MATLAB-BASED ACCELERATOR PHYSICS APPLICATIONS FOR THE TPS COMMISSIONING AND OPERATION AT NSRRC

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Abstract

Taiwan Photon Source (TPS) is the second synchrotron light source in Taiwan which is currently under construction at the NSRRC existing site. With a 3 GeV beam energy, low emittance, 24-DB structure in the storage ring, the TPS can generate higher brilliance and more abundant X-ray sources. TPS is in complementary to the overbooked 1.5 GeV Taiwan Light Source (TLS). The MATLAB-based accelerator physics application programs planned for the TPS commissioning and operation is a high-level software collection including the MML, AT, LOCO, etc., developed at ALS and SLAC. In this report, the testing results by employing this package to the Taiwan Light Source (TLS) are given and the simulations of the TPS virtual machine are also demonstrated.

INTRODUCTION

The preparation of the high-level application software is under way for the commissioning of the TPS scheduled in 2013. The accelerator physics application programs are developed based on the following considerations:

- Instead of using the homemade control system of the TLS. The TPS control system will adopt the EPICS.
- Without using the TLS machine physics application programs (using the X window and C programming language).
- MATLAB is chosen as the common programming environment. We mention that there are already rich MATLAB-based resources linked to the EPICS worldwide. It will save us manpower in the program development.

The TPS accelerator physics application programs (APAP) mainly base on a collection of MATLAB-based tools including the MML[1], AT[2], LOCO[3], etc., developed and integrated by Gregory J. Portmann *et al*, for the application on the ALS and SPEAR3. This package has also been ported to recent 3rd generation light sources such as CLS, ASP, SOLEIL, DIAMOND, SSRF, and ALBA. Following these successful experiences, we have set up this package at NSRRC. We link it to the TLS homemade control system for the testing on the TLS and prepare the TPS virtual machine for the simulation of the TPS commissioning. We present the testing results by employing this package to the TLS and demonstrate the simulations of the TPS virtual machine in the following sections.

APPLICATION PROGRAMS OVERVIEW

The structure of new APAP at NSRRC for the TPS is shown in Figure 1. The AT is used for machine modelling as a virtual machine. With the connection by the MML, the data is linked among the machine layer by the Channel Access (CA) such as LabCA, machine modelling (AT), and high-level applications. We have linked this APAP to the TLS control database including the EPICS of new turn-by-turn BPM system for testing. Some MATLAB applications such as the linac beam parameter measurement may also work independently through the extensive Data Access Interface.

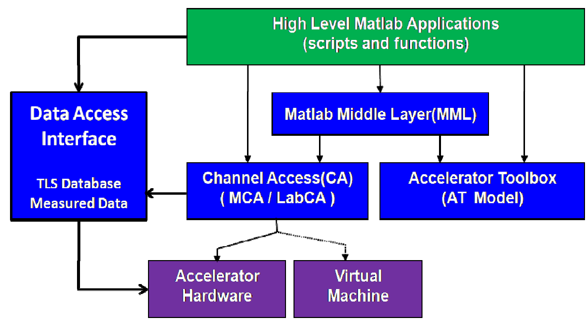

Figure 1: NSRRC/TPS APAP structure.

The MATLAB-based APAP provides not only the on-line control of the accelerators but the off-line machine simulations. Following functions are available for the control:

- Energy ramp
- Configuration save/restore
- Global orbit correction
- Local photon beam steering
- Insertion device compensation
- Beam-based alignment
- Tune correction
- Response matrix measurement
- Script-based physics studies
- Chromaticity correction

The accelerator applications at the high layer include Beam-based alignment (BBA) [4], orbit correction, lattice calibration (LOCO), beam parameter measurement, and so on. According to the requirements, the designer can develop different applications and the graphic user interfaces (GUI) to strengthen the functions of the APAP.

CURRENT STATUS OF APAP

At present, we have already built up some application programs and the databases of the TLS and TPS. We also have tested some programs on the TLS because the TPS is still under construction. For user-friendly operation

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purpose, every application originally run by scripts is improved by the operational GUI.

Control and Simulation of the TLS and TPS

Refer to the AT lattices of the TLS storage ring and the TPS accelerator complex, the related MML databases have been set up for data linking among the TLS storage ring hardware, TPS virtual machine and AT machine models. Figure 2 shows the on-line mode TLS storage ring. The BPM data can be picked up from either the TLS control database or the new EPICS such that the electron trajectories in both the horizontal and vertical planes are presented. The TLS storage ring includes nine operational IDs such as the superconducting wavelength shifter SWLS, elliptical polarization undulator EPU56, undulators U5 and U9, wiggler W20, superconducting wiggler SW6, and three in-arc superconducting wigglers IASWA, IASWB, and IASWC.

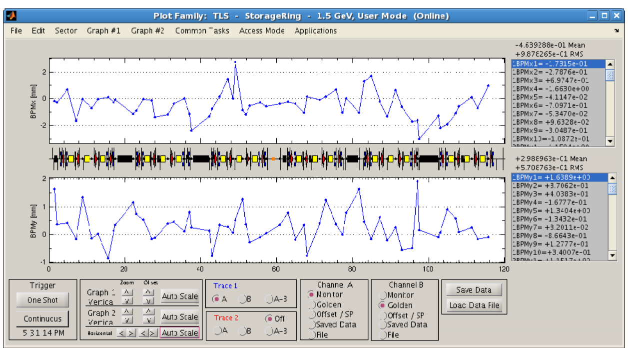

Figure 2: TLS storage ring (on-line mode).

The simulation of TPS closed orbit distortion (COD) due to specific corrector settings of the storage ring is shown in Figure 3. The COD patterns are characterized corresponding to the horizontal and vertical betatron tunes (26.18, 13.28).

Besides the storage ring, the booster and transfer lines (LTB and BTS) are also shown in Figure 4. We have checked and compared the accelerator parameters (twiss function, emittance, tune, chromaticity, etc.) with the design values (MAD results) to confirm and verify all these TLS and TPS databases are credible.

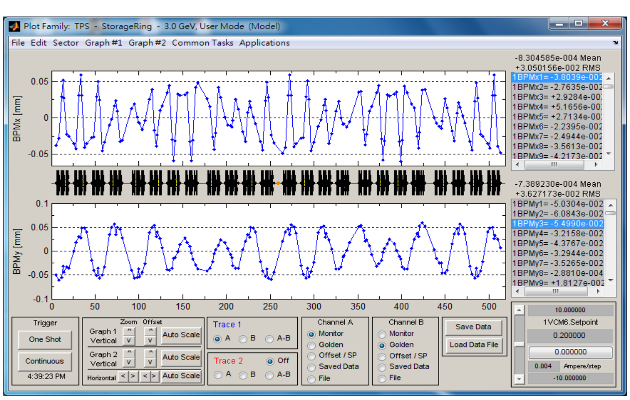

Figure 3: TPS storage ring simulator.

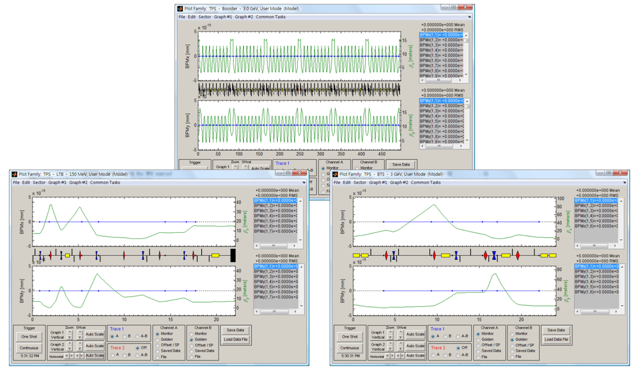

Figure 4: Simulators of TPS LTB and BTS transfer lines and booster ring.

TPS Linac Beam Parameter Measurement

The linac diagnostic beam line LTD (Linac To beam Dump) GUI shown in Figure 5 is developed for the linac beam parameters measurement. Using the beam size measured by the "quadrupole scan technique" on a screen monitor after a set of quadrupoles and drift spaces, the beam parameters β, α and ε at the entry of the LTD can be determined.

Varying the quadrupole strengths $\boldsymbol{k_1}$ and using the screen monitor to measure the beam size, we can calculate the beam parameters by Eq. (1-3). If the beam parameters are correct, the fitting results of the beam size will be very close to the measurement results.

$$\sigma \equiv \begin{pmatrix}\sigma_{11} & \sigma_{12}\\ \sigma_{12} & \sigma_{22}\end{pmatrix} = \varepsilon\begin{pmatrix}\beta & -\alpha\\ -\alpha & \gamma\end{pmatrix}, \quad \sigma_{11}\cdot\sigma_{22}-\sigma_{12}^2=\varepsilon^2 \quad (1)$$

$$\begin{pmatrix}\sigma_{1,11}\\ \sigma_{2,11}\\ \sigma_{3,11}\\ \vdots\\ \sigma_{n,11}\end{pmatrix} = \begin{pmatrix}C_1^2 & 2C_1S_1 & S_1^2\\ C_2^2 & 2C_2S_2 & S_2^2\\ C_3^2 & 2C_3S_3 & S_3^2\\ \vdots & \vdots & \vdots\\ C_n^2 & 2C_nS_n & S_n^2\end{pmatrix}\cdot\begin{pmatrix}\sigma_{11}\\ \sigma_{12}\\ \sigma_{22}\end{pmatrix} = M_\sigma\cdot\begin{pmatrix}\sigma_{11}\\ \sigma_{12}\\ \sigma_{22}\end{pmatrix} \quad (2)$$

$$\sigma_{11}(\vec{k}_1) = C^2(\vec{k}_1)\cdot\sigma_{11} + 2C(\vec{k}_1)S(\vec{k}_1)\cdot\sigma_{12} + S^2(\vec{k}_1)\cdot\sigma_{22} \quad (3)$$

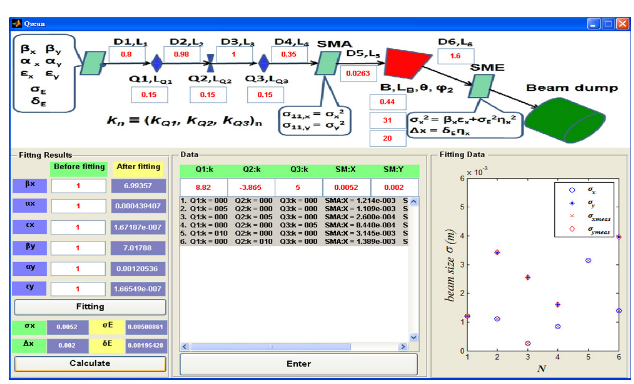

Figure 5: Linac diagnostic beam line LTD GUI.

Beam-Based Alignment GUI

Using BBA to determine the quadrupole field centres is one of the important items of the machine commissioning. In order to test the effectiveness of BBA, we revise the MML to connect with the homemade control system of the TLS. We successfully apply and test the BBA on the TLS storage ring.

Ideally the electron orbit should pass through all the magnetic field centres of lattice to reduce the feed-down effects. From the measurement results of the BBA, we could adjust the electron orbit to pass through the quadrupole field centres. This is identified as the so-called golden orbit. In addition, BBA could also be applied to the sextupole magnets.

Instead of running the "quadcenter" command to execute the BBA, we develop a BBA GUI (see Fig. 6) in order to have more convenient usage for the operation with following advantages:

- Select one or all quadrupole families at the same time
- Users can change the parameter settings by the GUI
- Monitor the variations of the orbit and the correctors
- Display the information of the relative BPM and corrector to the quadrupole
- Review the results on the GUI

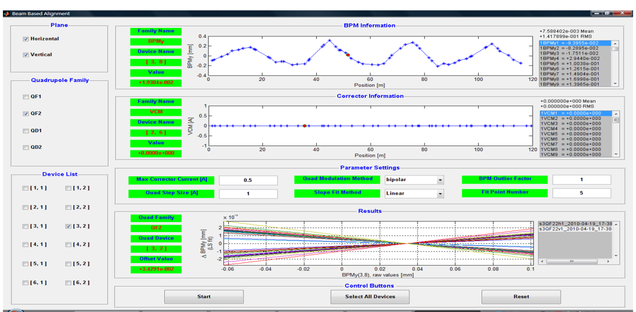

Figure 6: Beam-based alignment GUI.

Figure 7 shows the BBA results of the TLS storage ring. We have done the measurements twice in order to understand the reliability of the measurement results. From the data analysis, the majority of the measurement data are consistent.

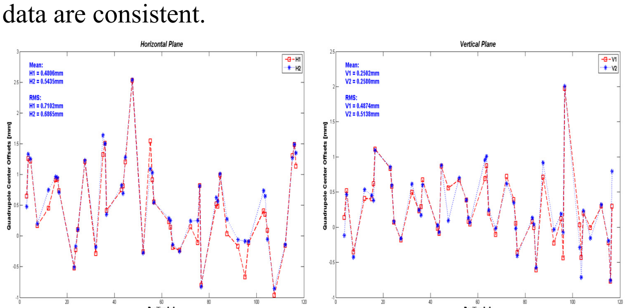

Figure 7: BBA results of the TLS storage ring.

Orbit Control Interface GUI

Orbit adjustment/correction (see Fig. 8) is necessary for the machine commissioning and daily operation. There is an "orbitgui" [5] for orbit control originally built in the MATLAB-based package. We have modified it to fit different accelerators and tested it on the TLS storage ring for the program improvement.

This application uses the "SVD" method to correct the orbit. The response matrix related between BPMs and CMs for the orbit control can be measured from the TLS real/virtual machine or be generated from the AT model. The measured orbit response matrix of the TLS storage ring is shown in Figure 9.

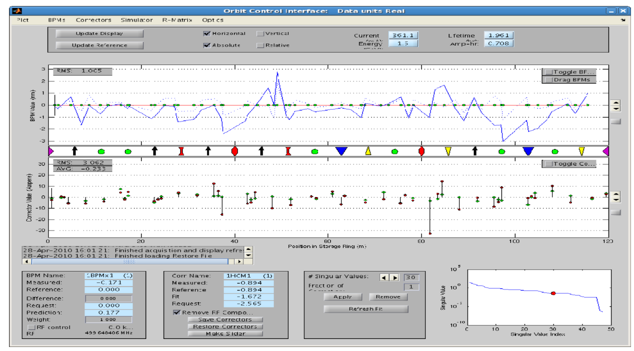

Figure 8: Orbit control interface of the TLS storage ring.

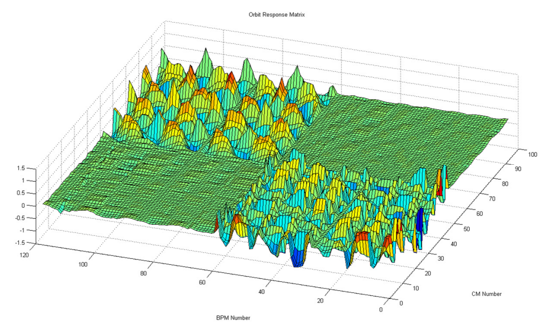

Figure 9: Orbit response matrix of the TLS storage ring.

SUMMARY AND ACKNOWLEDGEMENT

The preparation of accelerator physics software for the TPS commissioning and operation is presented. The required database except the EPICS channel names linked to the TPS accelerator hardware has been set up for simulation and testing. We have tested some programs on the existing TLS storage ring to get the experience for further improvement. We will continuously develop related applications and GUIs for user friendly operation.

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