RHIC STOCHASTIC COOLING MOTION CONTROL*

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Abstract

RHIC beams are subject to Intra-Beam Scattering (IBS) that causes an emittance growth in all three-phase space planes. The only way to increase integrated luminosity is to counteract IBS with cooling during RHIC stores. A stochastic cooling system [1] for this purpose has been developed, it includes moveable pick-ups and kickers in the collider that require precise motion control mechanics, drives and controllers. Since these moving parts can limit the beam path aperture, accuracy and reliability is important. Servo, stepper, and DC motors are used to provide actuation solutions for position control. The choice of motion stage, drive motor type, and controls are based on needs defined by a variety of special needs required for remote operations in an accelerator environment. In this report we will describe the remote motion control related beam line hardware, position transducers, rack electronics, and software developed for the cooling pick-ups and kickers.

INTRODUCTION

There has been a series of progressive generations of motion control for the evolving cooling hardware during the development effort at BNL since 2002. This report will primarily focus on the most recent advancements that include new horizontal and vertical transverse pick-ups and kickers. These devices in the RHIC warm regions are baked to 150C in order to maintain ~10^{-10} torr range vacuum. The moveable kicker cavities have stainless plumbing for water flow to closely regulate cavity temperature during operations. Also included here is a brief description of the older motion hardware that drives the pick-ups and kickers [2] inherited from the Tevatron. Many of these existing subsystems will remain installed and in service until all of the new hardware is deployed in the near future.

PICK-UPS

The pickups of a stochastic cooling system sense the Schottky signals from the beam. They need to be fully retracted to maximize the beam aperture during RHIC injection and acceleration. For cooling, the opposing plates are moved in slowly close to the beam in order to maximize the coupled signal level. The next generation pick-ups are based on a BNL design that employs the same internal Tevatron pick-up planar detectors, and improved motion actuation mechanics that uses a single drive actuator for each pick-up detector, see Figures 1-3. Full range of each pick-up detector is ~40mm, each can travel a few mm's beyond beam centerline.

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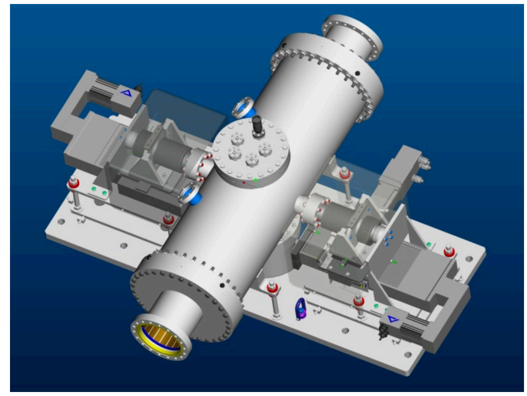

Figure 1: Horizontal transverse pick-up top view, right side has plunge and longitudinal stages, left side has only plunge stage.

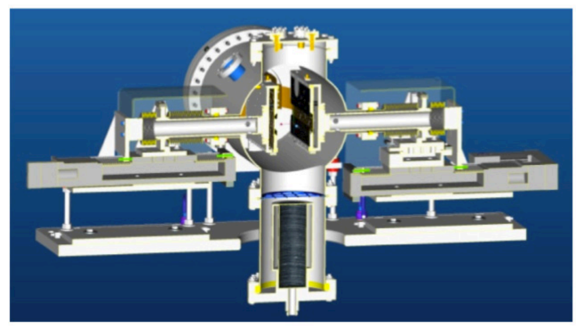

Figure 2: Horizontal transverse pick-up cut-away showing dual planar detectors and drive mechanics.

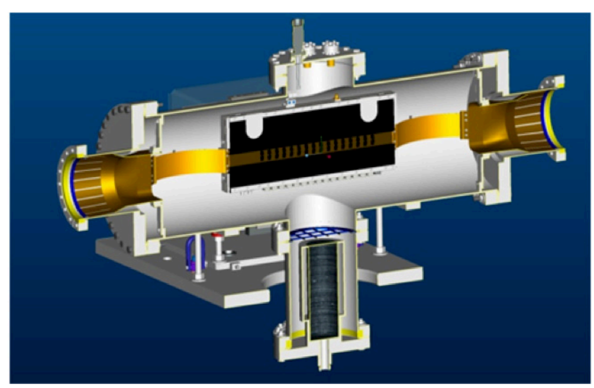

Figure 3: Horizontal transverse pick-up cut-away showing one planar detector.

To prevent a possible collision between opposing detectors, a set of bare copper conductors are mounted on top of the pick-up detectors that will make contact when the detectors are in close proximity. Sensing circuitry is provided to inhibit insert motion when contact is made. Linear pots LCP12A-50, and LCP12A-12 from ETI Systems are installed as position transducers, in addition to 1000 line incremental encoders, with RS-422 line driver outputs, that are integrated into the commercial stage assembly. Matching the relative longitudinal alignment of the two opposing internal pick-ups is critical because a longitudinal misalignment as small as 60 microns could ruin the common mode rejection required to suppress the coherent revolution harmonic power [3]. The new BNL design uses an additional external stage for this purpose. A few mm's of longitudinal motion range on one of the pick-ups is translated via bellows for proper longitudinal alignment.

New Pick-Up Stages and Controllers

Aerotech [4] provided hardware that can achieve submicron resolution for the actuation of the new pick-ups. The two transverse stages per pick-up are model number ATS150-100-U-20P-NM-NC-9DU-FB-BRK1-STD, the one side that has the longitudinal stage is ATS100-050-U-20P-NM-NC-9DU-STD. All are powered using a BMS60-AH-D25-E1000ASH-BK1 NEMA23 slotless brushless 0.33Nm (46 oz-in) servomotor, with 0.8Nm (112 oz-in) max holding torque brake, and 1000 line incremental encoders. Matching Aerotech Ensemble CP10-MXU PWM digital controllers with USB and Ethernet interface are employed, and installed in remote service buildings to reduce possible radiation damage and to provide convenient access during operations. Long (~100m) extension cables were installed between the controller and stages with no detrimental effects.

KICKERS

The kickers are multi-cell TM_{110} and TM_{120} cavities operated in π mode for longitudinal and transverse respectively. There are two similar versions of the new transverse kicker assembly, horizontal and vertical, each type actuates the split cavity along its respective axis.

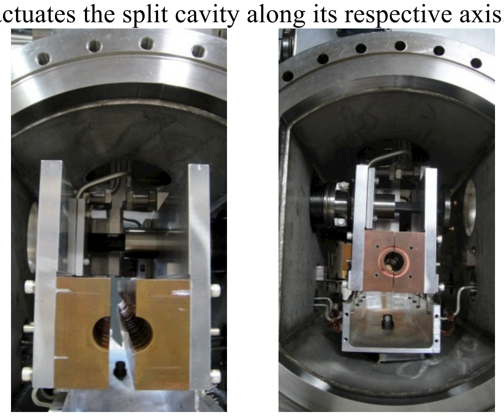

Figure 4: Original Kicker, open left, closed at right.

The cavities are split on the median plane and open when not in operation to provide a greater clear aperture for injected low energy beams. When the kickers are closed they become the limiting apertures in the collider. The maximum cavity frequency is limited to 9 GHz by the beam bore of 20 mm. Early kicker versions use internal sliding parts for alignment, and stepper driven worm gears and ball screw linkages with very large mechanical advantage to actuate the split cavities, see Figure 4. These drives have the capability of delivering excessive force on the mechanics when the cavities were closed tightly, resulting in reliability problems.

The new improved motion strategy employs a scissor like motion configuration as shown in Figures 5 & 6. Initially one side of the cavity is slowly driven (~10 degrees of rotation per side) into an internal mechanical stop, and then the other opposing side is slowly driven in until almost closed. The motor reaches the end of its power stroke and begins free-wheeling ~1mm before closed. Finally, the cavity closes fully with enough force provided by internal springs, and gravity force from an internal ~70lb stainless weight. The closing force is pre-adjusted during assembly so all of the cavities resonate at the correct frequencies.

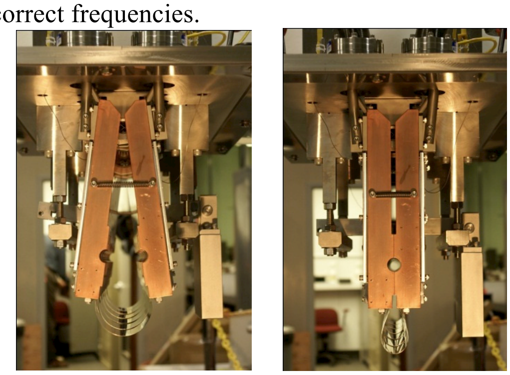

Figure 5: Photo of new vertical transverse kicker, end view, beam aperture 20mm diameter, open left, closed right. Note internal rectangular ballast weight, lower right.

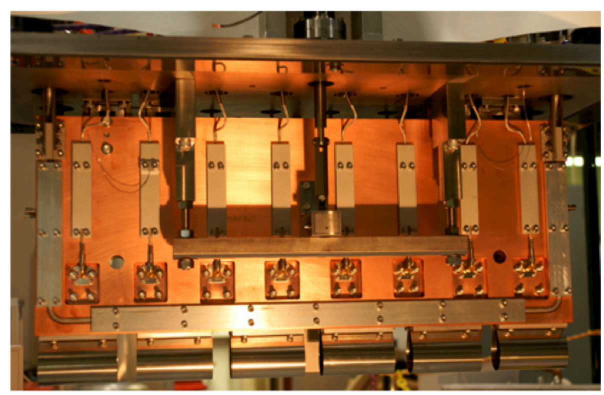

Figure 6: New vertical transverse kicker (~70cm long), side view showing single actuator drive (center), and fixed horizontal stop bar suspended on either side.

The moving cavity structure is joined at the top by pivot bearings [5] that allows rotational motion with no moving parts that touch or rub (thus no lubrication) which is essential for the ultra-high vacuum in RHIC. A set of pillow blocks is used to hold the pivot bearings. One block is fixed; the other allows for thermal expansion (of ~1.5mm over the expected 50C change) in the longitudinal direction via dicronite coated stainless slide pins. Both transverse kicker cavity drives employ DC motors, 73464-400 24V, connected to a ball drive actuator, 85151DUB, and a 1600:1 gear reduction, all parts from Motion Systems Corporation.

SURVEY

The Leica AT401 laser tracker, and Spatial Analyser software from New River Kinematics was used to accurately position and align the pick-ups and kickers. Two rectangular frames shown in Figure 7 were installed and used in conjunction with a set of survey monuments mounted on the pick-up tank body as references to accurately locate the position of the internal moving detector arrays.

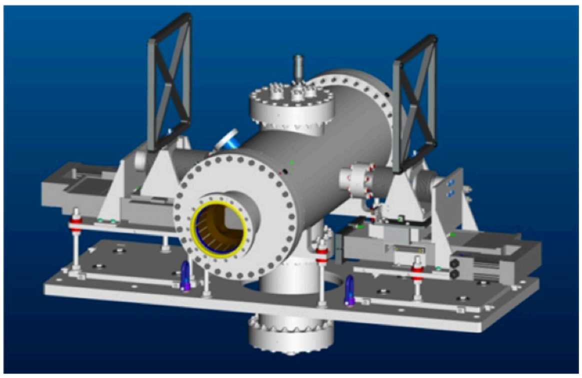

Figure 7: Pick-up showing survey frames for precision laser survey alignment.

PIN DIODES

A pair of Bergoz Beam Loss Monitors (BLM) that employ 7.34 mm^2 coincidence PIN diodes are mounted downstream of each pick-up and kicker. These are used to avoid primary beam impact. They measure low level loss counts with a 1 second update rate as the internal parts slowly move, over several minutes, closer to the beam to prepare for cooling.

STEPPER CONTROLLERS & DRIVERS

The motion control for the original pick-up and kickers we inherited from the Tevatron are all actuated by stepper motors. Many of these will continue to be in service until the next generation pick-ups and kickers are fully deployed.

Stepper Controllers

Controllers for stepper motion are primarily based on the VME based Oregon Micro Systems OMS VX2-022. Each board can control 2 axis of stepper motion with encoder feedback. A BNL designed VME V186 transition module was designed to provide field isolation, a convenient interface on the front of the VME chassis, and an array of status LED's.

Stepper Motor Drivers

We initially used Pacific Scientific PD2406Di-001-E drivers to drive the Slo-Syn M062-CE09E, 125 oz-in bipolar series steppers from the Tevatron. These drivers were attractive since they are field configurable via RS-232 and a laptop, and can drive long cables (>150m) without stability problems. Eventually these drivers became obsolete, and suffered from lack of output protection circuitry. The next generation Pac Sci P70530 driver we use has all the features of the previous model, better user interface, automatic tuning routines, output protection, and is about 1/3 the cost.

HIGH LEVEL CONTROLS

Applications were created using Java, see Figure 8, on a Linux Red Hat platform for each subsystem. A software manager runs behind the scenes to handle all of the functional dependencies. Engineering level pet pages were created in an ADO (Accelerator Device Object) development environment on the same Linux platform to control and monitor all aspects of the moving parts. Standard ASCII communication is used between Linux and Aerotech controllers. An automatic tape sequencer that is prompted by programmed events in the RHIC cycle is used to automatically insert all pick-ups and kickers at the beginning of a RHIC store, and retract before injection.

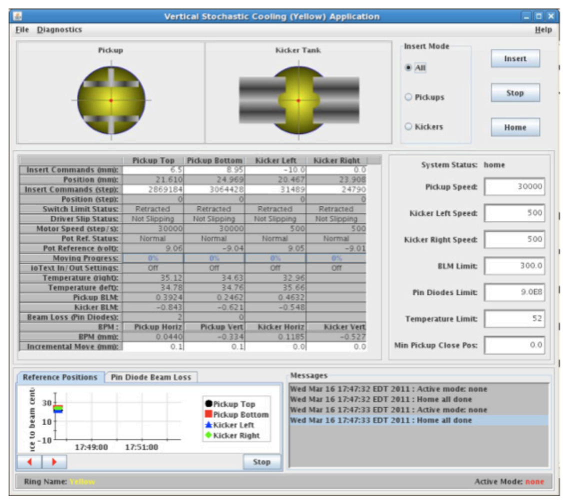

Figure 8: Motion control Java interface example.

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