

A New 50 MHz RF Cavity for Aladdin*

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Abstract

The 50.58 MHz RF system for the Aladdin synchrotron light source at the University of Wisconsin – Madison has been upgraded with the installation of a new aluminum RF cavity. The new cavity is a foreshortened quarter wave type designed to eliminate multipactoring under high field conditions by incorporating a toroidal shape for the short circuit end[1]. Rigidity and ease of construction are enhanced by machining critical components from solid aluminum instead of using welded assemblies. A novel diaphragm tuner was incorporated to avoid the introduction of tuner modes. Drive power is coupled through a loop in air using a ceramic thimble for vacuum isolation. Coating of surfaces in the gap region with titanium made penetration of the first order multipactor region very easy and has eliminated all higher order multipactoring in the accelerating gap.

I. INTRODUCTION

The original Aladdin RF cavity was an aluminum quarter wave coaxial resonator. The cavity was installed in one of the long straight sections provided in Aladdin to allow the installation of insertion devices. Aladdin is now developed to the point where it is desirable to free the RF straight section for the installation of an insertion device as all three of the remaining sections are already committed. The old cavity also had high field multipacting problems when operating above 100 kV. For these reasons a new cavity was built which would fit into a smaller space and be capable of operating at higher fields without difficulty.

II. CAVITY DESIGN

A. General

The new cavity (Fig. 1) was designed with the URMEL code. The cavity parameters are listed in Table 1. The shunt impedance and Q are approximately the same as the old cavity. A large tuning range is required because Aladdin is operated with low RF voltage at injection[2]. Substantial reactive compensation is required under high beam loading conditions. The RF input coupling loop is in air and is isolated from the cavity vacuum by an alumina thimble that protrudes into the cavity. The thimble was given a light coating of titanium to prevent multipactoring.

The cavity was constructed from 6061-T6 aluminum. It is built in three sections using aluminum wire seals that function both as vacuum seal and RF contact. Wire seals are also used in transitions to the stainless steel vacuum chamber of the ring and to seal the titanium thimble flange. The short circuit end of the cavity is constructed with a toroidal cross section to suppress multipacting at high fields. Areas such as the loading disc, stem core and toroidal end section that required extensive cooling were machined from solid aluminum with integral cooling passages. The machined

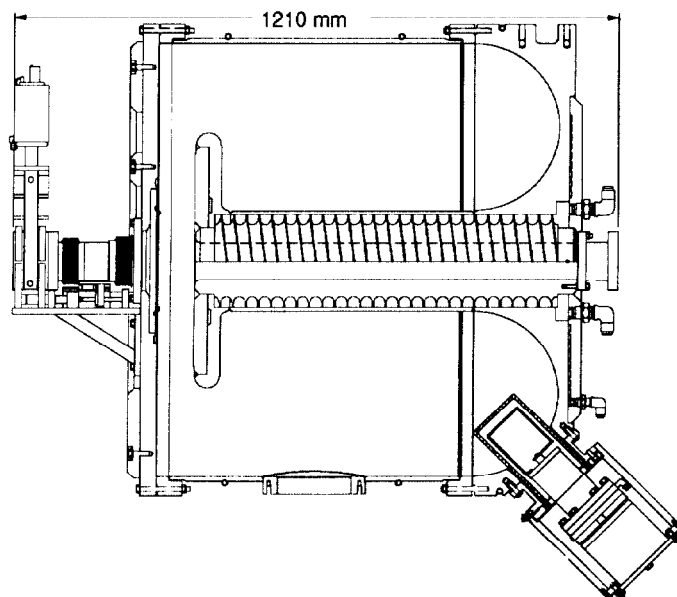


Figure 1. 50 MHz Aluminum Cavity

pieces give the cavity excellent rigidity. Assembly of the cavity was also facilitated because of the smaller number of welds required. The high precision of the machined pieces also made the remaining welds easier to perform.

Frequency	50.582 MHz
Shunt Impedance	800k Ω
Q(unloaded)	13000
Tuning Range	250 kHz
Max. Gradient	120 kV
Max. Cavity Loss	9 kW

Table 1. Cavity Parameters

B. Thermal Design

The small size of the cavity results in high power densities, especially in the stem and inner portion of the toroidal end section. In addition, the large capacitive loading required to resonate such a short cavity makes the resonant frequency very sensitive to dimensional changes in the inner stem. For these reasons the design of the cooling passages for the stem was approached with a great deal of care. Finite element models of the cavity temperature distribution were used to determine the location of cooling passages and their flow rates. Simulated heat loads were applied using data from URMEL power distribution plots. The effects of various cooling configurations were modeled and used to calculate temperatures in the cavity. Several iterations were used to optimize the cooling configuration.

The use of a double helix heat exchanger for the stem gives maximum water contact to the inner skin of the stem and allows a single water path to cool the stem and end

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loading disc. The helix core is machined from bar stock with a hole bored in the center forming the beam aperture.

A spiral heat exchanger cools the rear of the cavity. A cooling passage is machined into a plate that is welded into a recess in the cavity end section. The inner portion of the toroidal section is cooled by the stem core. This is the most difficult area to access and also has a high thermal load. Having the end section machined from a solid plate makes cooling this area much easier.

Heat loads are much more reasonable on the outer shell and outer portion of the end section. A single cooling tube set into a groove in the outer diameter of the end section is sufficient to cool it. The outer shell is cooled with two hoops of tubing clamped into shallow grooves in the shell. Convection over the large shell surface provides additional cooling. The heat load on the gap end plate is so low that no additional cooling is required.

The end result of this effort is a rigid, well-cooled cavity that shows very little sensitivity to vibration or water flow noise. Detuning of the cavity due to RF heating is less than 25 kHz at maximum power.

C. Diaphragm Tuner

It was desired to tune the cavity by a method that did not introduce additional HOM's or use sliding contacts. A large tuning range was also required. A segmented capacitive diaphragm covering part of the accelerating gap was designed. It is constructed from 250 μm beryllium copper and incorporated into the gap end plate (Fig. 2). The diaphragm was plated with 50 μm copper to increase its electrical and thermal conductivity. Less than 10 W is dissipated in the diaphragm at maximum power so it is cooled by conduction to the aluminum end plate. The diaphragm segments are held in place by retaining rings on their inner and outer diameters. The inner ring is attached to a section of tubing that acts as the actuating link as well as providing the beam aperture.

Axial displacement of the diaphragm is permitted by incorporating an S-shaped section near the center of each segment. The tuner is driven by axially moving the beam pipe attached to its inner diameter. A pair of bellows isolates this motion from the cavity and the rest of the ring. The bellows next to the cavity is automatically shielded from RF by the beam pipe that passes through it.

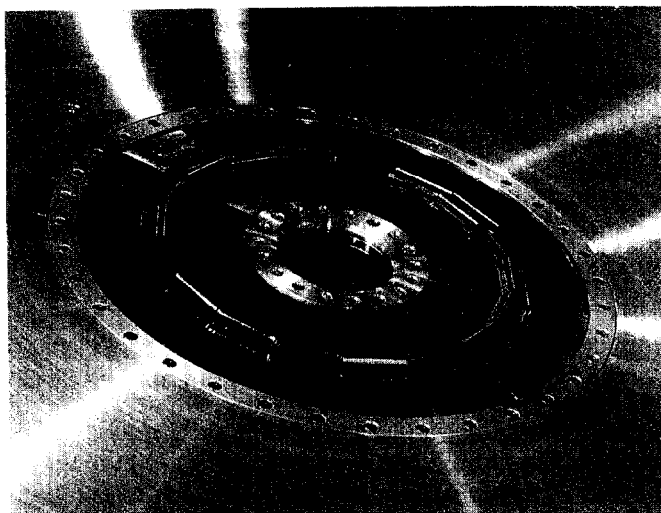


Figure 2. Diaphragm tuner installed in cavity end plate

D. Anti-multipacting Coating

Low field multipacting is a serious problem in aluminum cavities. Initial conditioning of a bare cavity of this type is nearly impossible due to the large areas that need to be conditioned. To suppress multipacting, the accelerating gap and coupler port were coated with a layer of titanium that was applied by sublimation. Titanium wire held in a rotating fixture was used for the gap and a commercial sublimator was used for the loop port. Processing consisted of sublimation at a moderate rate for about 15 minutes at $\sim 10^{-5}$ torr followed by backfilling with N_2 . The composition of the final coating is probably more oxide than nitride but this does not seem to affect its performance.

This procedure gave excellent results. Without the coating breaking through the first multipacting level at about 500 V took over a day with pulsed drive. With the coating breakthrough can be achieved in about one hour using low power CW drive. Without the coating higher order levels were observed in the 5–10 kV range and the conditioning did not seem to be permanent. With the coating no high order levels were observable provided the coating thickness was adequate. No degradation in the coating effectiveness has been observed over time. Re-conditioning after vacuum cycling appears to behave similarly to initial conditioning. No high field discharges that did not condition away were evident below 150 kV.

E. Vacuum

The vacuum system of the new cavity consists of a 220 l/s ion pump mounted on the bottom of the cavity. The pump port is equipped with a grid that carries the RF current in the cavity wall. This also prevents coupling of the pump modes to the cavity. A titanium sublimation pump is attached to the bottom of the ion pump to assist in pump down. An RGA head is attached to the roughing port to provide in situ leak checking and vacuum analysis capabilities.

Aluminum cavities require more care in vacuum preparation than copper cavities. The porous coating formed on an aluminum surface can adsorb large quantities of water. This makes it necessary to perform a thorough bakeout in order to obtain the lowest possible pressure. The cavity was baked for one month at 150°C . After baking the pressure was 4×10^{-10} torr. Operation at full power results in a pressure in the low 10^{-9} range.

III. HOM DAMPING

Higher order modes are a concern in Aladdin due to its low injection energy. Radiation damping is so weak that it is practically impossible to eliminate coupled bunch instabilities at injection. The method used to attack this problem in the new cavity was to concentrate damping efforts on modes that have the potential of causing the most trouble for injection, in order to minimize injection difficulties. The injection bunch length of 5 ns means that modes below about 500 MHz are the most important ones to damp. The cavity design helps in this because it has no modes below 235 MHz. However, the use of a low frequency cavity means that high frequency modes (≈ 1 GHz) which are potentially troublesome at the operating energy are very numerous and difficult to attack without knowledge of how the system performs with beam.

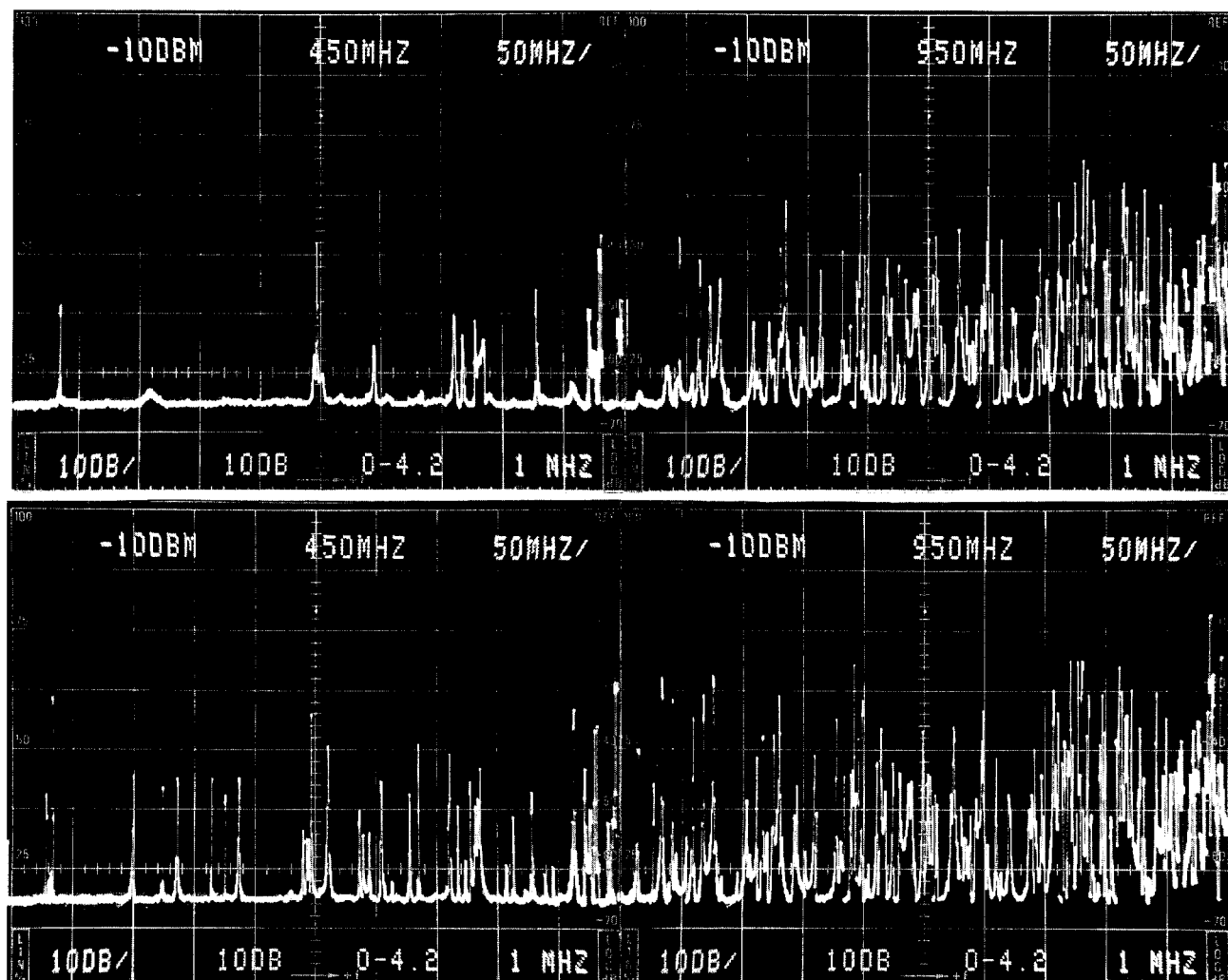


Figure 3. Cavity HOM spectrum with and without damping loads installed

HOM damping is accomplished using four damping antennas inserted radially through the outer shell of the cavity. Axially oriented antennas were precluded by the design of the end section. Two antennas damp modes in the 500 MHz region with two additional antennas cut for 235 MHz and 375 MHz. The position of the antennas was determined using URMEL field plots. Coupling of the fundamental mode to the antennas is reduced by terminating them in tuned coaxial stubs which also allow some adjustment of the damping at particular frequencies.

The antennas are constructed from commercial UHV copper tube feedthroughs with machined copper tips. The tips are attached by hydrogen brazing with AgCu eutectic. The antennas are cooled with water from a tube that runs down their central bore. The tuning stubs allow easy separation of the water and RF paths.

Figure 3 shows the HOM spectra of the cavity with and without damping in the frequency range from 200 to 1200 MHz. The damping is very effective up to about 700 MHz. The tuning of the antenna stubs was adjusted to optimize the damping over the low end of the frequency range shown.

IV. PERFORMANCE

The cavity was installed in January 1993 and has performed well. Injection performance is much better due to the elimination of a severe coupled bunch instability caused by low frequency HOM's in the old cavity that made stacking at high currents difficult. Operation at 800 MeV has revealed a coupled bunch mode that appears to be caused by a mode in the cavity at about 1 GHz. Future experiments are planned using microwave absorbing materials in the coaxial feedline to the cavity to damp some of the high frequency modes via the RF input coupling loop. Tests have shown that damping can be achieved in this way without dissipating a large amount of power at the fundamental frequency. The absorber might possibly be able to serve another function as a damping element for the RF power amplifier, suppressing unwanted resonances in the anode circuit when the cavity is off resonance.

V. REFERENCES

- [1] R. Boni et al., *IEEE Trans. Nucl. Sci.* **NS-32**, No. 5, 2815 (1985).
- [2] K. Kleman, these proceedings.