H^+- AND H^--BEAM POSITION AND CURRENT JITTER AT LANSCE*

J. D. Gilpatrick#, B. Blind, M. S. Gulley, C. Pillai, J. Power, LANL, Los Alamos, NM, 87545, U.S.A.

Abstract

During the CY2005 and CY2006 Los Alamos Neutron Science Center (LANSCE) beam runs, beam-development shifts were performed in order to acquire and analyze beam-current and beam-position jitter data for both the LANSCE H^+ and H^- beams. These data were acquired using three beam-position monitors (BPMs) from the 100-MeV Isotope Production Facility (IPF) beam line and three BPMs from the Switchyard (SY) transport line at the end of the LANSCE 800-MeV linac. The two types of data acquired, intermacropulse and intramacropulse, were analyzed for statistical and frequency characteristics as well as various other correlations including comparing their phase-space characteristics in a coordinate system of transverse angle versus transverse position. This paper will briefly describe the measurements required to acquire these jitter data, the analysis of these data, and some interesting implications to beam operation.

BEAM DEVELOPMENT SHIFT DESCRIPTION: JITTER EXPERIMENTS

Several beam-development shifts were used to acquire and record the bunched beam currents and positions (in order to calculate angles) in both the IPF beam line and the SY beam line [1]. These centroid-jitter data, and the resulting calculated trajectory angles, were acquired using six separate BPM systems. For the 100-MeV H^+ beam entering the IPF beam line, BPMs IPPM01, IPPM02 and IPPM03 were used, and for the 800-MeV H^- beam entering the SY area, BPMs XDPM02, XDPM03, and LXPM01 were used. The H^+ beam was allowed to impinge on the IPBL beam stop ~1.5 m downstream from IPPM03, while the H^- beam was allowed to impinge on the Switchyard Direct beam stop, several meters downstream for LXPM01.

During these development shifts, there were two primary types of data acquired, intermacropulse and intramacropulse beam-jitter data. The intermacropulse beam-jitter data are defined as a series of sequential single samples per macropulse during nominal beam operation, where nominal operation is defined as 1-Hz repetition rate and 0.6-ms macropulse length. Generally, the goal for intermacropulse data was to acquire 1200 sequential samples, requiring ~20 minutes of uninterrupted beam delivery. However, there were times when the linac was unable to provide this long of a period without a source trip, Fast Protect system trip, etc. So data were recorded even with these beam interuptions and the irrelevant data were removed during data analysis. An updated version of the LabVIEW Virtual Instrument that exists on each of the PCIOCs writes an intermacropulse file to the PC hard disk. Position and current data were acquired and stored from each of the three IPF and three SY BPMs with three delays from the macropulse start, 0.1-ms, 0.35-ms, and 0.5-ms. These three delays allowed the analysis of the beam-jitter data at the beginning, middle, and end of the macropulse.

The intramacropulse beam-jitter data were acquired by digitizing a single macropulse's BPM-electrode signals simultaneously using external digital oscilloscopes. The top, bottom, right, and left BPM-electrode signals were injected into a 4-channel oscilloscope so that all of these signals were acquired simultaneously. The digitizing rate of 10-MSamples-per-second was used while acquiring these digitized signals (typically >2X the cutoff frequency of the BPM electronics processor analog front end of ~ 4.5 MHz). Signals were also acquired from a particular axis for two separate BPMs, such as top and bottom electrode signals from both LXPM01 and XDPM02. This allowed for acquiring and analyzing position and angle data during a single macropulse.

During these beam-jitter tests, the H^+ beam is allowed to drift to the IPBL beam stop with all of the quadrupole magnets turned off. Furthermore, all of the steering magnets were reduced to a near-zero level while maintaining a nearly centered beam throughout the first section of the beam line (this beam centering was accomplished by adjusting the upstream Transition Region steering magnets). Only bending magnet IPBM01 was turned on, so that the beam trajectory could be bent into the IPBL01 beam stop, and therefore, through IPPM03 [2].

There are no quadrupole magnets between XDPM02 and LXPM01, and to the Switchyard Direct beam stop. So for these beam tests, the H^- beam is allowed to drift into the Switchyard Direct beam stop without any focusing elements to change the beam's trajectory. Furthermore, all nearby steering magnets were reduced to a near-zero levels while maintaining a nearly centered beam throughout the area.

BPM INSTRUMENTATION DESCRIPTION

The beam's position and bunched-beam current are measured with a BPM and associated cable plant, electronics processors and associated LabVIEW Virtual Instrument software [3,4]. All six of the BPMs used during the jitter experiment shifts had similar characteristics, in that they are a "standard" 50-Ω characteristic impedance micro-stripline designed device.

* Work supported by the US Department of Energy
# gilpatrick@lanl.gov

Each of the IPF and SY BPMs' characteristics were mapped in order to measure its individual position-sensitivity transfer function. A wire-based BPM mapper acquired the 201.25-MHz position-sensitivity surface and a 2-D, 3rd-order equation was fitted to these data. Equivalent inverse coefficients were then calculated and used in a LabVIEW Virtual Instrument data file to interpret the raw data into a precise beam position.

2005 IPF AND SY JITTER DATA

During 2005 beam runs, various beam-development jitter experiments produced a base set of beam-current jitter measurements [2,5]. The average beam current acquired during the December '05 beam-data collection shift was 9.1 and 8.4 mA, for SY and IPF, respectively. The H^+ and H^- intermacropulse jitter was measured to be 0.35 and 0.22 mA, respectively. The H^+ and H^- intramacropulse jitter was measured to be 0.12 and 0.13 mA, respectively.

For both the IPF and SY beams, the slower intermacropulse bunched-beam current jitter amplitude was at least twice that of the faster intramacropulse bunched-beam current jitter. The SY H^- beam also exhibited a wide range of spectral components to ~ 500 kHz that appeared to be ~25% of the dominant 4-kHz components. Also, both the H^- intramacropulse and intermacropulse have a nonsymmetrical distribution, albeit with tails at opposite sides of the distribution. The IPF H^+ beam does not display the nonsymmetrical intramacropulse bunched-beam current jitter distribution that the SY H^- beam has. The spectral lines near ~4 kHz are the dominant spectral lines with the second largest single spectral components at ~65 kHz.

The beam-centroid phase-space scatter plots were produced using the measured position at XDPM02 and the calculated angle between XDPM02 and LXPM01 and measured position at IPPM01 and calculated angles between IPPM01 and IPPM02. With a lab-measured position precision of ~ 0.05 mm, the angular resolution defined by the two positions and drift distances between the two position measurements is ~ 10 and 45 μr for the SY and IPF angular measurements, respectively. Of course, for these angular precisions to be correct, the two position measurements must be acquired simultaneously. For the intramacropulse data, the oscilloscope channels were all triggered within < 1 ns. However, the intermacropulse data have a +/- 1-μs ambiguity that limits this measurement's precision.

The intermacropulse position jitter probability distribution's shape were Gaussian with the SY horizontal plane being ~ 50% larger than the vertical plane. However, the IPF intermacropulse position jitter distribution shapes were less Gaussian in that they had strong cores and the distributions had significant deterministic wings. Further discussions about the IPF jitter distribution shapes will be provided later in this paper.

The SY horizontal projected positional jitter is larger than the vertical jitter by ~ 45% and the intramacropulse projected position jitter is ~85% of the intermacropulse projected positional jitter. These jitter data are plotted in a phase-space scatter plot (Fig. 1 for the SY intermacropulse data) where the beam's angle centroid is plotted as a function of the beam's position centroid.

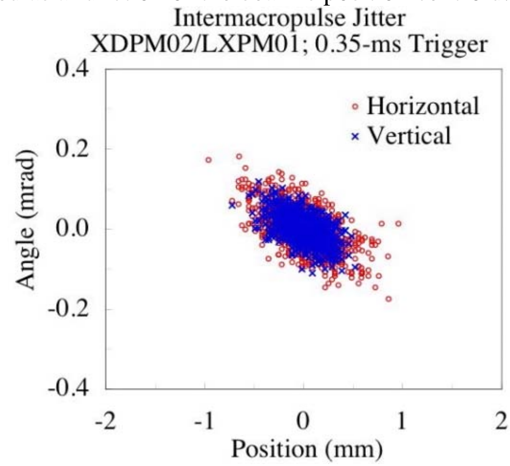

Figure 1. This graph shows the SY H^- intermacropulse jitter data plotted in a phase space scatter plot. In this case, 1200 samples were acquired, each delayed 0.35 ms from the start of each macropulse.

Each point corresponds to a centroid sample and represents a single macropulse of the intermacropulse data. It was observed that as the acquisition time was delayed further into the macropulse, the collective distribution become smaller. While the first 0.1 to 0.2 ms could have issues related to beam neutralization or RF-cavity feedback loops, these arguments do not fully explain the further reduction in jitter distribution later in the macropulse.

The same beam-centroid xx' and yy' scatter plot representations for the SY intramacropulse jitter were acquired and displayed during the last 0.41 ms of a single macropulse. It is interesting that the xx' and yy' orientation or correlation was different from the intermacropulse xx' and yy' correlation. Furthermore, the intermacropulse jitter area is ~4X that of the intramacropulse jitter area.

An equivalent set of IPF beam-centroid data were acquired similarly to the SY jitter data. The intramacropulse projected vertical- and horizontal-plane position jitter data do not appear to have the "distribution wings" of the intermacropulse data (although there is some indication of these wings in the vertical plane).

Fig. 2 shows the IPF intermacropulse vertical- and horizontal-position jitter data with a sample 0.35-ms delay time from the macropulse start. These displayed jitter data also show an additional inner "hot core" that appears to have no deterministic distribution but has wings or edges with definite deterministic shapes.

The same beam-centroid xx' and yy' scatter-plot representations for the SY intramacropulse jitter were acquired and displayed during the last 0.41 ms of a single

IPF macropulse. As in SY intramacropulse data, these jitter data have a completely different shape, orientation (or "phase-space" correlation) and are contained in a smaller area than even the "hot core" of the intermacropulse xx' and yy' space centroid jitter data.

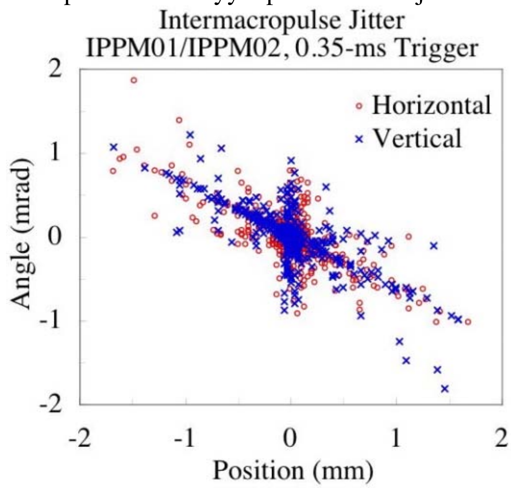

Figure 2. The above graph shows IPF intermacropulse beam-jitter data acquired in CY2005. In this case, 1200 samples were acquired, each delayed by 0.35 ms from the start of each macropulse.

CY2006 IPF JITTER DATA

During CY2006, several development shifts were performed to complete the documentation and follow-up beam-jitter studies not completed during the CY2005 studies. One of the results attained during these runs was the decrease of the IPF intermacropulse jitter, compared to the jitter present in CY2005. The comparison between Figs. 2 and 3 shows this reduction.

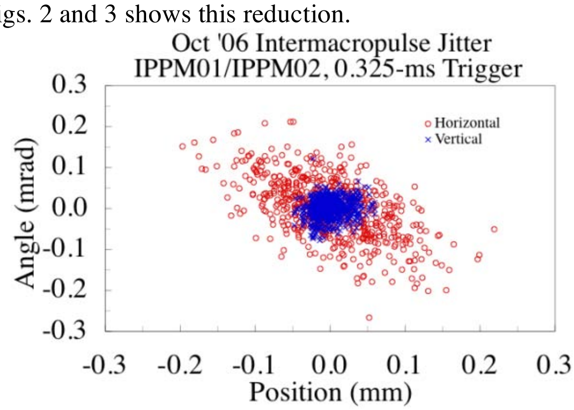

Figure 3. The data displayed in the above graph is the same as in Figure 2, but acquired during the CY2006 beam-development shifts. Note the size is much smaller than that of Figure 2 and none of the deterministic jitter motion exists.

During the CY2006 outage of January through March of 2006, the resistor stacks within the H^+ Cockroft-Walton source were cleaned and repaired. The result, shown in Figure 3, is much less intermacropulse H^+ beam-position and -angle jitter and no deterministic jitter behavior. Note now how the horizontal jitter is ~3X that of the vertical jitter. One theory for these beam-position variations is slow horizontal drift-tube movements due to water-pump pressure variations. Note that the maximum jitter values for the 2005 data in Fig. 2 were ~10X those of the data shown in Fig. 3. Also, the current jitter was 0.013 mA of a total average DC current of 7.7 mA.

SUMMARY

During the LANSCE beam-development shifts of CY2005 and CY2006, H^+ and H^- beam-current and transverse-centroid jitter were measured using three BPMs in the 100-MeV H^+ beam line and 800-MeV H^- beam line. These beam jitter measurements were performed such that both position and trajectory angle data were acquired, analyzed and plotted. These jitter data show that the H^+ and H^- beam-current jitter was <1% and 5% of the average-current values, respectively. Furthermore, the current and transverse-centroid jitter were dominated by the low-frequency intermacropulse variations, typically less than a few kHz. The rms intermacropulse IPF position jitter was measured for 2006 to be ~1/10 that of the same beam jitter acquired during 2005. These simple measurement techniques have provided additional insight into the LANSCE beam operation.

ACKNOWLEDGEMENTS

The authors would like to also thank the AOT–OPS accelerator operators for their help during the beam jitter development shifts. Also, the authors would like to thank Fermin Gonzales, Derwin Martinez, and Gary Sanchez for helping maintain the beam diagnostics equipment used during these beam-jitter data collection shifts.

REFERENCES

[1] M. Gulley, et al., "The LANSCE Switchyard Kicker Project," 2005 Particle Accelerator Conference, Knoxville, TN, June, 2005, p. 3310.
[2] J. D. Gilpatrick, et al., "Acquisition and Initial Analysis of H^+- and H^-Beam Centroid Jitter at LANSCE," BIW06, May 2006, p. 325.
[3] J. D. Gilpatrick, et al., "Beam Position Measurements at Los Alamos: Isotope Production Facility and Switchyard Kicker Upgrade," 2003 Particle Accelerator Conference, Portland, OR, June, 2003, p. 2512.
[4] J. D. Gilpatrick, et al., "Operation for the Position Measurements for the Isotope Production Facility," 2004 European Particle Accelerator Conference, Lucerne, Switzerland, July, 2004, p. 2813.
[5] B. Blind, et al., "Lansce-Linac Beam-Centroid Jitter In Transverse Phase Space" this conference.

