ELECTRON BEAM STABILITY AND BEAM PEAK TO PEAK MOTION DATA FOR NSLS X-RAY STORAGE RING*

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Abstract

In the past two years, a significant reduction in electron beam motion has been achieved at the NSLS X-Ray storage ring. The implementation of global analog orbit feedbacks, based on a harmonics correction scheme, has reduced the beam motion globally. Implementation of six local analog feedback systems has reduced the beam motion even further at the corresponding beam line straight sections. This paper presents beam motion measurements, showing the improvement due to the feedback systems. Beam motion is measured using a spectrum analyzer and data is presented at various frequencies, where peaks were observed. Finally, some of the beam motion sources are discussed.

I. INTRODUCTION

The X-Ray storage ring at the National Synchrotron Light Source (NSLS) is now in its tenth year of operation. Amongst other developments[1 and 2], improvement in the orbit stability has been a major goal of the department, second only perhaps to the machine's operational reliability. The early part of this effort was devoted to improving and upgrading several key systems such as magnet power supply system, RF system. This contributed to a fair amount of beam stability improvement but far from the acceptable range. Next, local feedback systems[3] were implemented where each system kept the electron beam stable at the two ends of an insertion device straight section. Although, the results at these beamline met our expectations, the beam motion at bending magnet beamline user's locations was far from satisfactory.

In December 1989, a prototype analog global feedback in the UV storage ring[4] (2nd storage ring at NSLS) showed a significant improvement in beam stability. This system showed lot of promise for the X-Ray ring. A crash program was, therefore, put into effect for an operational system for the X-Ray ring. This was achieved in August 1991 with excellent results[5].

This paper presents analysis of the beam motion at all pue locations both in frequency as well as time domain and then identifies some of the sources of beam motion. Further, it tabulates beam position data quantitatively at all pue's locations.

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II. CHARACTERIZATION OF THE BEAM POSITION INSTABILITY

The single most important part of the beam instability is the "Orbit Drift" and is discussed in section 3. When the beam is originally centered or aligned by a dc orbit correction, an "Orbit Drift" is observed by as much as 0.5 mm horizontally and 0.2 mm vertically over the operational run of 12 to 24 hours (with no feedbacks implementation). In addition, a beam "bounce" or fast peak to peak motion about its nominal position exist which is characterized by analyzing the spectrum of the beam position. The amplitude and the frequency of the beam bounce depend on various factors and are discussed in section 4.

III. ORBIT DRIFT

Typical horizontal beam motion for an X-Ray operational run is shown at one pue location in fig, 1. This is a run of 8 hrs following a fill, where beam current decays from 200 ma to 100 ma (shown by the smooth curve). It can be seen that the majority of the drift occurs during the initial 2 to 3 hours period after the fill. The cause appears to be the coupling of the chambers to the magnet[6] due to uneven cooling. The cooling configuration of the vacuum chamber and the constriction of the vacuum chambers in the many magnets, distorts the vacuum chamber causing the main magnets to move and also the orbit as a function of the beam current.

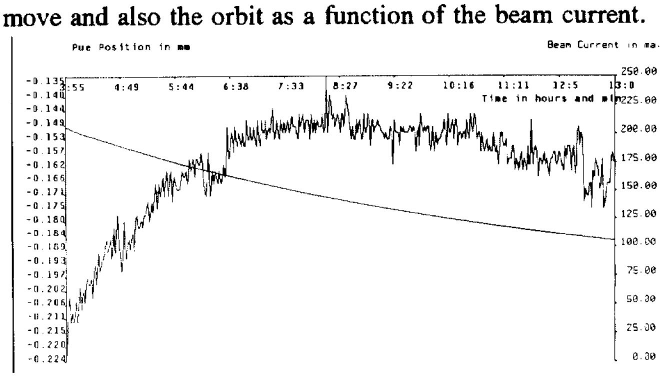

Fig. 1. Typical horizontal orbit drift at PUE 05

The orbit drifts in horizontal and vertical planes are tabulated in Table 1 at each pue location for an operation, indicating which pue is a part of local or global feedback systems. This same data is plotted in Figure 2. As expected, the least drift is noted at local feedback pue locations (shown by circled pues in figure 2), where feedbacks are implemented.

X Ray beam drift for operation run on 5/10/92 and location of global/local feedback pues				
PUE #	Hor. Drift (microns)	Hor. Feedback	Vert. Drift (microns)	Vert. Feedback
3	57	-	10	-
4	48	-	26	-
5	99	Global	24	-
6	67	-	22	-
7	67	-	23	-
8	70	Global	24	Global
9	37	-	15	-
10	41	-	19	-
11	76	Global	45	-
12	48	Local(*)	46	Local(*)
13	50	Local(*)	19	Local(*)
14	85	Global	21	Global
15	57	-	28	-
16	63	-	30	-
17	68	Global	36	-
18	44	Local(*)	10	Local
19	38	Local(*)	5	Local
20	66	Global	22	Global
21	33	-	9	-
22	54	-	9	-
23	51	Global	27	-
24	39	Local(*)	17	Local(*)
25	56	Local(*)	14	Local(*)
26	84	Global	22	Global
27	68	-	24	-
28	59	-	22	-
29	42	Global	24	-
30	26	Local	7	Local
31	23	Local	8	Local
32	45	Global	24	Global
33	50	-	40	-
34	89	-	31	-
35	68	Global	24	-
36	51	-	19	-
37	46	-	29	-
38	79	Global	20	Global
39	49	-	42	-
40	50	-	47	-
41	26	Global	40	-
42	23	Local	9	Local
43	17	Local	8	Local
44	50	Global	25	Global
45	58	-	14	-
46	56	-	27	-
47	40	Global	32	-
48	17	Local	7	Local
1	20	Local	7	Local
2	41	Global	19	Global

*These local feedbacks were not implemented at the time of data taken.

Table 1. Maximum orbit drift

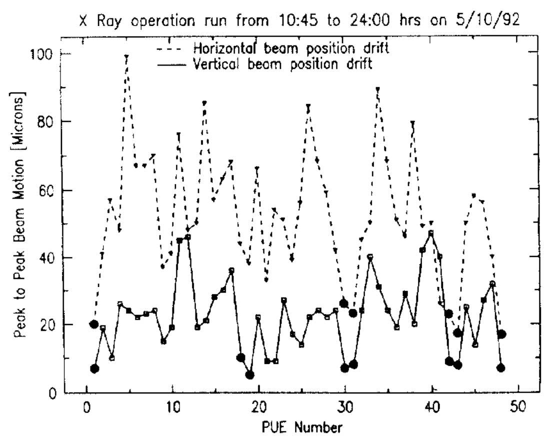

Fig. 2. Maximum orbit drift

Before the implementation of the feedback system, the orbit drifts were measured to be in the range of 200-500 microns horizontally and 50-200 microns vertically. Feedback systems reduce this motion to 17-100 microns horizontally and 7-50 microns vertically.

IV. BEAM "BOUNCE" OR FAST PEAK-TO-PEAK MOTION

Spectrum analysis of the beam motion, shown in figure 3, reveals that there are several peaks from 0.5 hz to 500 hz, however the magnitude of these peaks depends on the external conditions. To explain, the spectrum is divided into 3 frequency ranges: a) 0.5 hz to 10 hz; b) 10 hz to 60 hz; c) 60 hz and its harmonics.

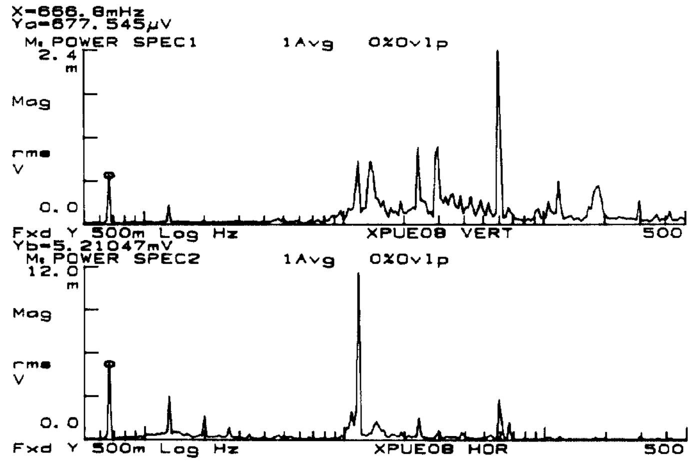

Fig. 3. Spectrum at PUE 08 - 1 mV rms $\simeq$ 5.6 microns p-p (measured on 5/3/93 - dry weather conditions)

The frequency range a) contains peaks at the fundamental frequency 0.67 hz and its harmonics which are present only when NSLS booster is on (ramp rate of 0.67 hz). This coupling occurs magnetically to the electron beam in the X-Ray ring. The figure 4 shows the horizontal displacements at the 2nd harmonic frequency (1.33 hz) due to NSLS booster, with global feedback off and on. The remaining bump towards pue 41 and 44 (with feedback on) in figure 4, tells us that this is the location where coupling occurs and where magnetic shielding should be attempted.

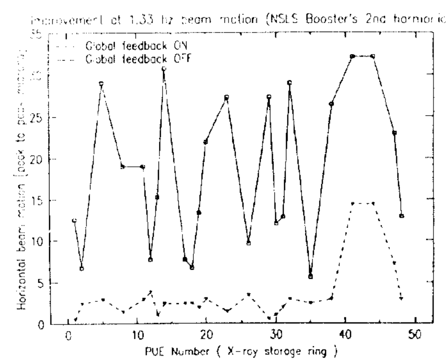

Fig. 4. Horizontal peak-to-peak beam motion at 1.33 hz.

The bounce components in the 10 hz to 60 hz range have been shown, mostly, to be related to several mechanical vibration modes of quadrupole girder support structure. After vibration evaluation[7], significant improvements in vibration reduction were achieved by performing: grout repairs on the magnet installation, removal of lead shielding from the magnet (thus detuning the natural frequencies) and tightening the bolts holding the magnet structure. The predominant horizontal 11.89 hz peak in the bottom trace of figure 3 is excited by the action of a nearby High Flux Beam Reactor (HFBR) Helium compressor which is about 1000 feet away. Vibration measurement results[7], also show that this amplitude increases significantly (by a factor of 3 to 5) during periods of heavy rainfall. It supports the fact that transmissibility of soil vibration waves increases dramatically with moisture contents. During rainfall conditions, the amplitude at this frequency is in the range of 25 to 250 microns horizontally and 5 to 20 microns vertically. When HFBR compressor is off, the bounce component in the 10 to 60 hz frequency range is less than 50 microns horizontally and 10 microns vertically. Spectrum peaks with significant amplitudes are tabulated in table 2.

Higher frequency components occurring mainly at 60 hz and its harmonics are electrically induced, although their sources are not totally known. The amplitudes at 60 and 120 hz are given in table 2.

Figure 5 provides a typical beam motion, in time domain, at horizontal pue 8 measured during the wet conditions (4/21/91). The top trace shows the motion when both the NSLS booster and HFBR compressor are off. The middle trace shows the motion when NSLS booster is turned on with peaks occurring every 1.5 seconds. The bottom trace shows the motion with both NSLS booster and HFBR compressor on. It should be noted that p-p 11.89 hz motion in figure 5 is about 250 microns (5 boxes x 50 microns = 250 microns p-p). This motion is larger by a factor of 3.7 to that measured in figure 3 (12 mv rms x 5.6 microns/mv p-p = 67.2 microns p-p). This is due to the dry conditions that existed when the measurements were made for figure 3 (5/3/93).

X Ray electron beam p-p motion at various frequency (or frequency range) as measured at 48 pues around the ring

Catagory	Frequency range	Horizontal (microns p-p)		Vertical (microns p-p)	
		Global fdbk off	Global fdbk on	Global fdbk off	Global fdbk on
a	~ 0.5 hz to 10 hz (Booster Effect)	50-100	10-50	5-20	< 1
b	11.89 hz (HFBR Compressor On)	25-250	10-100	5-20	2-10
	10 to 12 hz (HFBR Compressor off)	10-50	2-10	1-5	< 1
	24.41 hz	2-10	1-5	2-10	1-5
	29.85 hz	2-10	1-5	2-10	1-5
	54.64 hz	1-10	NI	< 1	NI
c	60 hz	5-15	NI	5-15	NI
	120 hz	1-5	NI	1-10	NI

NI - No improvement

Table 2. Peak-to-peak beam motion at various frequencies.

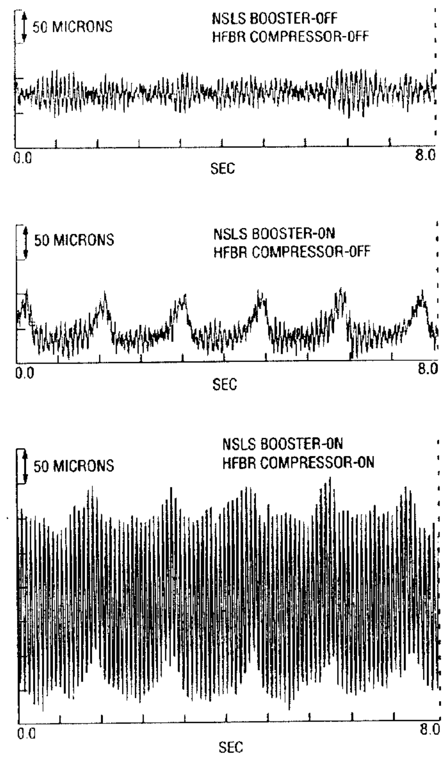

Fig. 5. Time domain beam motion at PUE 08 (measured 4/21/91 - heavy rainfall conditions)

ACKNOWLEDGEMENTS

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