MEASUREMENTS OF MECHANICAL TRIPLET VIBRATIONS IN RHIC*

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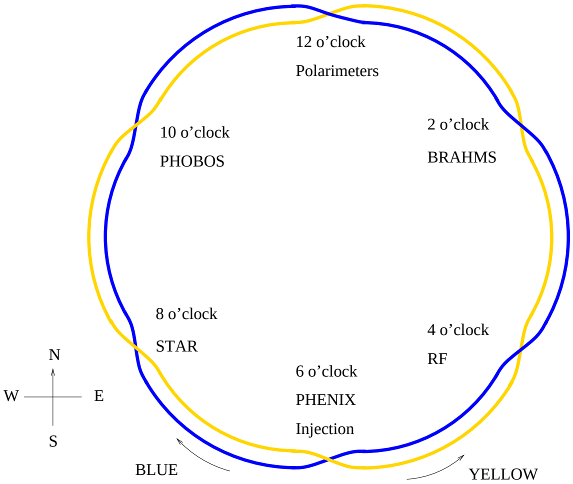

Figure 1: RHIC schematic overview.

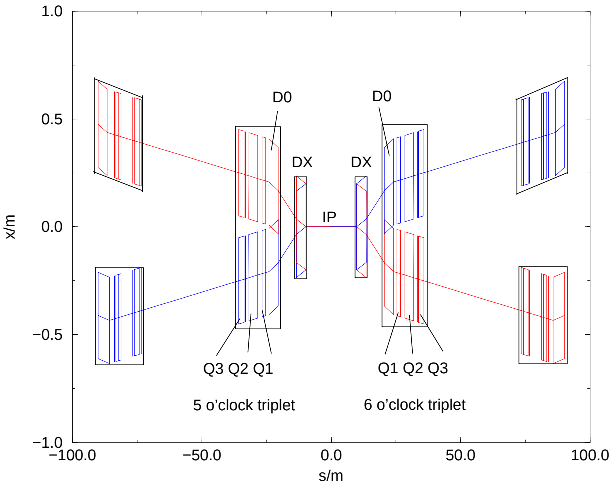

Figure 2: Schematic view of a RHIC interaction region. As a nomenclature example, the arrangement of the 6 o'clock IR is shown. Negative values of x correspond to the ring inside, positive values to the ring outside.

Abstract

Mechanical vibrations of the RHIC interaction region triplets has been identified as the dominant source of orbit jitter for frequencies up to 20 Hz. We report the results of detailed measurements that were performed to characterize these effects. We discuss the impact on beam dynamics and possible cures.

1 INTRODUCTION

The Relativistic Heavy Ion Collider (RHIC) [1] consists of two superconducting storage rings ("Blue" and "Yellow") that intersect at six equidistantly-distributed locations. The nomenclature of these intersection regions (IRs) is chosen in analogy to a clock, with "12 o'clock" being the northernmost IR, as shown in Figure 1. Within each of these IRs, the triplet on the right - as seen from the center of the RHIC rings - bears the same number as the IR itself, while the left triplet is named after the arc to its left. For example, in the 4 o'clock interaction region, the left triplet is referred to as the 3 o'clock triplet, while the right one is called the 4 o'clock triplet. Counter-rotating beams collide at four of these intersections, which are equipped with the detectors BRAHMS (2 o'clock), PHENIX (6 o'clock), PHOBOS (10 o'clock), and STAR (8 o'clock). The 12 o'clock IR is equipped with polarimeters, while the RF cavities are located at 4 o'clock.

Though beams only collide in four interaction regions, all six are identical to keep symmetric machine optics. Final focusing is provided by superconducting quadrupole triplets, which consist of two sets of magnets installed side-by-side, sharing a common cold mass. Since the two storage rings are lying side-by-side in the arcs, beam orbits are bent towards each other by D0 dipole magnets. To achieve head-on collisions, the resulting intersecting orbits are bent back by the DX dipole magnet, as schematically shown in Figure 2.

During the RHIC 2001 run, purely horizontal orbit jitter with frequencies of about $10\,\mathrm{Hz}$ was detected in both rings. The amplitude of this vibration corresponds to $5\ldots10$ percent of the rms beam size at a nominal emittance of $\epsilon = 10\,\pi\,\mathrm{mm\,mrad}$. A spectral analysis of this orbit jitter, as shown in Figure 3, revealed that spectra in both beams are nearly identical. Therefore this effect was likely to be caused by some common source.

As mentioned earlier, the only common magnetic elements in RHIC are the DX dipoles and the final focus quadrupole triplets, installed in the interaction regions. The observed horizontal orbit oscillation could therefore be caused by magnetic field fluctuations in the DX dipoles due to power supply ripple, or by mechanical vibration of the common cold mass of the final focus quadrupole triplets. During a maintenance day in October 2001, vibration measurements were performed at all triplets in order to determine the source of the orbit jitter.

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* Work performed under the auspices of the U. S. Department of Energy

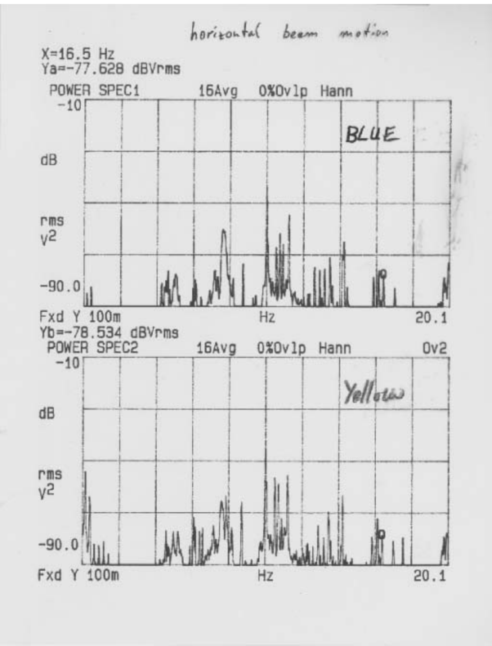

Figure 3: Simultaneously measured orbit vibration spectra in the BLUE (top) and YELLOW (bottom) RHIC rings.

2 VIBRATION MEASUREMENTS

Vibration measurements were performed on all RHIC triplet cryostats, using a 3-axis piezoelectric accelerometer as sensor. The sensor was connected to a spectrum analyzer to determine the vibration spectra in all three directions. Each triplet exhibited one or two dominant lines in the horizontal vibration spectrum around 10 Hz, which explains almost all dominant lines in the horizontal orbit motion spectrum. Figure 4 shows the acceleration spectrum of horizontal triplet vibration, together with the spectrum of horizontal beam orbit motion. The two peaks in the triplet vibration spectrum clearly show up in the beam jitter. Table 1 summarizes all major peaks within the beam jitter spectrum, together with the triplet at which these lines could be found in the vibration spectrum. As this table shows, 13 out of 14 dominating frequency lines in the beam spectrum can be traced back to specific triplets.

In contrast, the spectra of vertical and longitudinal motion did not show any dominant lines. This lack of dominant frequencies in the vertical vibration spectra is consistent with the observed absence of vertical beam jitter.

3 CONCLUSION

We have observed that horizontal beam jitter in RHIC is caused by mechanical vibrations of the interaction region triplets. A possible explanation of triplet vibration at frequencies around 10 Hz is an oscillating helium pressure wave in the downward-angled leads of the triplets [2]. When liquid helium reaches the warm end of the lead, it immediately changes into its gaseous phase, thus greatly increasing its volume. This pushes the liquid helium back until some equilibrium is reached. The helium gas is subsequently pumped away, leaving room for liquid helium, which again finally reaches the warm end of the lead. The resulting pressure wave oscillation could introduce sufficient force to the cold mass to cause the observed vibration. The mechanical resonance frequency of the cold mass on

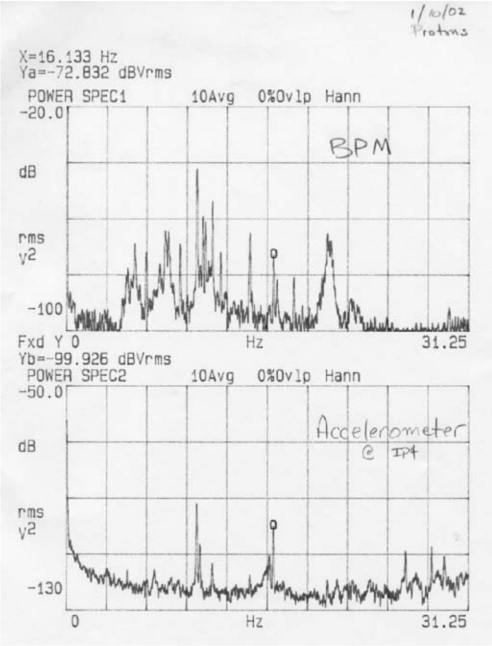

Figure 4: Simultaneously measured vibration spectra of the beam orbit in the YELLOW RHIC ring (top) and the 4 o'clock triplet acceleration (bottom).

Table 1: Dominant frequency lines of beam orbit vibration as shown in Figure 3, and triplets where these frequencies have been detected in the horizontal vibration spectrum. Triplet numbers in brackets indicate locations where the corresponding frequency is present in the vertical triplet vibration spectrum only.

Frequency	Triplet
7.75	12
8.825	8
10.14	4, 11, 12
10.625	9
10.825	2
11.00	11
11.325	6
12.700	(10)
13.000	1
13.275	unknown
13.55	9, (2)
14.325	2
15.950	2
16.133	4
16.500	8

its two posts is also near $10\,\mathrm{Hz}$, which could furtherly enhance this effect.

This explanation is consistent with the observation that the mechanical vibration of the triplets vanished after the machine was warmed up to room temperature during shutdown. A more direct test could be performed by increasing the helium flow in the leads of one particular triplet under investigation such that the entire lead eventually is cooled to liquid helium temperature, thus avoiding the reflection of liquid helium entirely. However, since the helium flow is now determined by fixed orifices, this test cannot be performed easily.

If this hypothesis explains the observed triplet vibrations, an increased helium flow in the leads will eliminate it entirely. Other possible remedies include installation of an active feedback system to stabilize orbit jitter. However, such a system would have to consist of correction elements close to the jitter sources in order to avoid long, oscillating closed-orbit bumps, leading to tune modulation via orbit length variations. Since nearly all twelve triplets contribute to beam orbit vibration, twelve correction dipoles are required per ring. Obviously, such a system is neither cheap nor simple.

Simulation studies are being performed to investigate possible emittance growth caused by beam centroid motion at the interaction points during beam collisions, and associated tune modulation. This work is still in progress.

4 ACKNOWLEDGEMENTS

We would like to thank J. Sondericker for interesting discussions concerning the cause of the vibration, and T. Satogata for reading the manuscript.

5 REFERENCES

[1] RHIC design manual

[2] J. Sondericker, priv. comm.