio frequency (RF) cavity which can provide higher accelerating gap voltage has been studied in Institute of Modern Physics, Chinese Academy of Sciences (IMP, CAS), Lanzhou. To select proper MA material to load the RF cavity, measurement for MA cores has been conducted. The MA core with higher shunt impedance and lower than 1 quality factor (Q value) should be selected. The theoretical calculation and simulation for the MA-core loaded RF cavity can be consistent with each other well. Finally 1000kW power was needed to meet 50-kV accelerating gap voltage by calculation.

INTRODUCTION

IMP plans to conduct high energy density physics and plasma physics research at HIRFL-CSR (Heavy Ion Research Facility in Lanzhou (HIRFL) and Cooling Storage Ring (CSR)) [1]. To meet the requirements of high energy density physics and plasma physics research, a higher accelerating gap voltage is required [2]. Therefore, a magnetic alloy (MA)-core loaded RF cavity (MA cavity) has been studied as R&D program at IMP. The MA cavity can provide a higher accelerating gap voltage than a standard ferrite cavity does. Because of its broad band frequency range, the MA cavity has no the tuning loop which is usually used in the case of a ferrite-loaded RF cavity [3]. In addition, because of its shorter length, the MA cavity can be used in the compact accelerator which might be constructed as a cancer therapy facility in the future.

MA SAMPLE CORES TEST AND SELECTION

For selecting proper MA material to load the RF cavity, we measured the characteristics of four kinds of MA sample cores, the type V1, V2, A1 and A2 as shown in Figure 1 which are produced by Liyuan Corp. Ltd (in China) [4]. These cores are Fe-based nanocrystalline tape-wound cores, and their differences are that the raw MA tape materials of V1 and V2 are from German, while A1 and A2 are from China. The saturation magnetic flux densities are about 1.2 T for type V1&V2 and 1.25 T for type A1&A2 respectively. The difference between V1 and V2, A1 and A2 is the insulation layer between MA ribbons. The insulation layer of A1 and V1 consists of SiO_2 and Silica Gel, while it is Silica Gel only for A2 and V2. V1 and V2 test cores have same dimension of 65 mm outer diameter, 35 mm inner diameter and 30 mm thickness. A1 and A2 test cores have the same dimension of 65 mm outer diameter, 35 mm inner diameter and 25 mm thickness. The measured shunt impedance (R_p) and the calculated Q values of the cores at different frequencies are shown in Figure 2 (a) and Figure 2 (b) [5].

Figure 1: the sample MA cores.

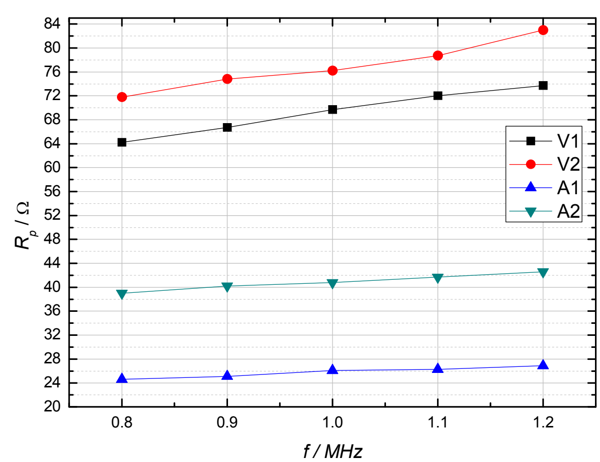

Figure 2: (a): R_p of V1, V2, A1 and A2 vs. frequency.

*Work supported by NSF under Contract No. 10921504.
#lrmei@impcas.ac.cn

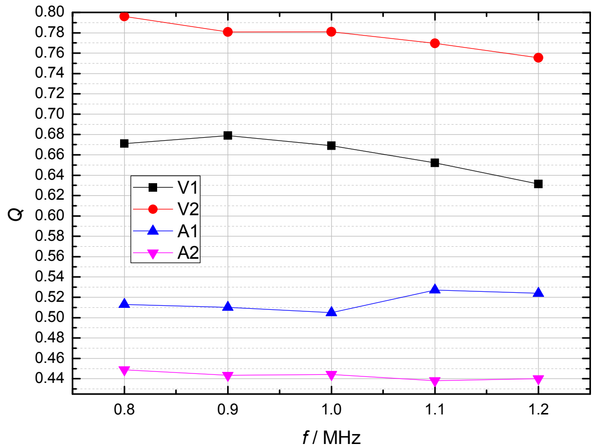

Figure 2: (b): Q Value of V1, V2, A1 and A2 vs. frequency.

From Figure 2 (a) we see that the type V2 has higher shunt impedance R_p than those of the three other types, and the shunt impedance is almost constant with 15% variation in the range of 0.8-1.2 MHz. The higher shunt impedance means lower power consumption. Figure 2 (b) shows that the Q values of V1, V2, A1 and A2 are less than 1 which indicates that any of these cores can be used for an untuned RF cavity. The above results indicate that the type V2 material will be the best candidate for the RF cavity in our case.

MA CAVITY

In HIRFL-CSR, four ferrite-loaded cavities have been used for regular operation. In order to conduct high energy density physics and plasma physics research at HIRFL-CSR, we were studying the MA cavity at IMP. A model draw of the designed HIRFL-CSR MA cavity is shown in Figure 3 and the design parameters are summarized in Table 1.

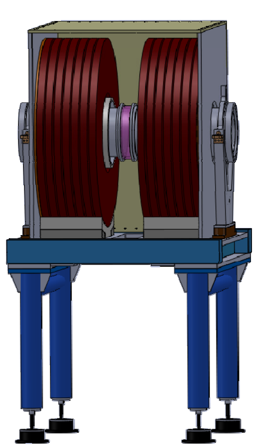

Figure 3: Model draw of the HIRFL-CSR MA cavity.

Table 1: The Design Parameters of the HIRFL-CSR MA Cavity

Parameters	**MA cavity**
Number of cavities	1
Frequency range (MHz)	0.8~1.2
Accelerating gap voltage (kV)	50.0
RF Power (kW)	1000
Duty factor (%)	0.05
Average power (kW)	0.5
Total length of cavity (mm)	900
Outer radius of inner conductor of the cavity, r_1 (mm)	140
Inner radius of outer conductor of the cavity, r_2 (mm)	440
Accelerating gap, d_{gap} (mm)	30
Inner radius of the MA core, ρ_1 (mm)	170
Outer radius of the MA core, ρ_2 (mm)	400
Thickness of the MA core, d_1 (mm)	30
Interval of two MA cores, d_2 (mm)	7
Loaded core number, n×2	14

Figure 4 gives the equivalent circuit of the HIRFL-CSR MA cavity; where C_{gap} is the gap capacitance, and C_{coax} is the coaxial distributed capacitance of the cavity. The distributed capacitance of the cavity can be calculated by $C_{cavity}=C_{gap}+C_{coax}/2$.

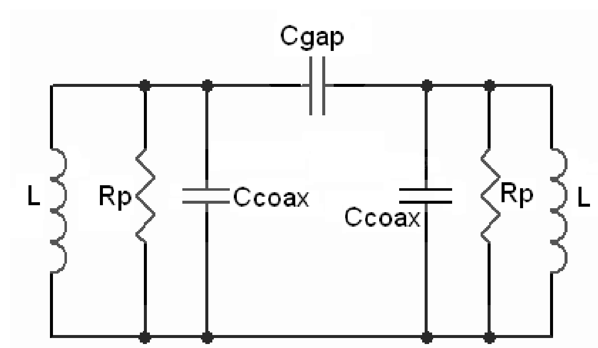

Figure 4: the equivalent circuit of the HIRFL-CSR MA-core loaded RF cavity.

The coaxial inductance of the MA cavity can be calculated by $L=\frac{n\mu_0\mu'_p}{2\pi}\cdot d_1\cdot\ln\left(\frac{\rho_2}{\rho_1}\right)$,

where $\mu'_p=\left(1+\frac{1}{Q^2}\right)\mu'_s$.

Therefore, the resonant frequency of the MA cavity can be calculated by $f=\frac{1}{2\pi\sqrt{2LC_{cavity}}}$. If V2 core material at the center frequency 1.0 MHz (μ'_s≈1570, Q≈0.781) is selected to calculate the resonance frequency of the cavity, we obtained f≈1.57 MHz which is far from the frequency 1.0 MHz. So an about 51 pF capacitor should be connected in parallel to the cavity to reduce the resonant frequency from 1.57 MHz to 1.0 MHz by calculation [6].

CAVITY SIMULATION AND RESULTS

The code of CST MICROWAVE STUDIO [7] is used to simulate the MA cavity. The simulated result is shown in Figure 5. The 51 pF parallel capacitor has been taken into account during the simulation. The resonant frequency is about 1.019 MHz from simulation, compared to the theoretical value 1.0 MHz we found that the simulated and calculated frequencies of the cavity show a good consistency.

In addition, we calculated the shunt impedance of the cavity, and the result is about 1.4-1.6 kΩ in the range of 0.8-1.2 MHz. The power source needs to provide about 1000 kW power to obtain 50kV accelerating gap voltage by calculation. The average power applied to the cavity is less than 500 W due to the duty factor is 0.05%, and the cooling for the cores could be done by forced air. [6]

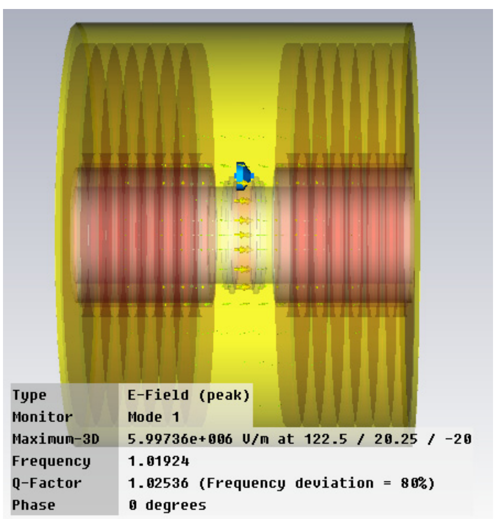

Figure 5: The simulated result of the cavity.

CONCLUSIONS

According to the measurements results for MA-cores, type V2 will be selected to load the RF cavity. According to theoretical calculation and simulation for the MA cavity, the results can be consistent with each other well. Finally about 1000 kW power is needed to obtain 50kV accelerating gap voltage by calculation.

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