VIBRATION MEASUREMENT FOR INSTRUMENTATION AND DIAGNOSTICS

S. Sarkar, E. Ilhoff, C. Sibley, S.B. Soong, S. Wells, E. Tsentalovich, T. Zwart
MIT Bates Linear Accelerator Center, Middleton, MA 01949

J. Shaw
University of Massachusetts, Amherst, MA 01003

Abstract

Experimental requirements at Bates place stringent excursion limits on some beam parameters and on measurements of beam properties such as position and charge. Steering elements and measuring devices may be affected by vibrations transmitted along the beam pipe from vacuum pumps and turbulent cooling water flows. A vibration measurement setup, capable of generating displacement spectra and detecting displacements of less than 100nm at 20Hz, has been used in detecting and correcting vibration induced beam parameter deterioration and measurement error. The measurement setup, plans for improvements and vibration monitoring on site are described.

1 INTRODUCTION

Two of the major ongoing experiments at Bates have extreme stability requirements. The parity violation experiment requires the electron beam intensity to be stable such that the centroid can be accurately measured for the two opposing polarization states of the beam. Feedback correction is then applied to balance the charge delivered to the experiment, between both states, to an accuracy of one part per million, over the course of each half hour run. This translates to an instantaneous beam intensity stability requirement of less than 1%. In the experiment to measure the interference response functions in the (e,e'p) reactions, even small systematic uncertainties may result in large errors in the extracted response function due to the small cross sections involved. The total error budget for this experiment is 1% of which 0.1% is allocated to errors in the measurement of total charge. This then sets the differential pulse to pulse accuracy limits for the data taking toroids. Clearly any interference, electrical or mechanical, which adds jitter to the intensity distribution of the beam or causes measurement errors must be located and minimized.

Common causes of errors such as EMI, power line pickup, improper signal grounding and marginal electronics were first identified and corrected. Differential signals and solid copper shielded cables were used as required. With each step measurement errors and beam quality improved but did not fully meet requirements for either experiment. The isolation of a mechanical chopper wheel from the laser table reduced vibration induced jitter and improved beam intensity stability. The addition of bellows for the isolation of turbo pumps and the bracing of beampipe sections near susceptible toroids reduced measurement noise. These fixes were just adequate but the effect of minor mechanical changes, such as changes to brace or support locations, were difficult to predict and often caused stability and measurement errors to deteriorate out of limit.

It became increasingly apparent that some of the remaining source of noise was vibration induced and that a system to detect and correct vibration induced errors was needed.

2 MEASUREMENT SETUP

The vibration measurement setup consists of An ADXL05[1] acceleration transducer and associated electronics connected to a HP 35670A[2] dynamic signal analyzer.

The ADXL05's sensing element is a micromachined polysilicon capacitive acceleration transducer. The chip contains signal conditioning circuitry and can be used for vibration (AC coupled) and inertial force or gravity (DC coupled), measurements. A few external components are required to set the signal scaling factor and the output signal bandwidth. Transducer calibration is done in the DC coupled mode by using the Earths gravity. The maximum transducer bandwidth of ~4 khz is adequate to cover the high frequency vibration from turbo-mechanical pumps and turbulent cooling water flows. Component values were selected to set the gain and bandwidth at 400mV/g and 1.6khz respectively.

The HP 35670A dynamic signal analyzer can be programmed for transducer sensitivity and can generate fourier analyzed displays of the acceleration and the computed displacement signal. The transducer, electronics and signal analyzer noise floors, the selected FFT resolution and the signal averaging used comfortably allow the measurement of displacements of less than 100nm at 20 hz with changes of 20nm being discernible as seen from measurements. This, however, requires that the signals be repetitive but stationary in time over the duration of signal acquisition and averaging and sets a bound on the achievable measurement resolution.

3 APPLICATION EXAMPLES

1.1 The Polarized Injector Laser Transport

Laser spot size and position variations on the GaAs photocathode of the Bates polarized injector can cause beam intensity variations due to quantum photo efficiency gradients across the crystal. Beam intensity stabilization is done to first order by Laser intensity feedback modulation. Initial beam intensity noise was traced to chopper wheel vibrations and to inband electrical noise causing errors in the feedback. These were corrected as described above. Beam intensity stability deteriorated and 28.5 hz intensity modulation was seen after a routine shutdown. This was traced to 28.5 hz vibrations (figure 1) on `mirror 3' which is the

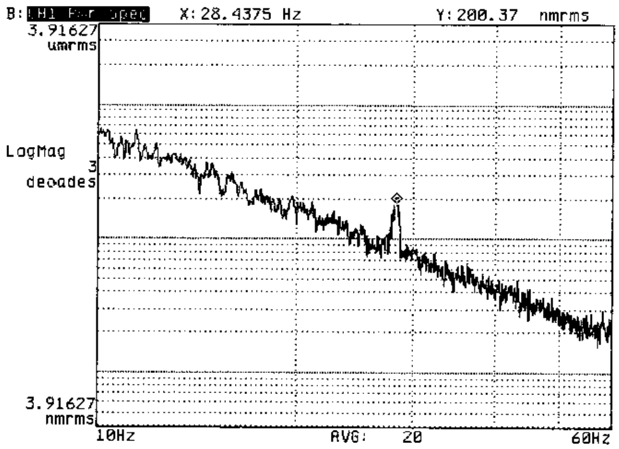

Figure 1: Mirror 3 Vibration

final mirror deflecting the injector laser beam onto the GaAs crystal. Resonance changes were probably caused by mechanical work done near the mirror box. Source of vibration was the cooling water flow in a nearby buncher cavity (figure 2) which is transmitted along the beam support

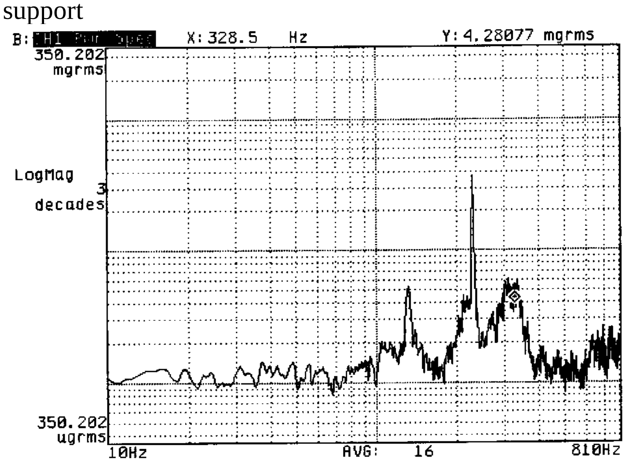

Figure 2: Buncher Cooling Water Flow Vibration

girder to `mirror box 3' support (figure 3). Damping had unpredictable effects, a lead shot filled bean bag did not eliminate the problem (figure 4), whereas two lead bricks in a particular position did (figure 5).

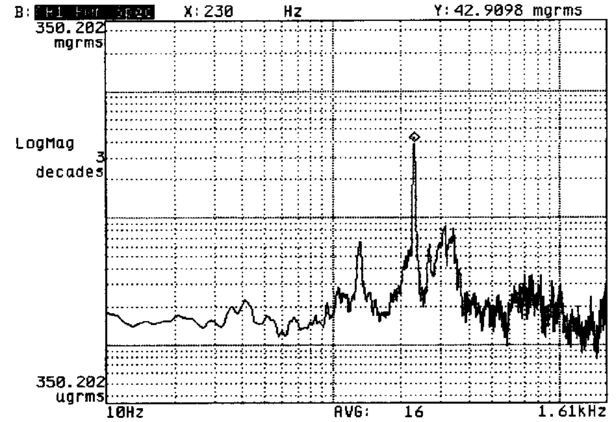

Figure 3: Vibration at Mirror Box 3 Girder

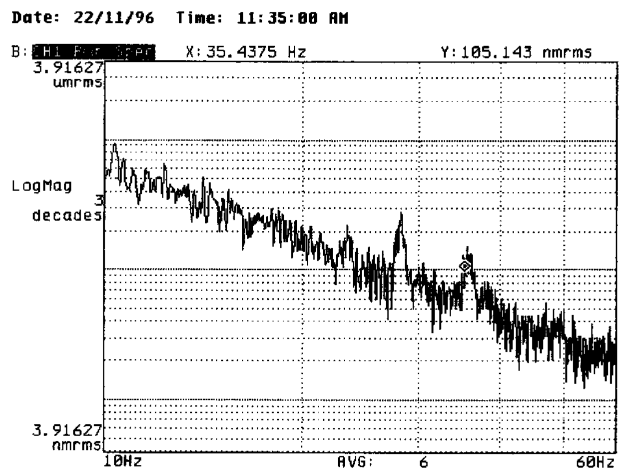

Figure 4: Effect of Lead Shot Filled Bean Bag

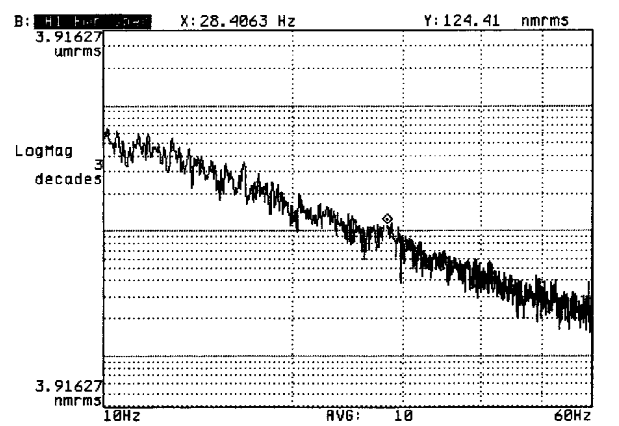

Figure 5: Damping from two Lead Bricks

1.2 The South Hall Datataking Toroids

The SH datataking toroids noise was reduced when turbo pumps were moved upstream, bellows isolated from the beampipe, water flow pipes were cushioned from common beam pipe support stands and the toroids were clamped. The pulse to pulse diferential error was reduced to less than the required 0.1% for a while for one of the two datataking toroids in close proximity to each other. However when braces were adjusted to try to reduce the noise for the second toroid the figure deteriorated to slightly above the required 0.1% for both of them and has never gone down. Due to running schedules adjustments to the braces using the vibration measurement setup have yet to be done. Another line of attack has been to measure the sensitivity of the toroids to vibration. Figure 6 shows a Pearson toroid subject to floor

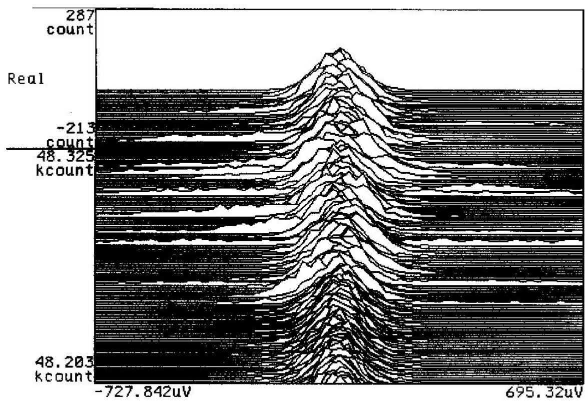

Figure 6: Unmodified Toroid Vibration Response

vibration, while figure 7 shows a modified pearson made to our requirement of potted core showing almost no sensitivity even with direct taps on the body of the toroid.

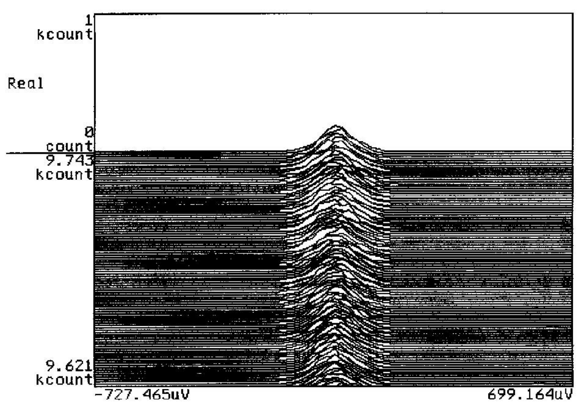

Figure 7: Potted Core Toroid Vibration Response

4 CONCLUSION

Vibration of position and intensity sensors such as beam position monitors and toroids can be interpreted falsely as position or intensity variations and data from these sensors used for feedback corrections can lead to errors deteriorating beam position or intensity stability.

Additions or modifications to beam line elements can cause changes in mechanical resonance characteristics of beam pipe sections causing the induced noise pickup of nearby transducers to change. Similarly physical routing of instrumentation analog signals, done by hand during installation of new systems or during the maintenance and upgrade of existing systems are prone to errors. Inadvertent routing or grounding errors or the incorrect setting of buffer gains offsets etc., which are measured and set to specifications by hand, may alter the path characteristics of the (re)routed signals and can change the electrical characteristics of signal provided to users.

We intend to put vibration transducers at selected locations along the Accelerator and experimental beamlines. Periodic or ongoing monitoring of vibration spectra at these locations along with information obtained using tuned magnetic field search coils when compared to signal spectra of interest can allow pinpointing and flagging of problems as they occur.

5 ACKNOWLEDGEMENTS

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6 REFERENCES

[1] `Design-In Reference Manual', Analog Devices, one technology way, PO Box 9106, Norwood MA. 1994.

[2] `HP 35670A Operator's Guide', Hewlett Packard Company, 8600 Soper Hill Road, Everett, WA. 1994.