JITTER IN H^- BEAM POSITION AT NEUTRAL PARTICLE BEAM TEST STAND*

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Abstract

Measurements of the time variation of beam position (jitter) during a single pulse and from pulse to pulse were made at various locations in the Neutral Particle Beam Test Stand [1] using five directional coupler (stripline) Beam Position Monitors developed by Los Alamos National Laboratory. The average measured beam jitter at the linac exit during a 100-μs long pulse was 130 μm in X and 50 μm in Y, and the pulse-to-pulse jitter was 30 to 50 μm in X and 30 to 40 μm in Y. At the entrance to the telescope, the beam jitter during a pulse was from 70 μm in X and 160 μm in Y for high current to less than 20 μm for X and Y for low current. The jitter from pulse to pulse varied from 150 to 160 μm in X and 70 to 80 μm in Y for high current and 60 to 70 μm in X and Y for low current.

Introduction

The position of the center of a charged particle beam as a function of time is not necessarily constant at a particular location in the beamline. If the central position is changing rapidly with time, it may affect beam control and stability. We have examined beam jitter from pulse to pulse and within a single pulse. At the Neutral Particle Beam Test Stand (NPBTS), the beam jitter is of particular importance at the linac output and at the entrance to the telescope. Jitter at the exit of the linac will obviously affect the magnitude of the jitter throughout the rest of the beam line. The telescope takes a very small beam at its entrance and expands it to a large-diameter parallel beam. Jitter in beam position or entrance angle at the telescope input will severely affect the telescope output and measurements made by downstream diagnostic systems, particularly diagnostics designed to determine beam direction. Measurements were made by digitizing the output from a system of Beam Position Monitors (BPMs) developed by Los Alamos National Laboratory (LANL) using the NPBTS Data Acquisition System.[2,3] This system, developed by M.R. Kraimer and R.T. Daly at Argonne National Laboratory (ANL), provides real time data acquisition, manipulation, and display.

Facility

The NPBTS is a research facility at ANL, funded by the U.S. Army Strategic Defense Command, where physics, engineering, system control, and systems interface concepts of neutral particle beams are studied. It shares the use of the 50 MeV H^- linac with the Intense Pulsed Neutron Source. NPBTS Line B transports the H^- beam from the linac exit to neutralization and experimental areas. Figure 1 shows the NPBTS Line B with BPMs, collimators, telescope, and experimental areas indicated. For these tests, the pulse width was 100 μs and the repetition rate was 1/2 Hz. Two different beam transport conditions (high current and low current) were studied by adjusting collimators C3, C4, and C5 to produce 600 μA or 75 μA current at the entrance to the telescope.

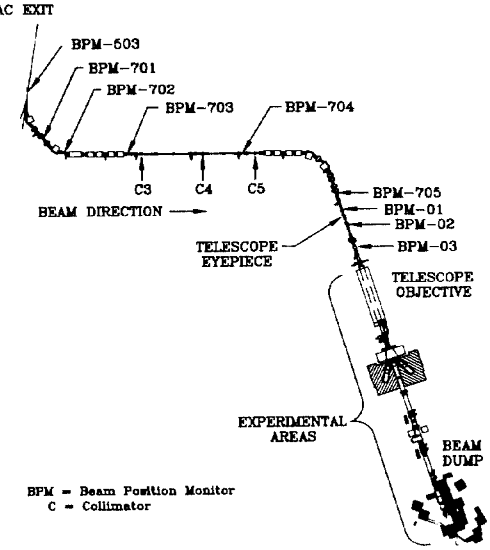

Figure 1: NPBTS line B facility diagram.

Beam Position Monitors

LANL has developed non-intrusive directional coupler (stripline) BPMs [4] to provide information on the position in X and Y of the H^- beam center and the beam intensity. Of primary interest were BPM 501, 705, 01, and 02. BPM 501 is the closest to the exit of the linac and has the highest current. Beam jitter at this location will affect jitter at locations further downstream. BPMs 705 and 01 are located after the second bend and just before the eyepiece to the telescope. The position of the beam centroid and the distance between these two BPMs can be used to determine the position and angle of the beam at the entrance to the telescope, since there are no magnetic elements between them. BPM 02 is located between the eyepiece and the objective lens of the telescope.

Electronics

Three Kinetic Systems Camac Modules Model 4010 Fast Transient Digitizers were used to capture the signal from the BPMs. Each digitizer was capable of digitizing two signals at 1 MHz with 10 bits resolution over a range of ±5 V. Therefore, up to six signals in any combination of position and intensity could be collected simultaneously. The digitized signal was collected and recorded by the NPB Data Acquisition System running a custom data acquisition task running under the standard NPB data acquisition program.

Each digitizer was programmed to collect 200 samples. The trigger for digitization was adjusted so that digitization began before the arrival of each pulse at the BPM. The beam pulse occurred from the

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35th to the 135th sample. Digitized raw voltage output from the BPMs was converted to a position using a conversion factor supplied by Los Alamos. In order to study beam jitter during single pulse, each pulse was divided into five consecutive 20-μs long regions. The digitized signal was averaged and converted to engineering units for each region. The raw digitized data and the averaged converted data were recorded for each beam pulse. Nine sets of data, each approximately 10 minutes or 300 beam pulses long, were collected.

Results

Figure 2 shows a typical intensity pulse for the high current condition for the linac exit and telescope entrance and also Y position at the telescope entrance. Note that the intensity may be rapidly changing during the first 20 μs of the pulse so that the position signals may not be as reliable during this time. Figure 2 shows that there is considerable variation in beam centroid position over the length of a single beam pulse.

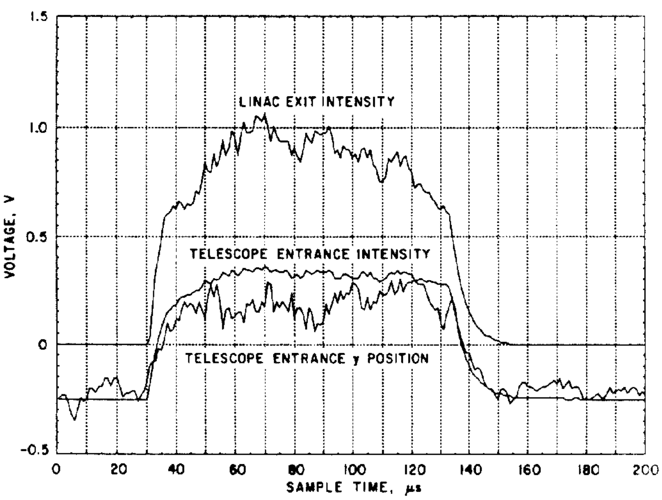

Figure 2: Raw digitized signal from a typical beam pulse from the linac exit intensity output, the telescope entrance intensity output, and the telescope entrance Y position output.

Figures 3 and 4 plot a portion of a typical data set at the telescope entrance for the low (Figure 2) and the high (Figure 3) current conditions, showing the average X position of the center of the beam in each 20-μs region as a function of time. The spread between the lines at any point show the jitter during a single pulse. The spread varies from about 75 to 300 μm for these samples. Although the position of the beam changed, due to the narrowed collimators for the low current condition, the maximum jitter during a pulse did not change appreciably.

Figure 5 shows the average position of the beam center at the linac exit and telescope entrance for the high current condition, for the center region of each pulse from 41 to 60 μs plotted as a function of time for a particular data set. This shows the range of jitter from pulse to pulse for an extended period of time. The maximum jitter at the telescope entrance in X and Y, ignoring the large spikes which may be due to source arcing, is on the order of 200 μm. At the telescope entrance, the maximum jitter in X is on the order of 750 μm, and the maximum jitter in Y is on the order of 300 μm.

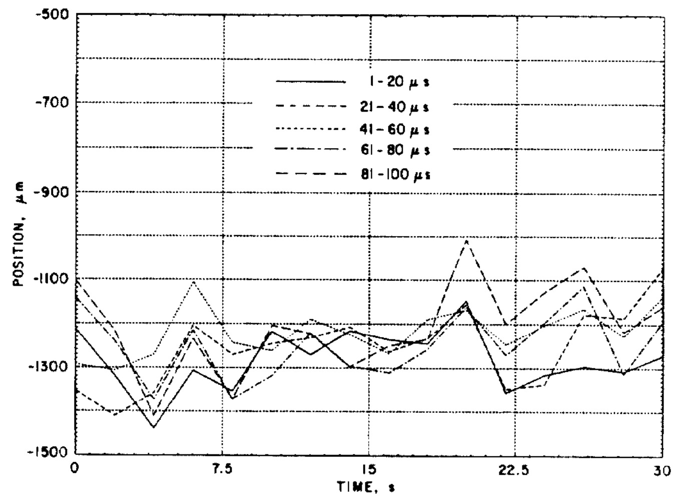

Figure 3: X position at telescope entrance for a portion of the data, low current.

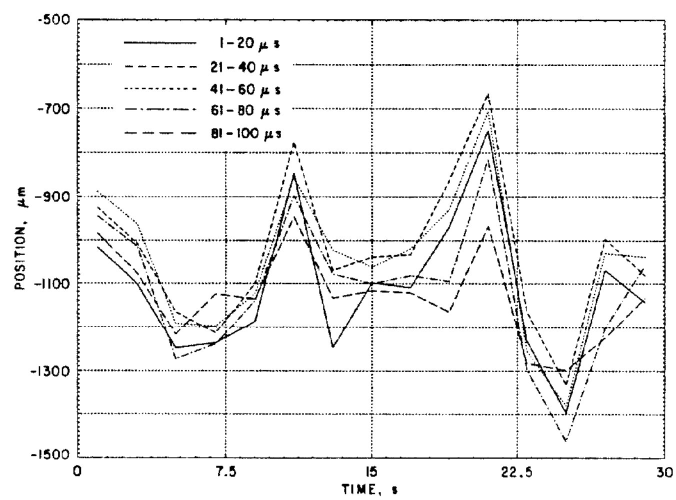

Figure 4: X position at telescope entrance for a portion of the data, high current.

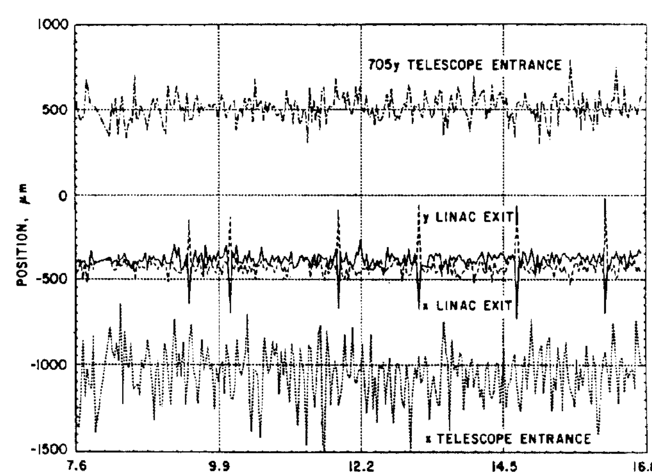

Figure 5: Beam position at linac exit and telescope entrance during the middle 20-μs region of the beam, high current.

Table 1 gives the mean and standard deviation for the average position of the beam at the linac exit during each of the five 20-μs regions of the beam pulse. The jitter in X during a pulse is (ignoring the first region) approximately 130 μm from an average position of 470 to 600 μm. The jitter in Y during a pulse is approximately 50 μm, again ignoring the first region. The standard deviation from the mean which indicates the pulse-to-pulse jitter is on the order of 30 to 50 μm. Tables 2 and 3 give the mean and standard deviation for the average position of the beam at the telescope entrance during each of the five 20-μs regions of the beam pulse. Table 2 gives the values for the high current case, and Table 3 gives the low current values. The values for 705 Y showed an unexplained large change in mean value from run to run and so are not reported in Table 3. In every case, the intra- and inter-pulse jitter for the low current condition was somewhat reduced from the high current conditions. The jitter in average X position during a pulse was on the order of 70 μm for high current and less than 20 μm for the low current. The jitter in Y average during a pulse was 160 μm for high current and less than 20 μm for low current. The standard deviation from the mean indicates the pulse-to-pulse jitter varied from 150 to 160 μm for X and 70 to 80 μm for high current and 60 to 70 μm for X and Y for the low current.

Table 1: Average position of beam center at linac exit for each 20 μs region of the beam

		(μm)			
BPM	1-20	21-40	41-60	61-80	81-100 μs
501 X	-434.0	-473.1	-530.6	-604.9	-492.7
STDDEV	34.57	33.26	35.84	39.07	48.47
501 Y	-356.0	-308.9	-279.9	-259.6	-280.4
STDDEV	33.22	35.10	37.83	41.30	42.25

Table 2: Average position of beam center at telescope entrance for each 20 μs region of the beam for the high (600 μA) current

		(μm)			
BPM	1-20	21-40	41-60	61-80	81-100 μs
705 X	-1142	-1051	-1056	-1116	-1121
STDDEV	156.2	159.4	154.8	160.8	112.7
705 Y	393.6	441.8	513.1	607.1	138.9
STDDEV	73.72	79.93	77.87	77.87	68.28

Table 3: Average position of beam center at telescope entrance for each 20 μs region of the beam for the low (75 μA) current

		(μm)			
BPM	1-20	21-40	41-60	61-80	81-100 μs
705 X	-1198	-1192	-1194	-1195	-1198
STDDEV	64.31	66.14	69.45	67.38	61.80
705 Y					
STDDEV					
01 X	-478.4	-476.9	-472.7	-471.2	-477.0
STDDEV	57.00	57.15	59.73	57.14	58.06
01 Y	-769.6	-767.0	-762.5	-763.8	-763.3
STDDEV	73.74	72.49	68.75	69.93	72.15

Conclusions

Beam jitter has been observed and characterized both during a single beam pulse and from pulse to pulse for a high current H^- beam and a low current H^- beam. Narrow collimation of the beam affected mean and standard deviation of beam position. Further work is in progress to study the correlation between BPM signals in time and to provide more detailed examination of the variations in beam pulse shape.

References

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[4] R. E. Shafer, "Characteristics of Directional Coupler Beam Position Monitors," IEEE Trans. Nucl. Sci., vol. 32, 1933 and 1985.