UPGRADED CAVITIES FOR THE POSITRON ACCUMULATOR RING OF THE APS

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Abstract

Upgraded versions of cavities for the APS positron accumulator ring (PAR) have been built and are being tested. Two cavities are in the PAR: a fundamental 9.8-MHz cavity and a twelfth harmonic 117.3-MHz cavity. Both cavities have been manufactured for higher voltage operation with improved Q-factors, reliability, and tuning capability. Both cavities employ current-controlled ferrite tuners for control of the resonant frequency. The harmonic cavity can be operated in either a pulsed mode or a CW mode. The rf properties of the cavities are presented.

1 INTRODUCTION

The APS PAR rf system employs two frequencies at 9.8 MHz and 117.3 MHz for the fundamental and the twelfth harmonic subsystems, respectively. Each subsystem has an rf cavity for the frequency. The cavities now used in the system were made as prototypes and were installed for initial commissioning of the APS. They have been working all right for positron accumulation and bunch compression so far. However, for higher reliability and performance of the PAR, new cavities are needed. Problems observed in the fundamental frequency cavity so far are narrow frequency tuning range, lower gap voltage limit, and rf heating at the joint of the ceramic flange and the cavity center conductor that effect degradation of the cavity Q-factor. Since the cavity volume outside the beampipe is exposed to the room air in each cavity, some corrosion due to the water in the air has been considered responsible. The harmonic cavity was made with stainless steel for lower Q-factor, but it has shown an even lower Q-factor than originally planned. The harmonic system also needed an option for CW operation mode. Therefore, a set of new cavities has been made and tested for the PAR. These new upgraded cavities were designed to provide improved performance in the electronic tuning range, immunity to corrosion, and higher voltage capability. For the fundamental frequency cavity, the design goal was a 40-kV accelerating gap voltage, a Q-factor of 6000, and an R/Q of 74 Ω for the accelerating mode. For the harmonic cavity, the goal was a 30-kV gap voltage, an R/Q of 41 Ω, and a Q-factor of 3000. The rf characteristics of both cavities were calculated using the URMEL-T computer codes.

2 CAVITY DESIGNS

The 9.8-MHz fundamental frequency coaxial cavity with capacitive loading plunger is shown in Figure 1. The fundamental cavity is a plunger-loaded reentrant coaxial structure [1] that can provide a low operating frequency in a specified volume with a moderately high Q-factor without using any dielectric or magnetic material inside. The end of the inner conductor near the ceramic window is a piston-shaped loading structure which consists of a circular disk and a cylinder. Designing low-frequency tuned rf accelerating cavities for high-power operation with a cavity length much less than a quarter wavelength needs extra capacitive loading. The center conductor contributes mainly as the inductor and the gap between the outer and inner cylinders form a capacitor.

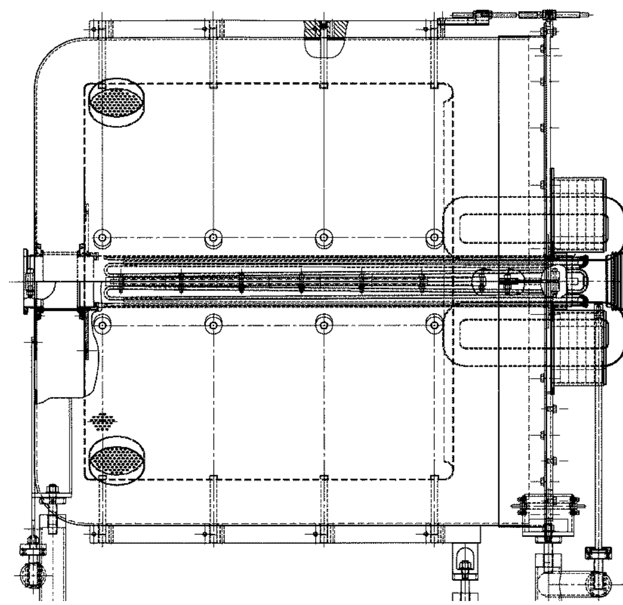

Figure 1: Fundamental cavity structure.

2.1 Fundamental Frequency Cavity

The cavity has a length of 1.6 m, a radius of 0.72 m, and an accelerating gap length of 13.0 cm. The voltage across the loading capacitor was found to be greater than 90% of the gap voltage across the ceramic window [1]. The inner cylinder is supported with rexolite dielectric posts. The input coupler is placed in the back plate where the tuners are located. The input impedance of the coupler is matched for 50 ohms with a smaller loop area. Therefore, the coupler is moved closer to the center conductor where the magnetic field strength is greatest. The measured frequency and Q of the cavity are shown in section 4 below.

The inner coaxial structure has a minimum of 12.5 cm of separation between conductors for reliable high voltage operation. The center conductor is made around the beam pipe where the vacuum is maintained. Outside, an air blower fills the center conductor with air for additional cooling of the cylindrical shells. The center conductor is made of silver-plated copper with copper tubing underneath for water cooling.

2.2 Harmonic Frequency Cavity

The harmonic frequency cavity is a reentrant type coaxial cavity as shown in Figure 2. The cavity is made of aluminum with a ceramic window at the center of the cavity inner conductor. During initial operation of the harmonic system, the automatic gain control loop developed oscillation problems that were caused by a multipactoring effect at the inner surface of the ceramic window. The ceramic window has been titanium coated from the inside surface that is in vacuum during operation. The cavity length is 60 cm, the outer conductor diameter is 1 m, and the inner conductor diameter is 30 cm.

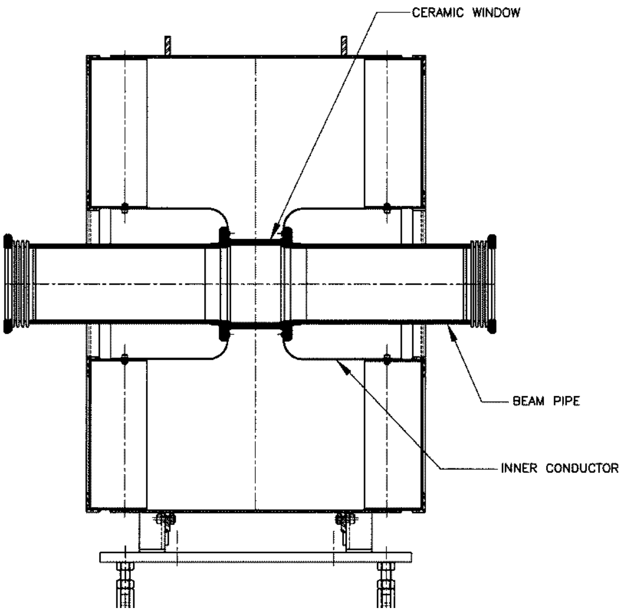

Figure 2: Harmonic cavity structure.

3 FERRITE TUNERS

For both cavities, ferrite tuners are used for electronic tuning of the cavity resonant frequencies. Copper housings are used with toroidal ferrite cores. The windings are placed inside the coupling loop that provides complete shielding and also penetrates the cavity. For all tuners, 250°C-rated high temperature wires were used. For CW operation in either system, the temperature in the tuners was measured at less than 55°C. These cavity tuners are needed for compensation of the resonant frequency drift of the cavity due to temperature change. The ferrite materials used for the tuners are shown in Table 1.

Table 1: Ferrite Materials Specifications

	Toshiba M4C21A	Stackpole C/14
O. D. (inches)	8.0	8.0
I. D. (inches)	5.0	5.0
Height (inches)	1.0	1.0
Initial permeability	42	12.5
Magnetic loss tangent	0.0085	
Curie temperature (°C)	340	510
Saturation magnetization (gauss)		2100
Dielectric constant	13.0 @40MHz	10.5
Dielectric loss tangent	0.0003 @40MHz	

3.1 Fundamental Cavity

Figure 3 shows the fundamental frequency cavity tuner. The coupling loop of the tuner needs to be placed near the cavity center conductor to permit greater coupling with the magnetic field with a minimum loop area. Therefore, the tuners are positioned in the back plate. Four tuners were needed to obtain the required frequency tuning range of 50 kHz. The control winding must be isolated from the rf field for better rf properties. The windings are put inside the coupling loop so that the winding can do its job without interfering with the rf field. Since the Toshiba material has low loss up to ~50 MHz with a greater initial permeability, this material is used in the fundamental frequency tuners. Six toroids are stacked together in each tuner.

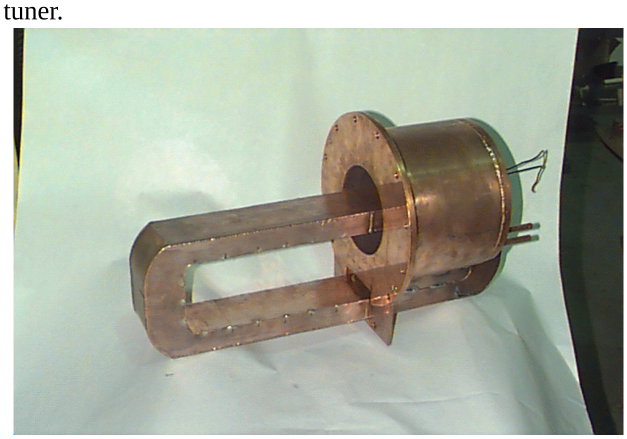

Figure 3: Ferrite tuner for the 9.77-MHz fundamental frequency cavity.

3.2 Harmonic Cavity

Two different ferrite tuners have been tested for pulse mode and CW mode. For pulse mode operation, cavity deQing is desired for improved beam stability during accumulation with the fundamental cavity. A detuned and damped cavity characteristic is obtained by a tuner using Toshiba material that is lossy for the frequency. However, for CW mode the cavity does not need to be damped but must be tunable with a stable, high Q-factor. For this purpose two separate tuners were built; and one tuner is used for each mode of operation. Two Stackpole toroids that have lower loss at higher frequency were used in the CW mode tuner. They can be mechanically switched for the two operation modes. Construction of the tuners is similar to the fundamental cavity tuners.

4 MEASUREMENT

Figure 4 shows the measured frequencies and Q-factors of the fundamental cavity. The fundamental cavity showed virtually no change in the Q-factor with a changing tuner control current. The measured frequencies agreed well with the simulation. The frequency tuning range of ~50 kHz is sufficient for tuning the cavity from frequency drift caused by any change in the operating conditions. For the required accelerating voltage of 40 kV, the input power is estimated to be about 4 kW.

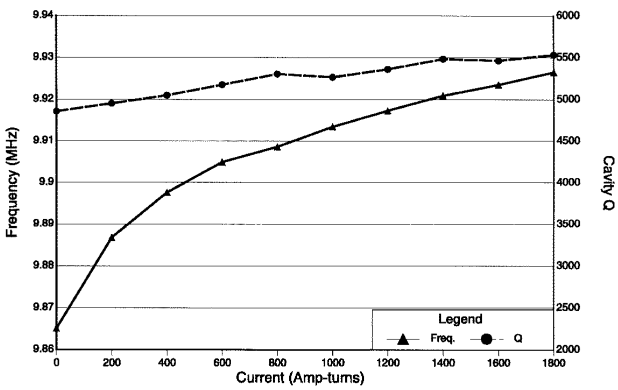

Figure 4: Fundamental cavity Q and frequency tuning characteristic vs. tuner control current.

Figure 5 shows the harmonic cavity Q and frequency tuning characteristic vs. tuner control current for pulse mode operation. Figure 6 shows the harmonic cavity Q and frequency tuning vs. the tuner control current for CW mode operation.

The harmonic cavity Q-factor is deQed and the frequency is detuned for pulse mode operation. The Q is about 20% of the maximum value and the detuning is about -150 kHz at zero current. The ferrite material is lossy in the operating frequency range, and the varying magnetization changes the permeability of the material and thus the resonant frequency. The increased magnetization decreases the magnetic loss and the permeability in the ferrite; the frequency increases as the Q increases. The peak tuner current will be varied to stabilize the frequency. The CW mode tuner has low loss and the change in Q of the cavity is much less than the change with the pulse mode tuner.

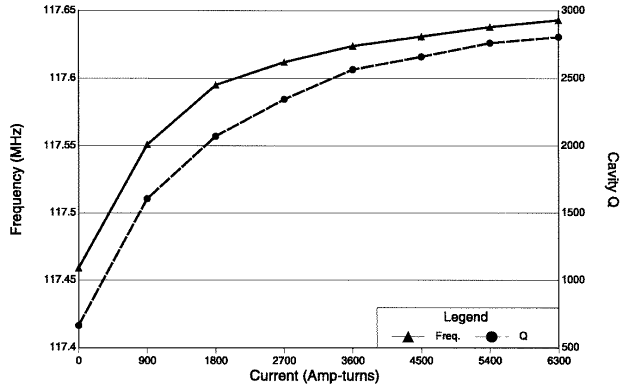

Figure 5: Harmonic cavity Q and frequency vs. tuner control current for pulse mode operation.

5 CONCLUSION

The loaded gap cavity is considered to be a good choice for the low frequency application. Comparing the simulation result with measurements for the above two cavities, it was found that they agree well. The ferrite tuners perform well and satisfy the system requirement. The upgraded cavities have improved rf characteristics and can be used in the system.

6 ACKNOWLEDGMENTS

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7 REFERENCES

[1] Y. Kang et al, “RF Cavities for the Positron Accumulator Ring (PAR) of the Advanced Photon Source (APS),” Proc. of the 1995 Particle Accelerator Conference, pp. 1693-1695, 1996.

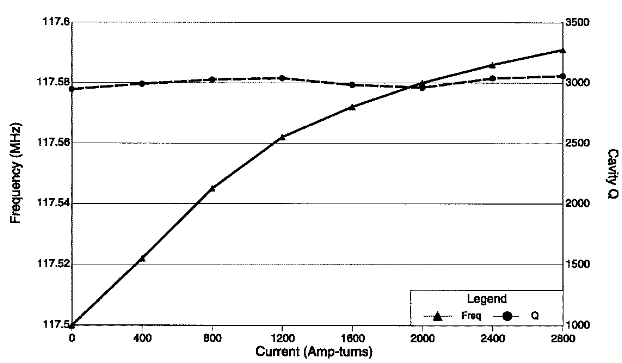

Figure 6: Harmonic cavity Q and frequency vs. tuner control current for CW mode operation.