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APPLICATIONS OF BEAM PARAMETER MEASUREMENTS IN TRANSPORT LINES AT CSNS

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Abstract

Several XAL-based applications for parameter measurements in Medium Energy Beam Transport line (MEBT) and Linac to Ring Beam Transport line (LRBT) at China Spallation Neutron Source (CSNS) have been developed. Algorithms and functions of these applications are introduced in this paper. Real Machine tests are carried out in the MEBT commissioning.

INTRODUCTION

China Spallation Neutron Source (CSNS) [1] has an H- linear accelerator as an injector and a rapid cycling synchrotron (RCS) of 1.6 GeV. The linac part consists of an H- ion source, a low energy beam transport line (LEBT), a four-vane RFQ linac of 3 MeV, a medium energy beam transport line (MEBT) and a four tank DTL linac working at RF frequency of 324MeV. The linac to ring beam transport line (LRBT) connects the DTL linac and the RCS and it reserves the space for linac upgrading in the further .

XAL[2] is a Java-based application framework which is developed at the Spallation Neutron Source (SNS) at first, then many other accelerator laboratories join the collaboration, including CSNS. XAL provides an accelerator physics programming interface to the accelerator, and it allows creation of general-purpose applications dedicated to various parts of the accelerator and various kinds of the accelerators. Although most tools in XAL application package can be transplanted directly for the use of CSNS, work of developing new essential tools to meets the distinct requirements of CSNS is still necessary.

XAL TOOLS FOR TRANSPORT LINE

Since the first accelerator device of CSNS was installed last October, the installations of ion source, LEBT, RFQ and MEBT have been finished. The commissioning of the front end is proceeding well and the MEBT transport line is going to start soon after. Applications for MEBT commissioning are based on XAL and some new tools have been developed for CSNS. In this paper some of the new developed tools for transport line parameter measurement are introduced, including tools for measuring twiss parameters at MEBT entrance, fudge factor measurement and dispersion function measurement. We are running tests of there tools on the real machine during the commissioning. Algorithms and functions of these applications are presented as follow.

Twiss Parameters Measurement Tool

MEBT of CSNS linac is located between RFQ and DTL, one of whose major functions is for beam matching both transversely and longitudinally. Figure 1 gives the schematic drawing of MEBT.

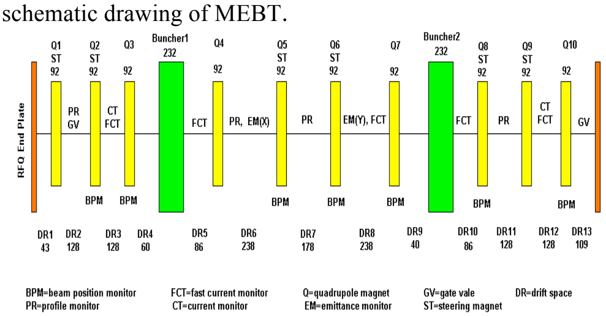

Figure 1: Schematic Drawing of CSNS MEBT.

The energy of MEBT is 3MeV and the peak current intensity is 15mA. Nonlinear space charge force must be considered seriously in the low-energy section of such a high intensity linac. Parmila[3] is an ion linac particle dynamics code. It is a versatile multi-particle code that generates the linac and transforms the beam, represented by a collection of particles, through a user-specified linac and/or transport system. It's widely used in linac designs and simulations, which have proved the accuracy in dealing with the low-energy optics calculation problems. To achieve good solution of MEBT optics matching, the twiss parameters at the MEBT entrance should be acquired first. By employing PARMILA code and 4 wire scanners devices installed in MEBT, a java-based tool was developed to fulfill this purpose. Figure 2 is the algorithm chart of the tool.

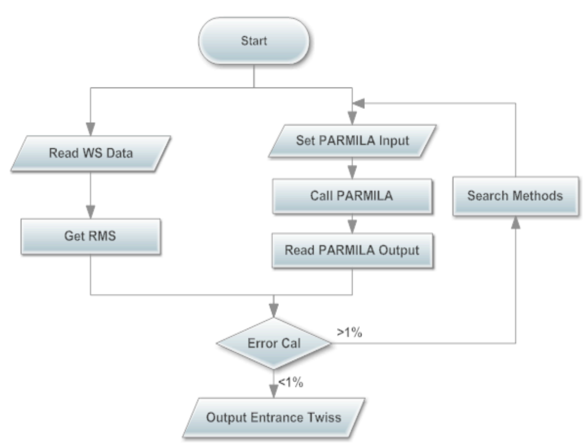

Figure 2: Algorithm Chart of Twiss Parameters Measurement Tool.

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First, we make wire scanners start to work and get RMS values of the experimental profiles. Then, pick a point upstream which is usually chosen at the beginning part of an accelerator section, MEBT entrance, e.g.. We set the initial twiss parameters and the limits on alpha and beta at this point, write them into the Parmila input file. Then call the Parmila code and read the output files to get the beam profile RMS values at the wires' locations. By iteration and methods of searching, we can minimize the discrepancy between the wire scanners' experimental data and the Parmila calculation results. When the discrepancy reach the satisfaction standard we set, iteration and searching stop, the final twiss parameters at the MEBT entrance are obtained.

XAL has tools with similar methods for getting twiss parameters at the entrance of a transport line. However, there are differences between the algorithms of the on-line model and Parmila calculation. To verify the results of each others, this tool is necessary. It can also be used in other low-energy accelerator sections where beam profile devices are installed.

Fudge Factor Measurement Tool

Due to the errors of all the components of an accelerator, the real optics will be different from the design one. The tool described as below is to deal with this issue and improve the optics in CSNS transport line.

a fudge factor AF was used to describe the correction of each quadrupole strength to restore the optics, it is defined as below:

$$K_{ps} = AF \cdot K_d \tag{1}$$

where K_{ps} is a strength after correction and set to magnet. and K_d is the original one set for the theoretical lattice. When the fudge factors are applied to the transport line, they will compensate the errors and lead to good agreement between theoretical and measured beam optics functions with small discrepancy.

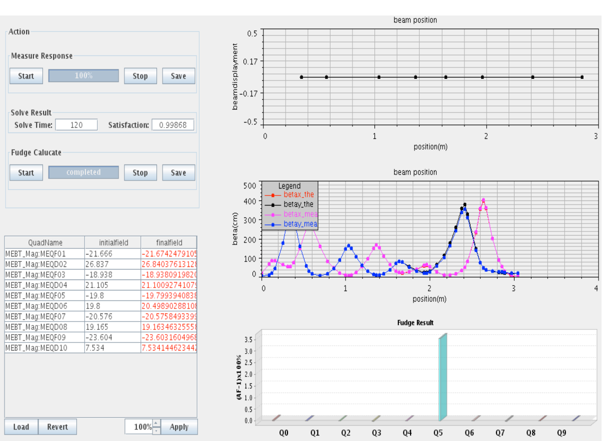

Figure 3: GUI of Fudge Factor Measurement Tool.

The method to get the fudge factors of quadrupoles' field by measuring the response matrix is widely used [4]. In the fitting procedure we minimized the discrepancy between model predictions and measured response matrix. An XAL optimization package was employed to do the fitting. The fitted results of the fudge factors are consistent with the input values.

Figure 3 is the GUI of the Fudge factor measurement tool. The left panel is mainly for different operations and the right panel shows the results of fudge factor and the beta function. In order to analysis and check the data after the measurement, the measured data are saved in MYSQL database.

The values of K_{ps} are obtained after getting the fudge factors of the quads. These values will be set to magnet power supplies for the optics correction. The beta function can also be calculated by the XAL model with these values. So this application is an indirect tool to get the beta function as well.

Dispersion Measurement Tool

Dispersion is generated at the places with bending magnets or dipole field. The measurement and correction of dispersion at these places are import for the optics. In the case of CSNS LRBT, if the dispersion is not canceled in the injection point of RCS, the extra transverse beam size increment brought by energy spread may cause more emittance growth and beam loss.

Dispersion measurements are usually based on measuring the orbit or beam profile for different energies of the beam. By scanning the upstream energy, the transverse orbit variations can be measured by BPMs downstream. The transverse orbit is usually expressed as below:

$$x(s) = x_0(s) + \eta(s)\frac{\Delta p}{p} + \eta(s)'(\frac{\Delta p}{p})^2 + \ldots \tag{2}$$

Where s is the position of the BPM used for orbit measurement and $x(s)$ is the transverse orbit read by BPM. The $\eta(s)$ and $\eta(s)'$ values are derived with a second order fit to the BPM data. $\eta(s)$ is referred to dispersion in this paper.

The energy of beam in LRBT can only be tuned by the upstream RF elements, debuncher or DTL. However, the range of energy tuning given by debuncher is quite limited, the orbit change may not be detected due to the resolution of the BPMs. And the output energy tuning of DTL tanks is quite complicated. Therefore, the orbit variation is difficult to be generated by beam energy scanning in our case.

Instead of beam energy scanning, each step all the local magnets' field are scaled in the same proportion but in the opposite direction. The orbit changes produced this way will be exact the same as that by energy scanning. Using this method, an XAL based dispersion measurement tool was developed. Figure 4 shows the application GUI. Dispersion can be measured in the transport lines of

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CSNS, and the dispersion correction function is being developed.

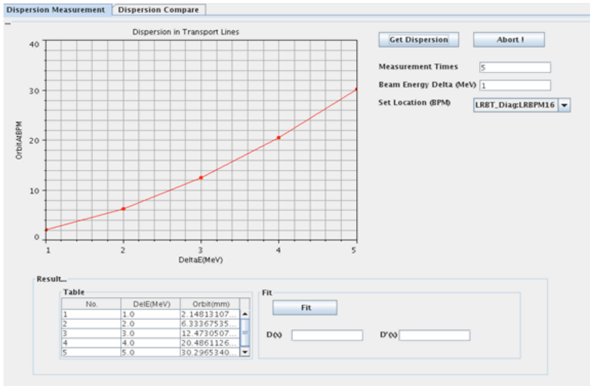

Figure 4: GUI of Dispersion Measurement Tool.

CONCLUSION

In this paper we have introduced three tools for beam parameters measurement in transports line commissioning of CSNS. These tested Java-based tools are good complements for the XAL application package.

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