DARHT II ACCELERATOR BEAM POSITION MONITOR PERFORMANCE ANALYSIS*

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Abstract

Accurate and reliable beam position measurements are required to commission and operate the DARHT II Accelerator. The Beam Position Monitor (BPM) system developed for use on the DARHT II accelerator consists of 31 electro-magnetic detector assemblies, a computer network based data acquisition system, and custom analysis software. During an accelerator "shot", each BPM uses arrays of B-dot detectors to intercept the electron beam's changing magnetic field. Post shot analysis of the BPM data provides the beam current and position information used for steering and tuning subsequent shots. This paper will analyze the performance of the BPM system, now that several thousand beam shots have been achieved.

INTRODUCTION

The Los Alamos DARHT II accelerator is operational and is producing multiple 17 MeV electron beam pulses per accelerator shot. An electro-magnetic Kicker is used to produce up to four short pulses from the long electron beam pulse produced by the accelerator. The magnitude and position of the electron beam up to and beyond the Kicker is monitored by Beam Position Monitors (BPMs) developed specifically for use on DARHT II. Several hundred accelerator shots have been achieved using the kicker to produce 1,2,3,or 4 short pulses. Enough BPM data has been collected now to allow for a study of the performance of the BPM system, with a focus on beam current variability.

BPM DESIGN

All of the 31 BPMs used on the DARHT II accelerator use the same basic design. Each BPM consists of arrays of evenly spaced, azimuthally oriented differential B-dot loops fitted into beam line flanges. Accelerator BPMs utilize four B-dot loops per BPM. The BPMs used at the exit of the accelerator and in the region beyond the kicker use eight B-dot loops to allow for measurement of beam ellipticity [1]. The beam tube radius of the BPMs varies from 7 inches in the injector reducing in size down to 2 inches at the exit of the accelerator as shown in Fig. 1.

BPM CALIBRATION

The calibration effort for the BPMs was an on going effort for 7 years. During that time, the availability of increasingly better data recorders led to variations on how the BPM calibration data was recorded. Also, two different calibration test stands were used depending on the size of the BPM. Due to these variabilities, cross checks of the test stands and digitizers were regularly performed to assure consistency. Overall calibration accuracy has been established and for any BPM is: current +/-1.0% and for position is +/- 200 microns.

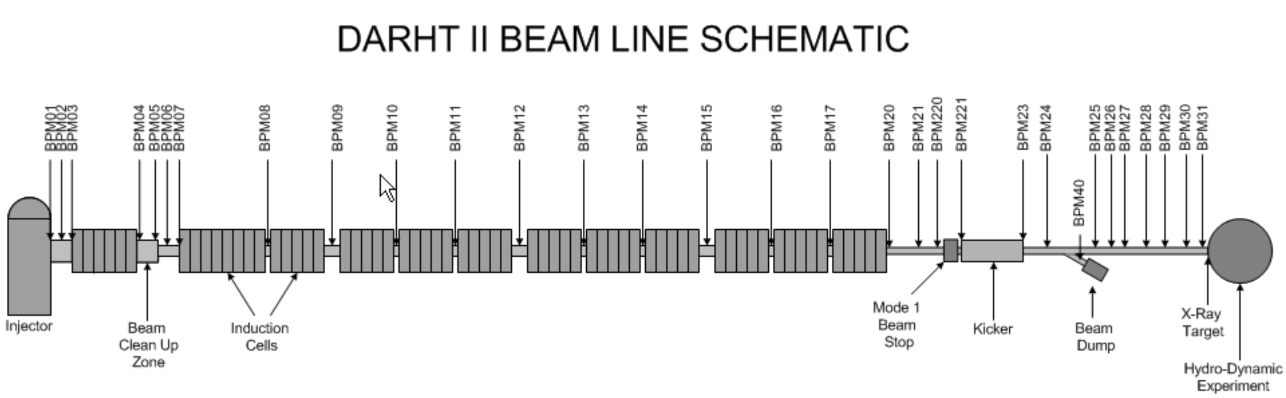

Figure 1: BPM locations as installed on the DARHT II Accelerator.

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DATA RECORDING AND PROCESSING

Originally, all of the signals produced by the B-dot loops were recorded directly with high speed digitizers. Integration of the derivative signals was performed with software after the data were recorded. Special recording and data processing techniques were developed [2] during the initial testing and calibration of the BPMs. This was necessary to reduce the integration error introduced by 8 bit recording, a necessity in order meet to the position and

current measurement requirement of DARHT II. This method worked well for BPM calibrations and accelerator commissioning activities. However, today, accelerator operations require the use of the injector crowbar switch to variably end the main beam pulse. This creates large variations in the amplitude of the derivative signal from the B-dot loops. As a result, the recorded signal gets clipped by the recoding digitizers and the recorded data beyond the time of the crowbar is not accurate. Since it is necessary for accelerator development that the BPM data beyond the crowbar time be accurate, the use of passive integrators is being applied as a solution to this problem. Today, eight of the BPMs are configured with passive integrators. After the BPM data have been recorded and saved, they are analyzed using custom IDL programs. Data reduction includes the use of a background noise subtraction routine to reduce the impact of pulse power noise imposed on the BPM data.

BPM PERFORMANCE

The BPM design, calibration, recording techniques, and data processing methods establish the base line for the systems performance. There are other elements that affect the performance and measurement variability of the BPMs. Such elements include noise from the pulse power systems, aliasing [3] due to the discrete number of B-dot loops in the BPM, changes in signal conditioning components, and other environmental factors. Rather than looking at the contributions of each element separately, we chose to evaluate the BPM system with all the elements combined. Note that using this method, any changes in the injector will be included as part of the measurement variability.

ANALYSIS

First, single BPM measurement variabilities were analyzed using BPM09 data from February 20, 2008 using the D2_Bdot program as shown in Fig. 2. The analysis window was set to look at a 0.5µS portion of the beam current flattop. Data from 20 shots were analyzed and found that the nominal 2kA beam current average flat-top varied by ±3.1 Amps or 0.11%. Data from other BPMs were comparable. This data set also confirms that the injector performance is quite stable.

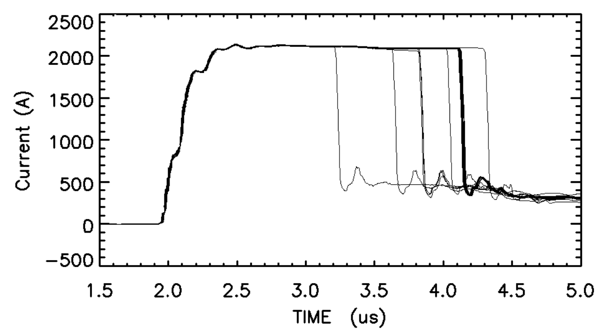

Figure 2 : BPM09 beam current data overlay of 20 shots (#7719-7738). Pulse length is stretched during operations.

Next, single shot multiple BPM variabilities were analyzed and are shown in Fig. 3. All of the Injector and accelerator region BPMs up to the exit of the accelerator cells were included. The same twenty shots were analyzed, and for any single shot, the RMS variation in beam current for any BPMs was a maximum of 0.90% of the nominal 2 kA beam pulse.

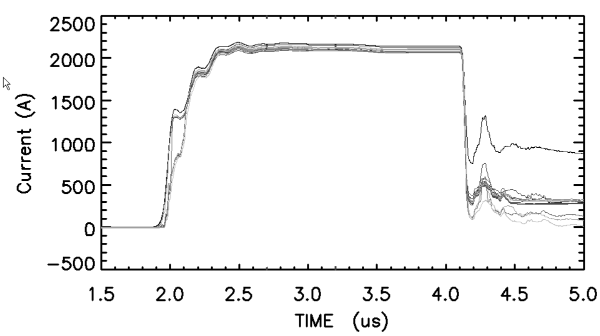

Figure 3: BPM01 through BPM17 beam current overlay for a single shot (#7730).

Lastly, The BPMs installed beyond the accelerator cells and up to the x-ray target showed a maximum RMS variation in beam current of 2.25% for any single shot. The analysis window was reduced to 0.015µS and starts at 2.915µS which is the flattop of the second of the four kicked pulses shown in Fig. 4. The primary causes for the variations seen in these BPMs are: 1) integration error introduced from recording (digitizer) noise, and 2) under sampling of those same data. Since there are no recording systems available that have both the dynamic range and bandwidth necessary to effectively record these derivative signals to meet our requirements, the use of passive integrators is currently being tested as a means to reduce measurement variabilities of these BPMs.

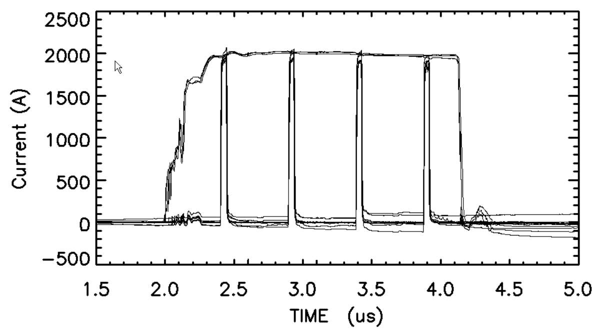

Figure 4: BPM20 through BPM31 beam current beam current overlay for a single shot (#7738).

CONCLUSIONS

The established calibration accuracy of individual BPMs is +/-1%. While individual BPMs show very stable shot-to-shot behaviour, there is a spread of more that 1% observed when analyzing the BPMs that monitor the kicked beam pulses. This spread is caused by data recording limitations of dynamic range and sample rate. Work is currently being done to improve our data recording method and also utilize hardware integrators as a way to reduce the measurement variability of these BPMs.

REFERENCES

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[2] Jeffrey B. Johnson, “B-Dot Detector Signal Recording at the DARHT II Accelerator,” *2007 IEEE Pulsed Power Conference, Digests of Technical Papers 1976-2007*, IEEE Cat Num 07CH37864C, ISBN: 1-4244-0914-4

[3] C.Ekdahl, "Aliasing errors in measurements of beam position and ellipticity," *Rev. Sci. Instrum*., vol 76, pp. 095108-095108-9, Sep. 2005