

NOVEL MECHANICAL DESIGN FOR RHIC TRANSVERSE STOCHASTIC COOLING KICKER

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Abstract

Based on the beam emittance measurement from the pickup, the RHIC Stochastic Cooling kicker uses sixteen narrowband high Q cavities (from 5 to 8 GHz) to kick (or to cool) the bunched beam on each of the two transverse planes in the two rings. The cavities are integrated to two pairs of cavity plates and installed in two UHV chambers. The new kicker features scissor like driving mechanism, frictionless flexure joints, water cooled cavity plates, small frequency shift (less than 0.05%) during the operation and maintenance free. Novel mechanical designs, including cavity plate, vacuum, cooling, driving mechanism, and support structure design, are presented. Structural and thermal analyses, using ANSYS, were performed to confirm chamber structural stability and to calculate the cavity plate deformation due to thermal and mechanical load. Good agreement between the calculated cavity plate deflection and the expected plate deformation from the cavity frequency shift measurements has been achieved. Three assemblies utilizing this design (1 for the vertical and 2 for the horizontal plane) were completed for the FY2012 run. Successful performance has been reported.

INTRODUCTION

RHIC has successfully employed the stochastic cooling technique to counteract the emittance growth in the high frequency bunched beam due to Intra Beam Scattering (IBS) in the past several runs [1]. Two essential components, a pickup (to measure the beam emittance in the transverse directions) and a kicker (to cool the beam transversely), are required for the transverse stochastic cooling. The new pickup design has been reported elsewhere [2]. This paper will focus on the mechanical design of the new transverse stochastic cooling kicker.

To minimize the input power, high Q resonant cavities were chosen as the new kicker in RHIC [3]. During the early stage kicker development, RHIC received a few stochastic cooling tanks from Fermilab as a gift, which were originally developed for the FNAL Tevatron. To take advantage of these tanks, the FNAL original vacuum chambers and the driving mechanisms [4] were used to

accommodate those cavities and to drive them from the cooling position (with a smaller aperture) to the standby position (with a larger aperture for the injected beam). There are several disadvantages with these designs: (1) The cavity plate guide shafts could get stuck in vacuum, (2) The beryllium copper RF spring fingers could lose their contact with the beam pipe, (3) The actuator could deliver an excessive force to bend the shaft, (4) The vacuum space is too small for the application, and (5) The cavity frequencies are not repeatable.

The newly developed transverse stochastic cooling kicker has addressed all the mechanical problems described above. Novel mechanical designs for the system are described below. Structural and thermal analysis results are also presented.

DESIGN REQUIREMENTS

The mechanical design requirements for the new transverse stochastic cooling kicker are: (1) To provide 16 high Q cavities, spanning the bandwidth of 5 to 8 GHz in 200 MHz intervals, for each kicker, (2) To split the cavities on the median plane and integrate them into two pairs of cavity plates, (3) To maintain repeatable cavity resonant frequencies, with a frequency shift of no more than 0.05% of their frequencies, (4) To provide a reliable actuator for the cavity plates, (5) To keep the cavity aperture at 20 mm, during the operation, and at no less than 124 mm, when not in use, (6) To provide a sufficient space in the vacuum chamber for an easy access and the installation of the cavity plates, (7) To provide adequate structural stability of the vacuum chambers and the support stands, and (8) To provide a bakable (up to 200°C) and maintenance free vacuum design.

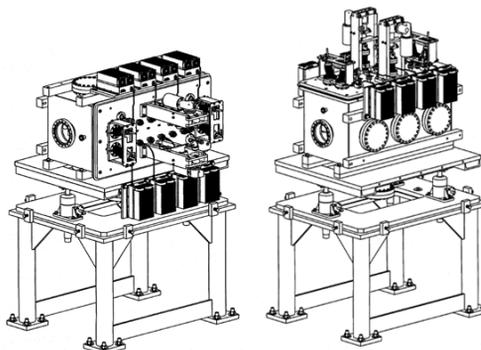


Fig. 1: One Half of a Horizontal and a Vertical Transverse Stochastic Cooling Kicker Assembly.

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TRANSVERSE KICKER ASSEMBLIES

The 16 cavities in each assembly are installed in two UHV chambers. Fig. 1 shows one half of a horizontal and a vertical transverse kicker assembly. One vertical and two horizontal kicker assemblies were completed for the FY2012 run.

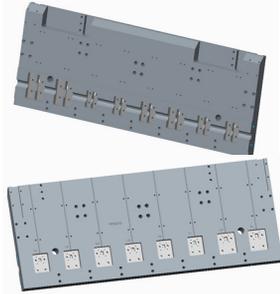


Fig. 2: A Typical Cavity Plate.

Unique Cavity Plate Design

Each 292 x 743 x 38 mm cavity plate is made of aluminum alloy 6061-T6 (Fig. 2), which is copper plated (25 microns thick) by Eper Technology. Flatness requirement on the split surface is within 13 microns along the plate length. Cavity shapes were accurately machined and fine cut by removing a small amount of material at a time to achieve the desired frequencies and the bandwidths. To obtain a repeatable cavity frequency, a closing force of ~ 13.6 kg (for the horizontal kicker) and of ~10 kg (for the vertical kicker), between two mating cavity plates, is required. Extension springs, by Lee Springs, were used on the side of each cavity to provide these forces (see Fig. 3). One cavity plate, with stiffer springs, serves as the hard stop to the mating plate, when the cavity plates are closing to each other.

The 50 ohms .14" (3.58 mm) OD semi-rigid shielded power cables, which were made by Advanced Technical Materials, are supported and cooled by the water cooled cavity plates (see Fig. 3 or Fig.4). Four ¼"-28 silver plated set screws, which are secured by four jammed set screws, are provided on each side of a cavity to tune the cavities (See Fig. 4).

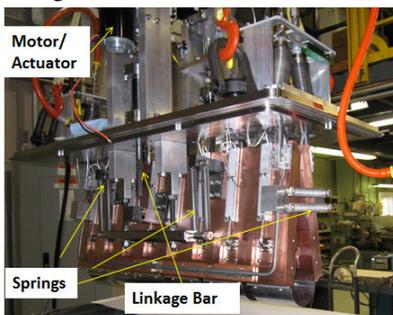


Fig. 3: Scissor Like Actuator.

Scissor Like Actuator

To take advantage of the commercially available

frictionless pivot bearings, the scissor like actuators (Fig. 3) were chosen to drive the cavity plates. Each actuator includes a ball screw actuator (Motion Systems, 85151DUB) and a linkage bar, which are driven by a DC motor (Motion Systems, 73464-400 24V). The actuator could be disengaged from the motor at both ends of the 25 mm stroke. Each cavity plate is supported by a pair of frictionless pivot bearings (C-Flex Bearings, JD-20). The cavity plates are lifted and rotated, like a scissor, about their pivot bearings. With both cavity plates rotated an angle of ~ 8 degrees from the vertical median plane in the opposite direction, the required aperture of 124 mm is achieved. A mechanical stop is provided to keep the two cavity plates parallel to each other when they are at the closed position.

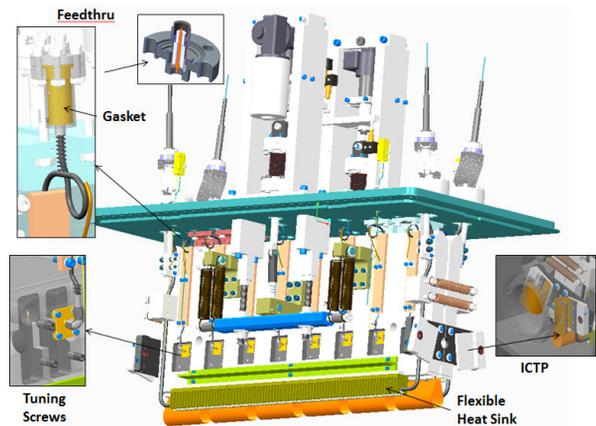


Fig. 4: Cavity Plate Assembly inside the UHV Chamber.

Custom Made Feedthru and Cable Strain Relief

To produce a reliable (high yield and bakable to 200°C) RF feedthru for the kicker, a custom designed RF feedthru was developed. The new 50 ohms SMA power connector is shown in Fig. 4, which has a stainless steel housing, a kovar center conductor, an alumina insulator and a Teflon insulator. The center conductor and the alumina insulator were silver brazed to provide the vacuum seal, which was fabricated by INTA Technologies. Ten custom made feedthrus were fabricated for testing, which were 100% leak tight and bakable to 200°C. To provide a strain relief to the unsupported cable, between the feedthru and the cavity plate, and to provide a vacuum seal to the feedthru, a novel dual purpose tubular shape copper gasket was also fabricated and installed (Fig. 4).

Stress Free Image Current Transition Piece

Image Current Transition Pieces (ICTP) are required to fill the gaps between the cavity plates and the neighboring beam pipes so that the excitation of high-order resonant modes could be avoided. Due to the scissor like motion of the cavity plates, the ICTP would fail easily with the

repetitive and excessive bending and twisting stresses. A novel stress free transition piece has been successfully developed for the purpose (see Fig. 4), which installs a single end flex-hinge (SDP/SI S99FXS-075020) between the ICTP and the cavity plate to prevent the piece from rotating with the plate.

Low Thermal Noise Water Cooling Design

During operation, the power dissipation from each cavity and from each power cable are about 3 W and 1 W respectively. With a water pipe rigidly attached the cavity plate (see Fig. 3), the calculated temperature gradient and the maximum thermal deformation on the cavities are 0.9°C and 160 microns respectively, which would result unacceptable frequency shifts in the cavities. Part of this deformation is caused by the different thermal expansions between the stainless steel pipe and the aluminum cavity plate. A novel flexible heat sink design (see Fig. 4) was developed to resolve the problem, which press fits the water pipe onto the fins of a convective heat sink (AAVID Thermalloy, Part no: 74925) so that the thermal contraction of the cooling pipe would not deform the cavity plate. Assuming that the water temperature was at 104°F (or 40°C), the thermal analysis result (using ANSYS) showed that the maximum temperature gradient would be ~ 1°C (see Fig. 5) and the maximum thermal deformation would be ~ 25 microns (.001”) across the cavities, which is equivalent to a frequency shift of ~5 MHz. The predicted frequency shift agrees with the frequency measurements on the cavities. To meet the design requirement, the frequency shift can be further reduced to ~2 MHz by a proper tuning on each cavity.

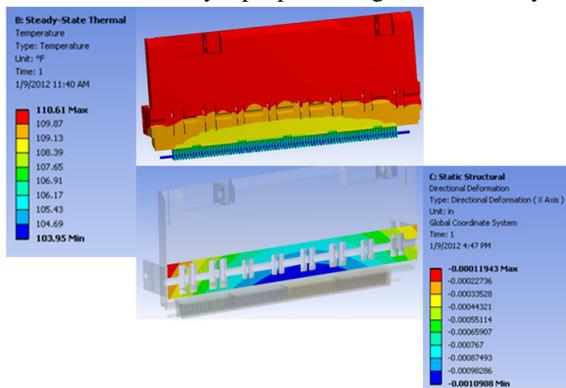


Fig. 5: Temperatures and Deflections on a Cavity Plate.

Large Rectangular Vacuum Chamber

Each UHV chamber has an interior dimension of 851 x 381 x 406 mm to allow install the cavity plates easily. Due to the rectangular opening and the long sealing length (~2565 mm long) on the top lid, no gaskets, including the Helicoflex metallic delta seal, could make a reliable UHV seal on top of the chamber. The solution

was to weld the top lid onto the chamber and to protect the weld with a few stiffener bars around the chamber (see Fig. 1). Assuming that a 15 psi (0.1 MPa) external pressure is applied on the stainless steel chamber, the calculated maximum Von Mises stress along the weld is 21086 psi (0.145 GPa) (a safety factor of 1.4 to yielding strength) (Fig. 6) and the maximum deformation on the chamber is 0.3mm.

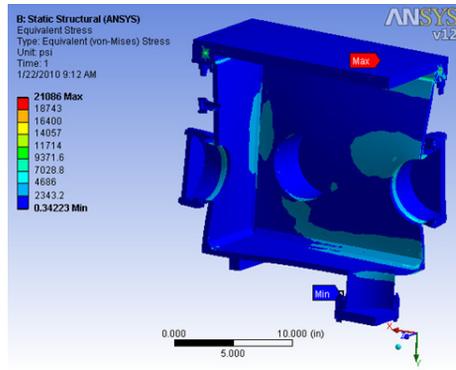


Fig. 6: Stresses on the vacuum Chamber.

CONCLUSIONS

We have developed a novel 5-8 GHz bandwidth bunched beam transverse stochastic cooling kicker, which uses scissor like actuators to drive the high Q cavity plates around the frictionless pivot bearings to obtain the required apertures. With a proper closing force applied on the cavity plates, using the flexible water cooled heat sink, and with some tuning, the cavity frequencies are repeatable within 0.05% of their frequencies during operation. By using the stress free Image Current Transition Pieces, eliminating wearable components, relieving strains on the power cables, silver plating or dicroniting stainless steel hardware, using only continuous water pipe, and venting all trapped vacuum volumes in the vacuum chamber, the vacuum components are virtually maintenance free. Three kicker assemblies were completed for the FY2012 run. Successful performance has been reported.

ACKNOWLEDGEMENT

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