A Design Upgrade of the RF Cavity and Its Power Window For High Current Operation of the NSLS X-Ray Storage Ring

P. Mortazavi, M. Thomas
National Synchrotron Light Source
Brookhaven National Laboratory
Upton, NY 11973

I. ABSTRACT

The existing rf cavities and their auxiliary equipment have been operating since the onset of the National Synchrotron Light Source project. Although most power supply components have since been upgraded, the rf cavities have remained unchanged. The continuous improvements of the two storage rings, notably the combined increase in energy and current level as well as their reliability, necessitated a new design. A complete description of the newly designed cavity and its input power window will be described in this paper. Selection of material, vacuum seal mechanism and thermal conductive ceramics are discussed. A comparison between the two designs and expected improvements will also be presented.

II. INTRODUCTION

The National Synchrotron Light Source (NSLS) is a dedicated user facility operating since early 1980. Its two electron storage rings provide synchrotron radiation with spectrums ranging from Infra-red to X-Ray. The booster and the two storage rings are powered with rf systems operating at 52.88 MHz.

The two storage rings' rf cavities have almost identical geometry but different output power requirements. Four cavities are currently providing rf power to the x-ray ring under operating conditions of 2.58 GeV at 250 mA. The design current of 500 mA will require an additional 75% power. The corresponding I^2R losses will also increase nearly 50% [1]. Should a fault in one system put demands on the remaining cavities, the cavity losses will be increased significantly.

The present rf cavities were constructed from copper clad steel. Economic restrictions at the time dictated the choice of this material and created both mechanical and electrical deficiencies. These included poor heat transfer, joints vulnerable to vacuum leaks, poor interior surfaces and water to vacuum joints. The performance of these cavities has necessitated the replacement of them with a new design.

III. NEW DESIGN CRITERIA

Most conventional rf cavities are fabricated from copper or aluminum material. The choice of aluminum presents some difficulties due to poor vacuum characteristics. Aluminum tends to adsorb water leading to oxidization. This increases the coefficient of secondary electron emission, a phenomena that is unacceptable for storage rings. Extensive conditioning, as well as employing various suppression techniques, may be needed for reaching an acceptable vacuum level. This characteristic is undesirable for storage rings.

The combined electrical, mechanical and vacuum characteristics of copper make it the better choice for this design. Disadvantages were the physical size and difficulties in joining the flanges to the main body. Therefore, the design philosophy was focused on minimizing the number of joints. This approach, although more expensive, considerably increases the reliability, which was a main criteria.

IV. DESIGN FEATURES

The basic cavity design consists of a center cylindrical piece, two end covers and a mushroom-shaped center electrode. In addition, the number of manufacturing operations were kept to a minimum with emphasis on no water-to-vacuum joints. To accomplish this, use of traditional Conflat flanges were eliminated by machining MARMON type directly onto the main forging. The use of a commercial spring loaded seal/clamp mechanism, such as Helicoflex, required that the sealing surfaces have a hardness of 40 on Rockwell "B" Scale. Several tests under various conditions (i.e. Rb>32, baked at 150°C for 24 hours), were performed to prove the repeatability and reliability of this design. A Rockwell "B" hardness of 30 proved to be a minimum for this type seal.

The center electrode accounts for 80% of thermal power, of which 58% is deposited in the stem section. A series of blind circular holes are to be gun drilled right beneath the rf surface. These holes serve to supply and return cooling water, and are linked to matching cooling channels machined on the center electrode's rear disk.

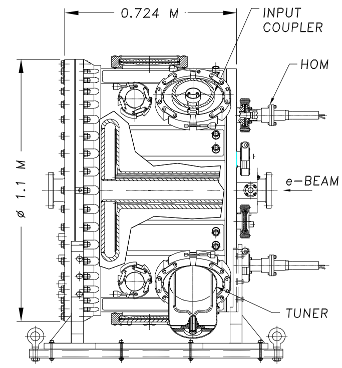

Figure 1. RF Cavity

The equivalent thermal loads were extracted from the output of the SUPERFISH computer code program. These values were used as boundary conditions on structural models using the finite element code ANSYS. A series of rectangular cooling channels are machined at optimum locations to maintain low temperature gradients. These channels will be covered with copper plates sealed by EB welds along all edges [Figure 1].

A detachable front cover provides both access to the interior as well as considerable latitude for coarse tuning. The use of Helicoflex seals is to serve both as a vacuum seal and an RF seal. This feature will provide the opportunity for future consideration of an adjustable gap tuning mechanism similar to that described in reference [2].

V. POWER WINDOW

The present power window utilizes alumina as a barrier between the air and vacuum. It is a six inch diameter, 50 ohm coaxial structure with a water-cooled coupling loop. The assembly is relatively heavy and cumbersome to install. A disadvantage of this design is the low thermal conductivity of the ceramic. This property, when coupled with localized multipactor electron bombardment, leads to vacuum breakdown. Both deficiencies have occurred during the course of NSLS operation. Future increased power requirements have also made it necessary to upgrade this design.

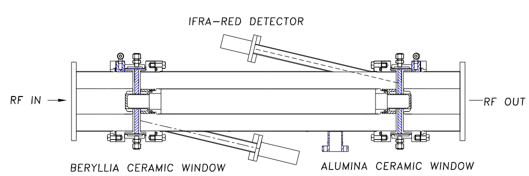

Figure 2. High power window test fixture

It is currently planned to change the alumina (Al_2O_3) to beryllia (BeO), whose electrical and mechanical properties are comparable. Each has a low dielectric constant, low loss tangent, and high electrical resistivity, but the thermal conductivity of BeO approaches that of aluminum metal. A test set-up consisting of two identical fixtures, but with two different ceramics (Al_2O_3 & BeO) is currently being assembled for comparison [Figure 2].

The temperature gradients of both ceramics will be simultaneously measured while under power with direct Infra-red recording. In addition, multipactoring activity can also be observed from windows on the vacuum side. The secondary electron emission coefficient can be lowered by coating the ceramic surface with metal compounds such as TiN. This technique is well documented and will be applied, if necessary. Although the thermal performance is expected to be proportional to the thermal conductivities, the overall results will be published at a later date. The proposed mechanical design of the coupling loop will be simpler than the existing one.

VI. CONCLUSION

The newly designed rf cavities for the x-ray storage ring are based on all OFHC copper material. This design incorporates use of spring loaded seals for both rf and vacuum, clearly a departure from the present norm of using Conflat flanges. Troublesome transitions between stainless steel and copper are eliminated, and the hardness requirements will be preserved by using EB welding (i.e. localized heating) as the joining technique. While a hardness of 32 on the Rockwell “B” scale on a test piece was found to be acceptable, the cavity’s flange will have a requirement for a hardness of 40 or better on the same scale. All peripherals will stay the same, including a series of water cooled antenna type dampers shorted by BeO resistor ceramics. The temperature control system is expected to be more responsive than before. The same feedback technique[3], using infra-red detection will be used. The means of detuning will also be the same as present, which is by insertion of a variable shorting loop in the cavity[3].

VII. REFERENCES

[1] Thomas, R. Biscardi, W. Broome, S. Buda, R. D’Alsace, S. Hanna, J. Keane, P. Mortazavi, G. Ramirez, J. M. Wang, “NSLS X-RAY SYSTEM UPGRADE”, Proc 1993 Part. Acc. Conf. Vol. 2, pp. 1419-1420.

[2] K. J. Kleman, “A NEW 50 MHZ RF CAVITY FOR ALADDIN”, Proc. 1993 Part. Accel. Conf., Vol. 2, pp. 924-926.

[3] J. Keane, P. Mortazavi, M. Thomas R. D’Alsace, H. Ackerman, J. Aspenleiter, W. Broome, S. Buda, G. Ramirez, “X-RAY RF SYSTEM UPGRADE AT THE NSLS”, Proc. 1993 Part. Accel. Conf. Vol. 2, pp. 1419-1420.