A QUEST FOR SYSTEM USER FRIENDLINESS WITH THE SNS ION BEAM BUNCH SHAPE MONITOR*

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Abstract

A new system for measuring the SNS ion beam longitudinal profile was recently upgraded to operational status. The hardware for this device was developed and delivered by Institute for Nuclear Research to the SNS as a part of its initial construction. The supplied LabVIEW user interface software was intended for proof-of-operation and initial setup of the instrument. While satisfactory for this, it was tedious to use in a practical context and lacked any form of interface to the SNS EPICS based control system. This paper will describe the software features added to make this instrument both easily tunable to the prevalent beam conditions by system engineers and easily usable by accelerator physicists only interested in its output data.

INTRODUCTION

The basic system operation of the BSM is shown in Fig. 1. Beam bunches cross an insertable wire target biased with a high negative voltage. Interaction of the beam with the target results in emission of low-energy secondary electrons. The electrons are accelerated by the target wire's electrostatic voltage and move in a radial direction away from it and the beam. A fraction of the electrons pass through an aperture and enter the influence of static bending electromagnets and sets of electroplates biased with various: static bending, static focusing and radio frequency (RF) bending voltages. The RF bending field is synchronized with the Spallation Neutron Source (SNS) LINAC's accelerating RF. Its deflection effectively replicates the principal of an analog oscilloscope with the resulting electron sweep structure reflecting that of the accelerator beam bunch structure. These electrons sweep across a second downstream aperture plate stripping all but electrons correlated with a particular RF phase. The resulting phase-correlated electron beam is then passed through a spectrometer (bending magnet) to isolate electrons truly emitted by interaction with the target and beam. Finally, the beam enters a Secondary Electron Multiplier (SEM) at high voltage. The amplified electrons are then output to the data acquisition system's main signal input. The phase of the RF bending field relative to the machine accelerating RF is controllable. In actual use, the acquisition system loops through a process of setting a phase, taking intensity data mirroring the bunch intensity at that phase and then incrementing the phase to the next measurement angle. A typical "scan" of the bunch profile typically takes about two minutes, depending on the range of phase and angle increment chosen. There are two BSM systems at the SNS, one with four channels (a channel being a separate target at a differing machine location) and a second system with two channels.

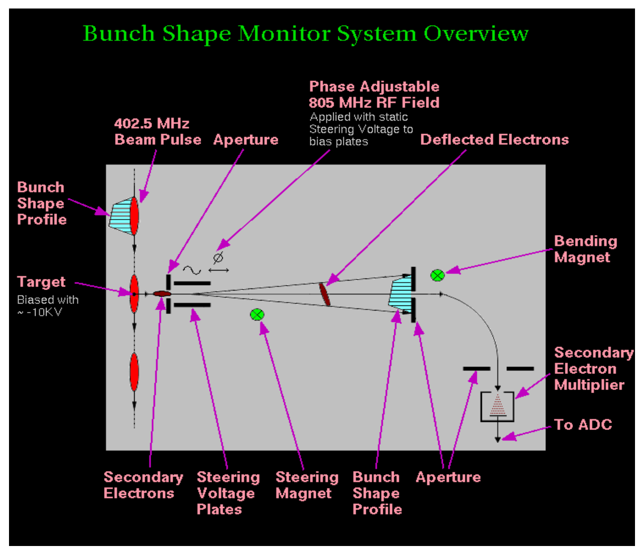

Figure 1: BSM system overview.

This device was developed and delivered to SNS by the Institute for Nuclear Research, and is now maintained by the SNS Beam Instrumentation Group (BIG). The National Instruments LabVIEW data acquisition software system delivered with the instrument provided the basic ability to control system set-points and acquire read-backs along with main signal strength measurements for a single BSM channel. This was used for system tuning. A separate software application allowed RF scanning with data being optionally saved to a file. This was to be the system user's interface. These delivered software applications have been combined and significantly modified by the BIG for use at the SNS.

SYSTEM TUNING

Expert tuning of each BSM channel is periodically required to maximize system response and resolution. This includes adjusting control values of static

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steering/focusing voltages and steering/bending magnet currents in order to maximize main signal strength. The process is complicated since these adjustments are non-orthogonal. Dialing in the sweet spot for any one of them potentially changes the sweet spot for others. The delivered software made this tuning process tedious and time consuming since the set-point adjustment and signal interpretation process was completely manual. Software tools were created by the BIG with the goal of making this multi-dimensional adjustment process as efficient as possible. Three modes of tuning operation were created – Free Run, Scan and 2-D. Free-Run mode is based upon the delivered software's abilities. A time trace of main signal strength (1M samples/sec), triggered by a timing signal synchronized with the SNS beam pulse, is continuously displayed. Control set-points may be adjusted and their effects directly observed.

The second mode, Scan mode, provides control set-point auto-increment capability. For a chosen control, a starting value, step-size and number of points are specified prior to starting a scan. At each set-point step, the system will establish the set-point and take a scan of main signal data. The computed mean value of a subset of data taken over a user-specified sub-interval (typically where beam is present) of the entire time trace minus the mean value of a user-specified background level sub-interval (region where no beam is present) is saved. These values are then plotted over the control set-point range used in the scan for user interpretation (Fig. 2). The set-point with maximum signal strength is reported. A button option to accept it as the new static value of the control is provided. Full width half max (FWHM) and root mean square (RMS) values are also computed (useful for adjusting lens voltage for best focus). Scans are available for bending magnet, steering magnet, steering voltage, lens HV, target position, RF phase.

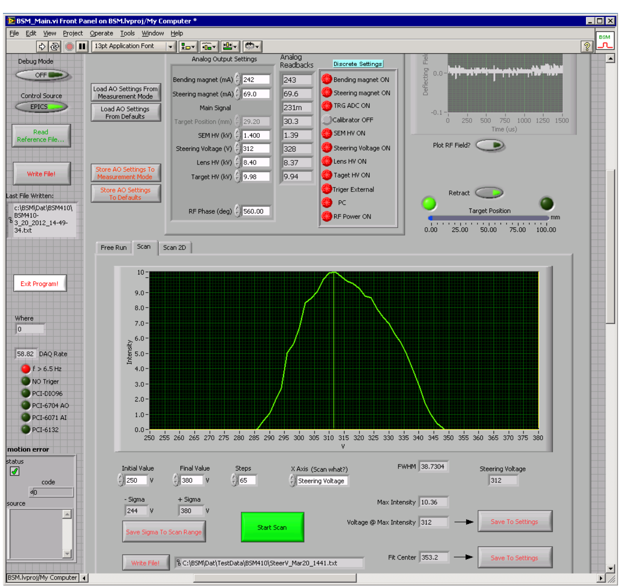

Figure 2: BSM front panel plot display.

The third tuning mode, 2-D mode, specifically scans lens HV verses steering voltage or RF phase. The lens HV and steering voltage are highly coupled when maximizing signal strength. Maximum strength will occur when the lens HV is set for best focus and the steering voltage correspondingly set for best transport through the aperture. A similar, but weaker, relationship occurs with lens HV verses RF phase. The 2-D scan display allows determination of these best case set-points (Fig. 3). Final operational set-points for each BSM channel, as a conglomerate, are now saved to file and restored upon system restart.

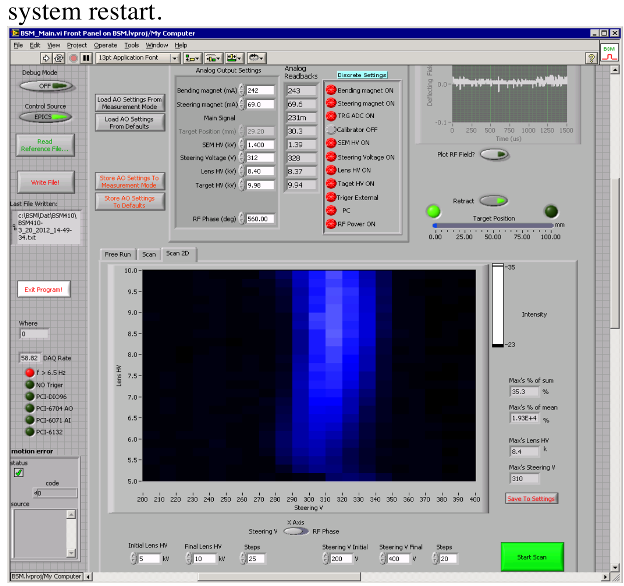

Figure 3: BSM 2-D scan display.

EPICS INTERFACE

The delivered data acquisition system conformed to the BIG's typical practice of using industrialized PC target computers running National Instruments (NI) LabVIEW on the embedded Microsoft Windows XP operating system. This presented a problem in that the main accelerator control system is primarily based on VME/VXI running the Experimental Physics and Industrial Control System (EPICS) with Wind River Systems VxWorks. EPICS software clients are used for most operator interfaces (e.g. EDM). The Windows' Remote Desktop interface to the BIG's target PCs is available from the SNS control room for system developer use, but its application by users is limited and generally frowned upon as non-conforming to their standard operational model of using EPICS. Several approaches to bridge the LabVIEW/EPICS divide have been developed, each with their own list of eccentricities. This EPICS interface complexity has led to a two-tiered software architecture being adopted for most BIG systems: a minimal EPICS network server end-user interface to the underlying LabVIEW for the bare essential functionality of the system along with the use of native LabVIEW instruments, via Remote Desktop, for all other expert user system aspects. The BIG's upgraded BSM software system was no exception to this approach.

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Basic functionality that a user required of the BSM, via an EPICS interface, included: setting of phase resolution/range, setting system electronic gain and target position, scan and stop-scan control, visualization of scanned data and the ability to easily save data to a file. An existing shared memory approach was used. This approach relied on LabVIEW application software invoking an API that ultimately called Windows DLL routines to access a block of shared memory. A modified EPICS soft IOC also ran on this PC and accessed the same shared memory block to provide a complete path between LabVIEW and EPICS. EPICS EDM screens were then created for the actual user interface. A single "Main" overview screen (Fig. 4) for all BSMs in an accelerator region was created, along with individual “Detail" (Fig. 5) screens for each channel. Help screens that described the system’s operation were also made available. System expert usage and tuning, as described previously, was still dependent on the native LabVIEW software exclusively, without EPICS support.

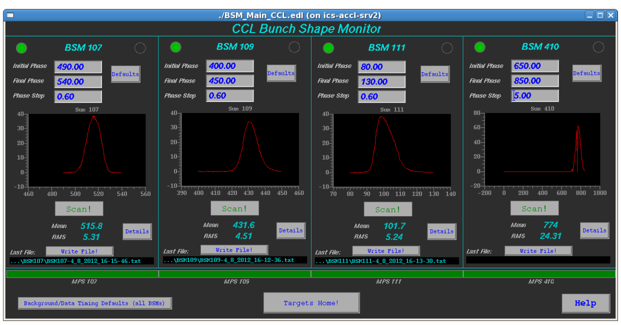

Figure 4: BSM overview display.

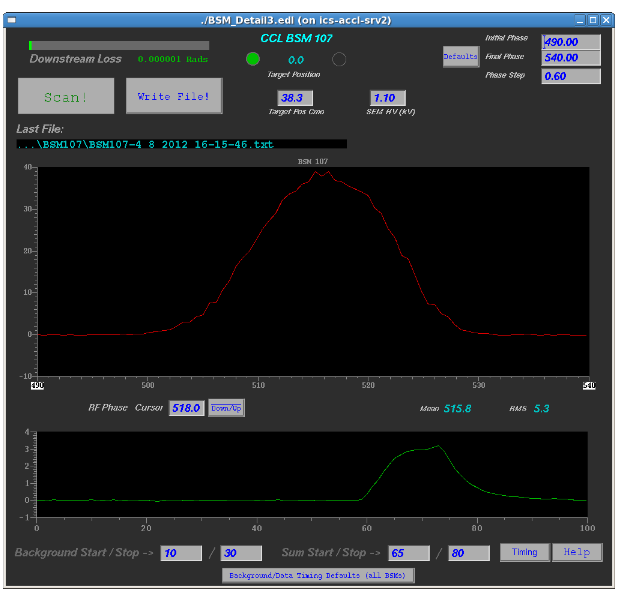

Figure 5: BSM detail channel display.

OTHER ENHANCEMNTS

Additional capabilities were also added to the BSM software system by the BIG. The most complex, and also the most beneficial, was adding autonomous simultaneous control of each BSM channel. As opposed to previously, BSM channels may now have their scans started and stopped independently and run simultaneously with differing scan parameters and states of completion (one or more may be at differing points of scan completion as others are started or stopped). Since a typical scan takes two or more minutes, scanning all channels effectively at the same time is a significant time saver for the user. The delivered software utilized the same ADC device for set-point read-backs as for the main signal acquisition. To allow greater flexibility in the simultaneous scan upgrade’s software design an additional ADC card was added strictly for the main intensity signal. This ADC also had the benefit of greater bit resolution over the original. While adding driver support for this card, the LabVIEW development environment was ported from the obsolete version it was using to a more recent version (now also close to obsolete). The hardware driver architecture for the system was updated as well (DAQmx replacing Traditional NI DAQ).

An oscilloscope type display was added for system set-point read-backs to augment the single value measurement available prior to this upgrade. This feature is useful with system troubleshooting in identifying noise issues and verifying data acquisition synchronization with the accelerator beam pulse. A simple data file viewing ability was added that enables examination of archived scan data in a manner similar to that of the most recent scan being displayed. Like all other set-points, the RF phase is controlled with a DAC output channel. Unlike the others, the device receiving this output is very non-linear. Polynomial expansion mapping was required to convert from the desired angle to DAC output value. Software tools were created to help automate the process of calibrating this mapping (deriving polynomial coefficients). Independent mapping, per channel, was added over the single map that was being used by all channels prior.

PLANS

These upgrades have elevated the BSM software system to operational status. Work will continue in the future with the addition of at least one additional BSM channel, an upgrade of the LabVIEW/EPICS interface and another LabVIEW version upgrade.

ACKNOWLEDGEMENT

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