AUTOMATIC BEAM POSITION CONTROL AT LASREF

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Abstract

Historically the Los Alamos Spallation Radiation Effects Facility (LASREF) has used manual methods to control the position of the 800 kW, 800 MeV proton beam on targets. New experiments, however, require more stringent position control more frequently than can be done manually for long periods of time. Data from an existing harp is used to automatically adjust steering magnets to maintain beam position to required tolerances.

1 INTRODUCTION

The LASREF uses the 800 MeV, 1000 μA proton beam from the Los Alamos Neutron Science Center (LANSCE, formerly known as LAMPF) to irradiate samples with protons and neutrons. Samples in the direct proton beam require control of the beam position; in past years these samples were large enough compared to the 30 mm beam diameter (Gaussian two sigma) that precise, continuous position control was not necessary. Operators checked beam position as infrequently as a few times per day to catch occasional beam lurches that could shift the beam far enough to cause cooling water leaks on some of the samples.

Beginning in 1996 and continuing through 1997, new samples consisting of 19 mm bundles of 3 mm diameter tungsten rods required much finer control of beam position. For comparison with calculations of radiation damage effects, it is important to maintain beam position to approximately ±1 mm. Typical uncontrolled beam motion is considerably larger than this, so a full-time operator would have been required to hold the beam position. Tight position control is also required to avoid water leaks from other samples, since the tungsten rods are sensitive to even small water leaks.

2 IMPLEMENTATION

Both budget and a short lead time limited the solutions that were feasible. An existing steering magnet and multi-wire harp were used. Software used to display harp spectra was modified to add control functions.

In the harp read-out system, charge accumulated on harp wires was digitized and read by a remote computer on demand from the main control computer. The main control computer provided an interactive user interface to allow selecting data acquisition parameters and to display the data. Hardware for controlling the steering magnet is not directly accessible from the remote computer, so implementation of automatic control in the remote computer was not considered.

The interactive harp display program on the main control computer was modified to produce a “harp watcher” program running as a detached background job that would not interfere with the interactive version. Code was added to the harp watcher to periodically read the beam position and resteer the beam. There was considerable concern that an error in the steering algorithm could cause the beam either to drill a hole through the beam line vacuum window between the harp and the samples or to steer the beam grossly off position, rupturing vacuum or water o-ring seals. Since there was little time to validate a steering algorithm, a minimalist approach was taken and a very simple algorithm was used. Since the simple algorithm proved good enough to meet the experiment’s needs, only minor changes have been made since the initial use.

```
DO (forever)
  sleep 10 seconds
  read harp x and y spectra
  calculate x and y centroids
  DO (x,y)
    IF (data is valid) THEN
      Δposition = desired_position - centroid
      IF (abs(Δposition) > tolerance) THEN
        IF (abs(Δposition) > max_change) THEN
          warn operators  !don't risk oversteering beam
        ELSE
          IF (steering_enabled) THEN
            ΔI = κ*Δposition
            change steering magnet current by ΔI
          ENDIF
        ENDIF
      ENDIF
    ENDIF
  ENDDO ! x,y
ENDDO ! infinite loop
```

Figure: 1 Algorithm initially used for controlling beam position. Error handling is shown only in one case.

The steering algorithm initially used is shown in Figure 1. To keep the algorithm simple, it makes no attempt to perform error recovery. Instead operators are informed of the problem by blowing a horn in the control room. The incidence of false alarms (a few a day) was felt preferable to a more complicated algorithm that might mis-steer the beam.

An interactive interface was provided to set the parameters *desired_position*, *tolerance*, *max_change*, *steering_enabled* and κ (conversion between position change and steering magnet current change). Harp spectrum centroids and widths and steering magnet currents were archived by the harp watcher for later analysis.

3 RESULTS AND CONCLUSIONS

Figure 2 shows harp centroids and steering magnet values over a two hour period for the Y direction. Data was recorded every 10 seconds by the harp watcher. The positions plotted are those before any attempt at steering was made. Some apparently out of tolerance positions do not result in magnet steering because a second data-take showed the first point was erroneous.

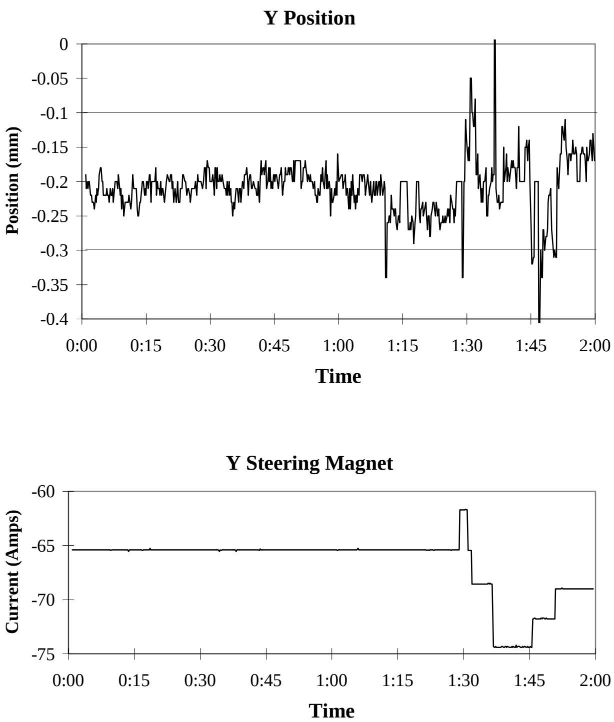

Figure: 2 Beam position and steering magnet current for Y direction. The ±1 mm tolerance band is -0.3 to -0.1 mm.

An early concern was that continuous steering of the beam would damage stepper motors used to control the steering magnet currents. As can be seen in Figure 2, the number of changes in current per hour is small and no problems with the stepper motors have been observed.

Figure 3 shows histograms of beam positions over a 24 hour period recorded every 10 seconds. The vertical bars indicate the tolerances requested by the experiment. The beam is held within tolerance 94% of the time for X and 99% for Y, meeting the beam stability needs of the experiment.

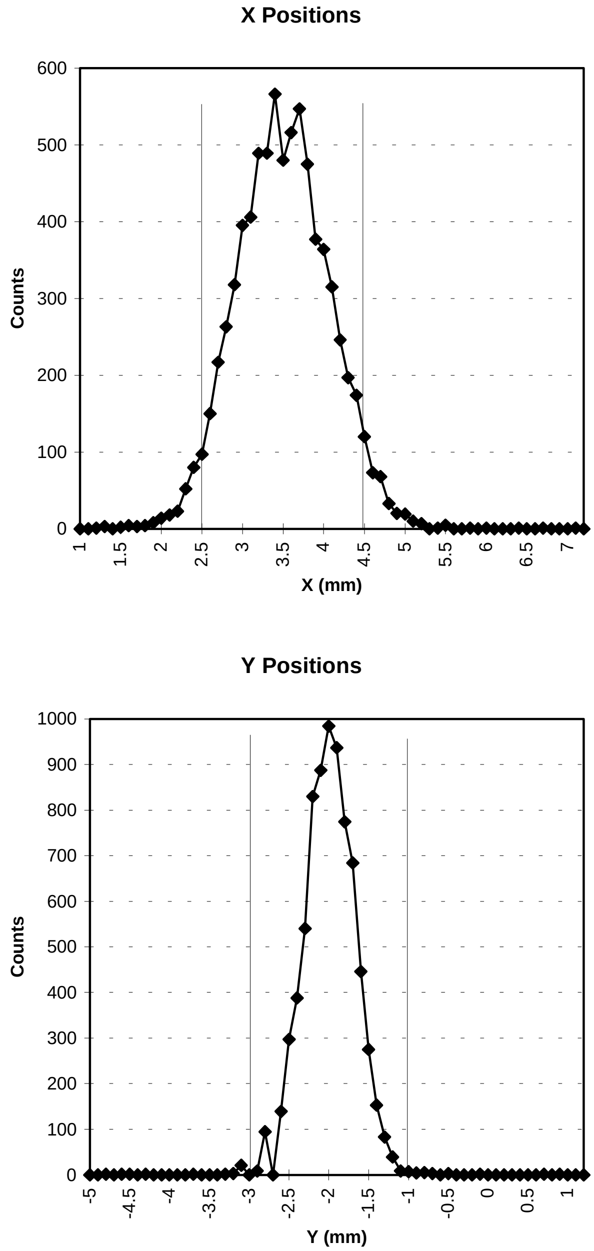

Figure: 3 Histograms of beam position over a 24 hour period. The vertical lines indicate the ±1 mm tolerance requested by the experiment.

The beam shows significantly more jitter in X than in Y. It is believed a small “pendulum” motion of the drift tubes in the front end of the accelerator are responsible for this jitter.

The only significant problem found with the algorithm after several months of use was a tendency to steer the beam in one direction followed ten seconds later by steering in the opposite direction. This was caused by short term beam lurches. The algorithm was modified to re-take the harp data after a delay of several seconds if the first harp spectrum indicated the need for steering. Steering was done only if both spectra indicated need for a similar change. This greatly reduced the frequency of the problem.

It was expected at the start of the project that the position control would need to be re-implemented in the remote computer to get adequate control without overloading the main control computer. The data acquisition and control functions proved to take 0.2% of the main control computer's cpu (a VAX 4000/500) and required about two input/output operations per second. Since Figure 3 shows the position control meets the needs of the experiment, this simple control system running on the main computer has been retained.

4 ACKNOWLEDGEMENTS

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