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DISCLAIMER

RHIC STOCHASTIC COOLING MOTION CONTROL*

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Abstract

Relativistic Heavy Ion Collider (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 the variety of mechanical specifications, the unique performance requirements, and the 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 RHIC stochastic 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. It is important to note that all beam line hardware in RHIC is 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, and an intermediate generation BNL designed kicker. 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 1-4. Full range of each pick-up detector is ~40mm, each can travel a few mm's beyond beam centerline. 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.

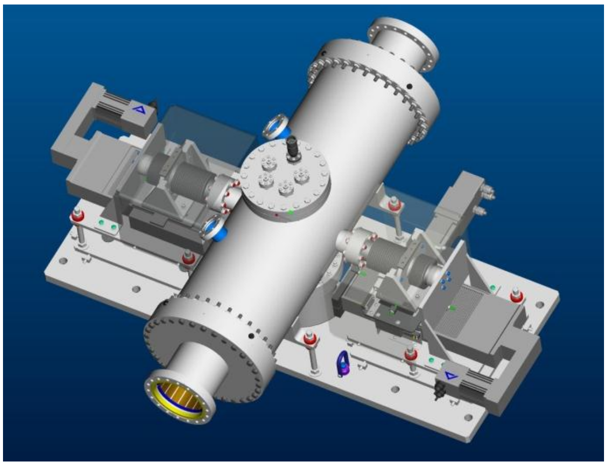

Figure 1. Horizontal transverse pick-up top view, right side has plunge and longitudinal stages, left side has only plunge stage.

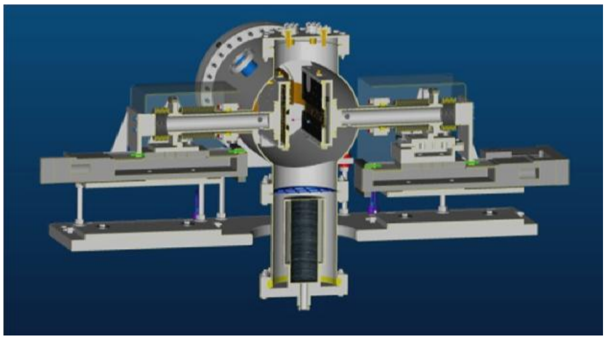

Figure 2. Horizontal transverse pick-up cut-away showing dual planar detectors and drive mechanics.

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. A few mm's of longitudinal motion range on one of the pick-ups is translated via bellows for proper longitudinal alignment.

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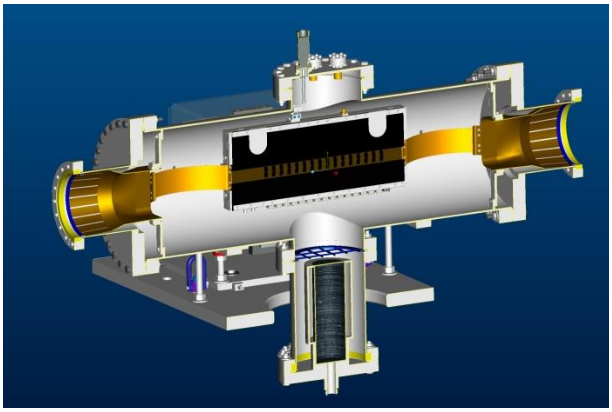

Figure 3. Horizontal transverse pick-up cut-away showing one planar detector.

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 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) cables were installed with no detrimental effects.

Survey

The Leica AT401 laser tracker, and Spatial Analyzer software from New River Kinematics were used to accurately position and align the pick-ups and kickers. Rectangular frames shown in Figure 4 were installed and used in conjunction with survey monuments on the pick-up tank as references to accurately locate the position of the internal moving detector arrays.

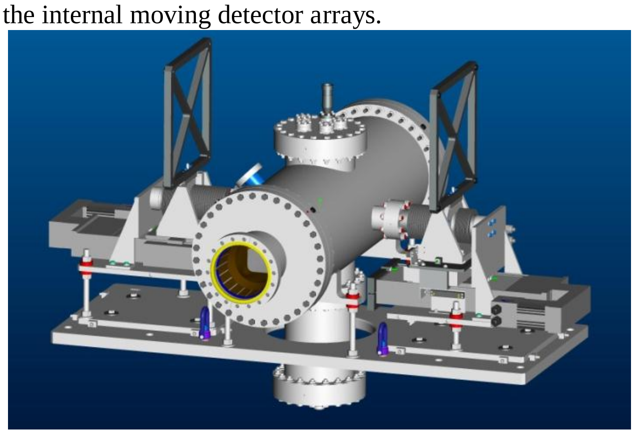

Figure 4. Pick-up showing survey frames for precision laser survey alignment.

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. 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. The maximum cavity frequency is limited to 9 GHz by the beam bore of 20 mm. When the kickers are closed they become the limiting apertures in the collider.

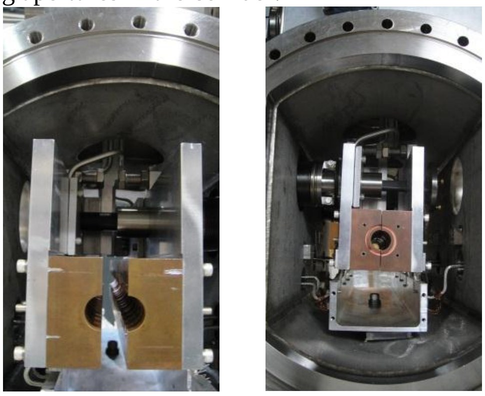

Figure 5. Original Kicker, open left, closed at right.

Early kicker versions use stepper driven worm gears and ball screw linkages with very large mechanical advantage to actuate the split cavities, see Figure 5. These had the capability of delivering excessive force on the mechanics when the cavities were closed tightly, resulting in reliability problems. The new improved design strategy drives one side of the cavity in a scissor configuration (~10 degrees of range), see Figures 6 & 7, into an internal mechanical stop, then the other opposing side is driven in until almost closed, and finally, it closes fully with enough force provided by internal springs so the cavities resonate at the correct frequencies.

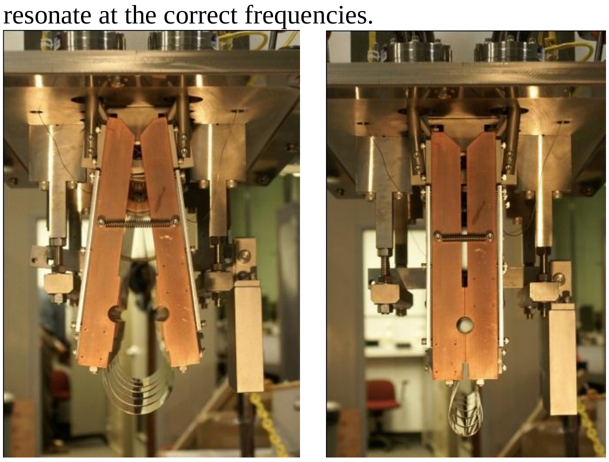

Figure 6. Photo of new transverse kicker, end view, beam aperture 20mm diameter, open left, closed right, each side moves ~10deg.

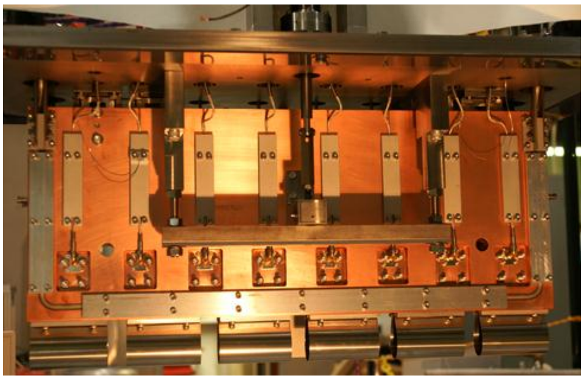

Figure 7. New transverse kicker, side view showing single actuator drive (center), and fixed horizontal stop bar suspended on either side.

The drive motors do not apply the closing force. Internal counter springs are used to reduce the force necessary needed for motion. The transverse kicker cavity drive employs a DC motor, 73464-400 24V, connected to a ball drive actuator, 85151DUB, both from Motion Systems Corp. The new transverse kickers shown above were designed by BNL and fabricated by Incodema [5].

STEPPER CONTROLLERS & DRIVERS

The motion control for the original pick-up and kickers we inherited from the Tevatron are 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 were attractive since they are field configurable via RS-232 and a laptop, and can drive long cables (up to 150m) without stability problems. Eventually these became obsolete, and suffered from lack of output protection circuitry. The next generation Pacific Scientific P70530 driver has all the features of the previous model, better user interface, automatic tuning routines, output protection, and is about 1/3 the cost.

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 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.

HIGH LEVEL CONTROLS

Applications were created in a Java user interface, 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 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.

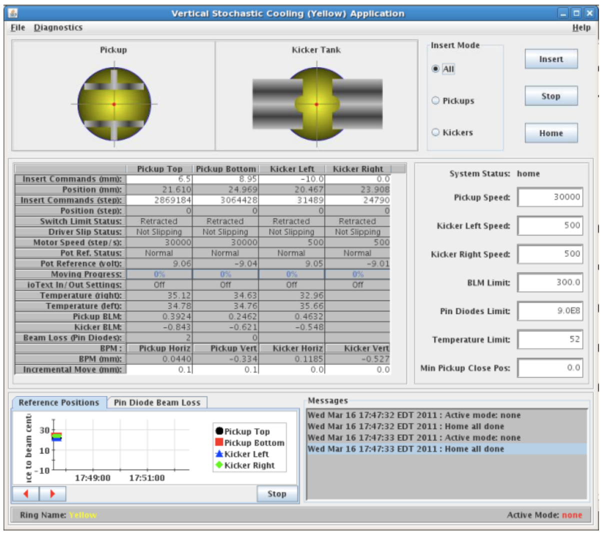

Figure 8. Motion control Java interface example.

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REFERENCES

[1] J. M. Brennan, M. Blaskiewicz “Stochastic Cooling in RHIC” PAC09, Vancouver, Canada, WE3GRI01

[2] D. McGinnis, et al. PAC 1991, p1389 and P. Hurh, G. Jackson, PAC 1993, p. 2148

[3] G. Jackson, et al, “Bunched Beam Stochastic Cooling in the Fermilab Tevatron”, PAC93, p. 3533.

[4] http://www.aerotech.com/

[5] http://www.incodema.com/ Ithaca, NY.