DEVELOPMENT OF INJECTION AND OPTICS CONTROL APPLICATIONS FOR THE SNS ACCUMULATOR RING *

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Abstract

A large suite of physics software applications is being developed to facilitate beam measurement and control in the SNS accumulator ring. Two such applications are an injection control and measurement application, and a ring optics control application. The injection application will handle measurement and control of the linac beam position and angle at the stripper foil, and measurement of the Twiss parameters and the dispersion at the foil. The optics control application will provide knobs for machine working point, chromaticity, arc phase advance, and harmonic correction. Both applications are written within the standard in-house XAL java-based framework. Presented here are first versions of the applications, along with plans for future development.

INTRODUCTION

The Spallation Neutron Source (SNS), under construction at Oak Ridge National Laboratory, will deliver a 1.4 MW beam to a liquid mercury target for neutron spallation. The SNS accumulator ring is designed to compress a 1000 μs, 1 GeV H^- beam to a single proton bunch with bunch length 695 ns. The ring is 248 meters in length and comprises 52 quadrupole magnets, 20 sextupoles, and a plethora of multipole corrector magnets. With a maximum baseline beam intensity of 1.5×10^{14}, collective effects in the ring are expected to be strong, and attaining good beam stability will require tight control of the ring optics and injection parameters. Convenient methods will be required for measuring and tuning the machine parameters. To address this issue, several software applications are being developed specifically for the SNS ring. These applications are in addition to other, more general-purpose applications which are also under development for the entire accelerator. Two of these ring applications are presented here: the optics control application, and the injection measurement and control application.

The ring applications are being developed in the JAVA language and within the XAL framework which is standard to all SNS physics applications [1]. The XAL framework provides an interface to the EPICS [2] control system, hiding most of the underlying connections from the user, and allowing for easy development of general-purpose physics applications. Additionally, the framework provides a common look and feel across all of the applications, and supplies functionality for saving and restoring application settings, for viewing help, and other general purpose windows-based features.

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RING OPTICS CONTROL APPLICATION

The accumulator ring is a four-sided ring with straight sections dedicated separately to injection, collimation, RF bunching, and extraction. The straight sections are regions of zero dispersion, such that all four arc sections are achromats. Six families of quadrupoles control the tune of the ring: two families in the straight sections, three families in the arcs, and one matching family joining the arcs and the straight sections. The SNS ring is tunable in the range of $Q_x = 5.0 - 7.0$, and $Q_y = 5.0 - 7.0$, with design working point $(Q_x, Q_y) = (6.23, 6.20)$. Additionally, four sextupole families in the ring are available for tuning the ring chromaticity [3], and quadrupole trim magnets are installed on every ring quadrupole for fine-tuning the optics and for providing harmonic correction [4, 5].

For the SNS ring, controlling the tune, chromaticity, and dispersion is not a two-knob problem. For instance, in order to preserve the achromat condition for anything other than a very small change in tune away from the nominal working point, all six families of quadrupoles must be altered. This differs from some other proton storage rings, such as the PSR in Los Alamos and the PS Booster at CERN, where tune changes can be accomplished with two families of quadrupoles. To provide a fast and efficient means of controlling the optics in the ring, an application has been developed which supplies user-friendly interfaces for managing the tune, chromaticity, and dispersion in the ring, and for applying harmonic corrections. The philosophy of the application is to provide operators with one-stop-shopping for controlling the ring optics.

The optics control application relies on a number of static input files which correlate magnet family strengths with optics parameters. These data files are built from MAD program output. For instance, for the tune setting portion of the application, the data file contains a grid of tune points spanning the available tune range, and each tune point is associated with a list of six families of quadrupole strengths that combined produce that tune. For each user-defined tune setting specified, the application performs a four-point interpolation over the data grid to find the correct magnet strengths. The grid spacing between tune points is $\Delta Q = 0.05$, and in general the four point interpolation produces an error of $< 0.1\%$ on the resulting tune predicted by MAD, except very close to integer tune values ($<$0.03), where the error is larger. After the interpolation is performed, the user is shown the predicted quadrupole family settings, and is given the option to assign these settings to the machine. Additionally, a tune resonance diagram shows the location of the last applied tune set-point. A snapshot of the application interface is shown in Figure 1.

The chromaticity and arc phase advance control are constructed in the same manner as the tune control portion of the application: the programs sample from an underlying grid of magnet strengths predicted by the MAD program. A complication for the chromaticity and dispersion control is that the magnet settings are correct only for a specific tune setting. For instance, sextupole settings which give zero chromaticity for a given tune setting do not necessarily give zero chromaticity for another tune setting. To provide some flexibility on this issue, the chromaticity interface will supply data grids for two different working points: the nominal working point and the first alternative working point; the arc phase advance control interface presently provides functionality for only the main working point, but the number of data sets can be easily increased as becomes necessary during operation. The long-term goal for the application is to replace the current database of MAD results with data derived from operational experience.

The last portion of the application deals with betatron harmonic correction, and is not yet developed. This feature will provide knobs for harmonics correction using the trim quads located on the quadrupole magnets. The application will provide independent knobs for control of non-structure even and odd harmonics [5].

RING INJECTION APPLICATION

The beam from the SNS linac will be strip-foil injected into the ring, and painted in both the horizontal and vertical directions. Four steerer magnets in the HEBT line will provide control over the linac beam spot position and angle on the foil. The final accumulated distribution in the SNS ring is a function of the injection parameters (linac spot position, closed orbit bump, etc), and the lattice optics at the foil. An injection application is under development to facilitate measurement and control of the injection parameters. The application will provide measurement and control of the linac spot position and angle on the foil, measurement of the linac Twiss functions at the foil, and measurement of the dispersion at the foil. The first of these tasks, the linac injection spot measurement, is described here.

The ring BPMs will be used to infer the position of the linac beam on the foil. There are 44 BPMs in the ring, each with a narrowband (402.5 MHz) measurement capability and a baseband ($\sim$ 1 MHz) measurement capability. Due to the fast decoherence of the 402.5 MHz linac microbunch structure ($\sim$ 6 turns) [6], the baseband capability provides a smaller measurement error and is therefore used in the first version of this application; the application will eventually be upgraded to utilize both bands. The injection spot measurement routine fits single-shot, turn-by-turn BPM data with a damped cosine function. The fit gives the tune of the beam, the first-turn horizontal and vertical position and angle at the BPM, and an arbitrary phase offset. If the Twiss parameters and the phase advance between the foil and the BPM are known, then the fitted parameters can be used to find the position and angle at the foil [7]. The Twiss and phase advance information is provided to the application by the online model, an XAL feature that allows on-the-fly calculations of beam parameters based on live machine settings [1].

One advantage of automating the injection spot measurement is that the interface allows the user to select an arbitrary number of BPMs and perform the fits simultaneously. The results of all of the fits are compiled in a table and the user is is given the option to plot each fit with its corresponding BPM data. The user can also accept or reject the data. The accepted fits are included in an averaging calculation which yields the final measurement result. Though presently unavailable, an error analysis feature will also be included in the fitting and averaging routines. Figure 2 shows the application interface.

The final result from the injection measurement is stored and used in the injection control portion of the application. This portion uses the online model to transport the beam position and angle at the foil backwards through the HEBT to the first of the four dipole steerers. Using this as an initial condition, the online model then adjusts the steerers to produce the user-specified new linac beam position and angle at the foil.

Other features of the application, including the Twiss and dispersion measurement at the foil, are still under development.

SUMMARY

Two applications under development for use in the SNS accumulator ring have been presented. A number of other ring-specific applications are also underway, including one for measuring and correcting the beam closed orbit, one for measuring and correcting the ring optics, one for measuring and controlling the beam in the transport lines to and from the ring, and one for viewing the losses in the ring. These applications are in addition to a large suite of general-purpose applications which have already been developed for use throughout the entire accelerator.

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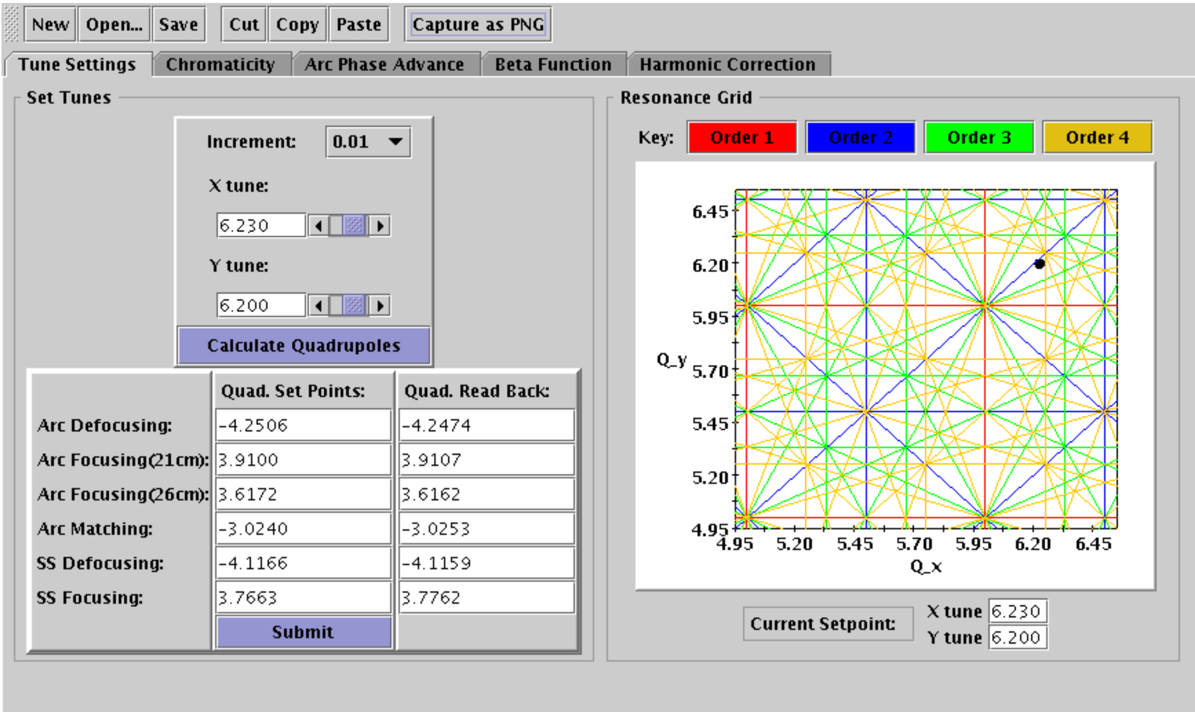

Figure 1: A snapshot of the GUI interface for the ring optics control application, showing the tune setting portion of the application

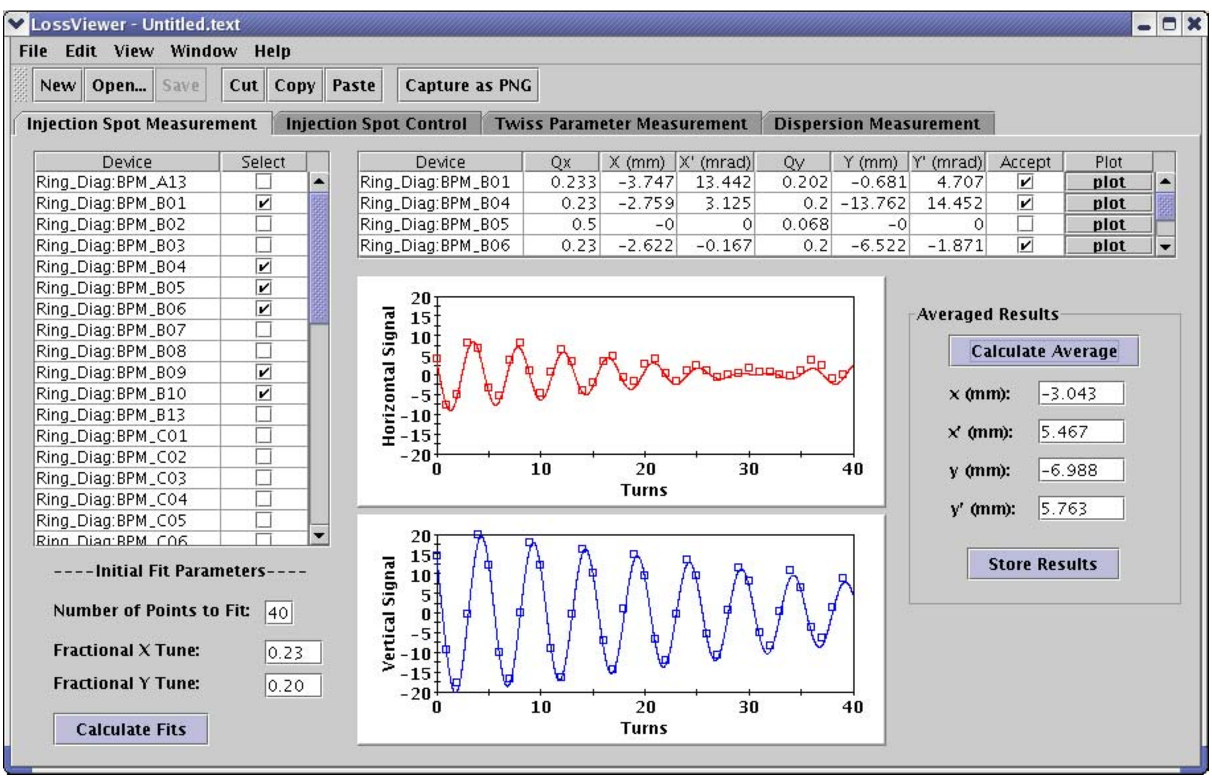

Figure 2: A snapshot of the GUI interface for the ring injection measurement and control application, showing the injection spot measurement portion of the application. Since the signal for the BPMs in this snapshot was generated by a dummy server, there is no correlation among the measurement results here. This will not be the case for the real machine.