RESURRECTION OF RESOLVE AT NSRRC PREPARED FOR THE FIRST TURN BEAM STEERING OF THE TPS COMMISSIONING

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Abstract

MATLAB-based high-level software for the 3GeV Taiwan Photon Source (TPS) has been built and tested on the 1.5GeV Taiwan Light Source (TLS) continuously. The RESOLVE program is surveyed and resurrected at NSRRC to support and help the first turn beam steering in the upcoming commissioning of the TPS accelerator complex. The RESOLVE contributed a lot in the past commissioning of SLC at SLAC National Accelerator Laboratory. Although most of the first turn beam steering of current light source machines may pass smoothly with well machine construction, we believe it will provide beam steering practical needs in the commissioning phase. In order to make the revised RESOLVE working, not only the compiling problem but also some memory bugs have been fixed. The updated RESOLVE can be run on PC/Linux and Mac/OSX computer systems. We are trying to apply and test it on the TLS storage ring with the turn-by-turn digital BPM system. Some exercises of the error finding in beam steering of the off-axis injection beam are performed for presentation in this report.

INTRODUCTION

The MATLAB-based high-level software of accelerator physics applications at NSRRC prepared for TPS commissioning and operation [1] has collected a lot of worldwide application programs such as:

- MML for accelerator control,
- BBA for searching the quadrupole field centers and helping the definition of golden orbit,
- Orbit correction with SVD, MICADO, or Simple Bound Constraint Most Effective (SBCM) methods,
- LOCO for lattice calibration.

Most of these applications are all performed when the particle beam can be stored. We haven't found the MATLAB-based application for the first turn beam steering in the public domain. The past experience of accelerator commissioning in the world shows that some unknown mistakes made during machine construction may cause the beam commissioning difficult. Such that the first turn beam steering may be a challenge to the machine construction quality control.

This beam steering issue was discussed in a regular beam dynamics meeting and we started to review what we have in hand to fulfill the requirement. The RESOLVE program is a model-based expert system developed by the team of Martin Lee [2]. With the beam-based analysis, it can be applied for the diagnostics of accelerators including misalignment and field error. We had an old VAX/VMS version of RESOLVE program from SLAC in the beginning of 1990's for the preparation of 1.3 GeV Taiwan Light Source (TLS) commissioning. The beam commissioning of TLS was performed base on the screen monitors such that the RESOLVE was not applied due to none BPM data input. After that, the computers for TLS control system were upgraded to workstations and PCs with UNIX-like OS. Although an updated UNIX-like version of RESOLVE was available to us a couple years ago, it was cast aside due to the occurrence of run-time core dump problem after compiling.

To meet the first turn beam steering issue of the coming TPS commissioning, we reactivate the RESOLVE by using the debugging tool "gdb" to trace the run-time memory and fixing the bugs of memory size problems in the program. Because the RESOLVE is not a MATLAB-based program we provide the required particle beam line and beam trajectory from the MATLAB programs which can access the data from the homemade TLS control system or the EPICS. We have applied the RESOLVE and its associated access programs to the TLS storage ring with the digital BPM system. In the following sections, we will demonstrate the result.

RESOLVE ANALYSIS FOR TLS STORAGE RING

For the purpose of improving the orbit feedback system [3], the digital Libera BPM system of TLS storage ring has been upgraded. The new BPM system provides the turn-by-turn BPM data to be accessed through the EPICS, which is adopted as the TPS accelerator control system. Referring to the injection scheme of TLS storage ring (see Fig. 1), we use the first turn trajectory of the off-axis injection beam for RESOLVE analysis.

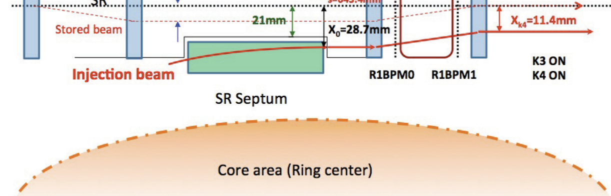

Figure 1: The injection scheme of TLS storage ring.

In order to simulate the commissioning of TPS storage ring, the first turn beam experiment of the TLS storage ring was performed under following conditions: almost

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magnets and insertion devices were turned off except the combined function bending magnets and the 4 quadrupole families of the TBA lattice and the fixed gap wiggler W200 which was out of control due to the transmission shaft damage. The configuration of TLS storage ring has prepared as a particle beamline input for the RESOLVE. All the data is also uploaded from the control system of TLS storage ring during the experiment. The electron beam was off-axis injected into the TLS storage ring in the normal multi-bunch mode. The least injection cycles was tested and applied such that the turn-by-turn BPM system can archive the injection beam signal.

Analyzing the first turn BPM data, we identified those BPMs with small sum signal (see Fig. 2) and the first two BPMs located between kickers K3 and K4, where the injection beam passes through the edge of their four buttons, as possibly the bad BPMs for the RESOLVE analysis (see Fig. 3).

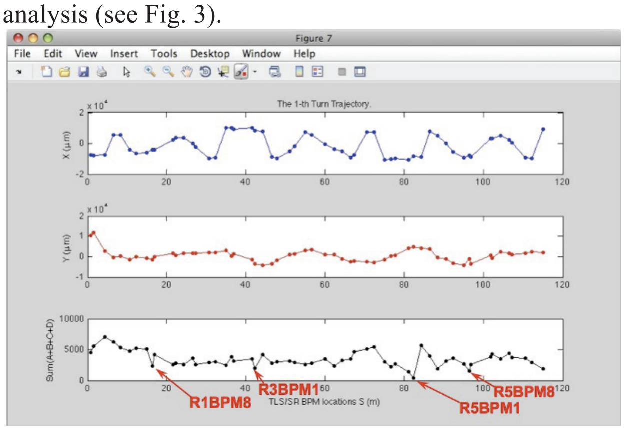

Figure 2: BPMs with small sum signal were identified during the BPM data processing. They may be the possible bad BPMs in the RESOLVE analysis.

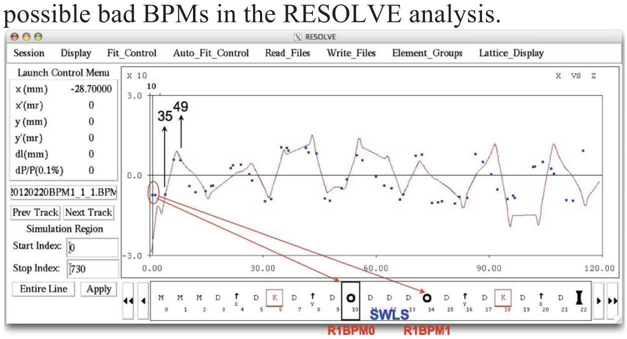

Figure 3. The first two BPMs in the first turn trajectory of TLS storage ring off-axis injection beam used for RESOLVE analysis were ignored due to the injection beam passing through far away from their centers.

The RESOLVE was applied for good region searching and error finding by fitting the measured BPM data with model-based simulation.

Searching Good Regions

Each good region was fitted by two variables. Due to the off-axis injection conditions x_0 = -28.7 mm and strengths of K3/K4 are 11.6/-11.6 mrad, the first good region (see Fig. 4) was fitted by the x'$_0$ and dP/P. Other following good regions were fitted by x0 and x'0 and the dP/P achieved in the first good region was preserved. These results are shown in Fig's. 5-7.

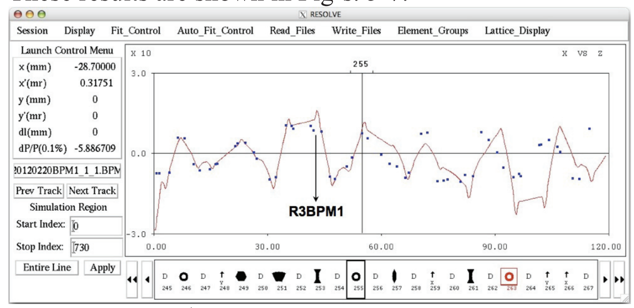

Figure 4: The 1st good region is obtained by fitting with two possible errors x'$_0$ and dP/P. The achieved dP/P was fixed for following good region searching. The x'$_0$ was mentioned for further error finding process.

Figure 5: The 2nd good region is obtained by fitting with two effective launching conditions x and x'.

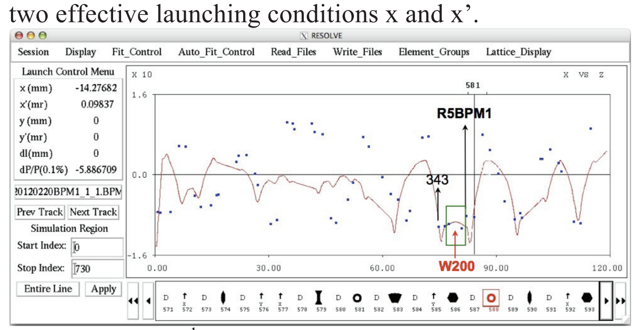

Figure 6: The 3rd good region is obtained by fitting with two effective launching conditions x and x'.

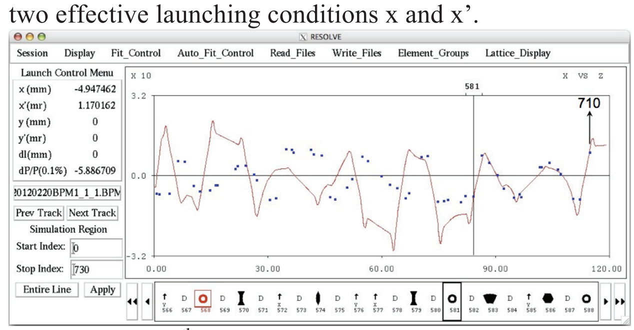

Figure 7: The 4th good region is obtained by fitting with two effective launching conditions x and x'.

Error Finding

The philosophy of error finding is that there must be something wrong between two continuous good regions such that the beam path is different with the prediction of the model-based simulation. RESOLVE allows setting misalignment and field error to connect good regions. The good fitting results decide the possible errors. Figure 8 shows the final fitting result and the possible errors are listed in Table 1. These possible errors should be confirmed or tested and then corrected or compensated.

There are three possible errors between the 2nd and 3rd good regions, two of the three possible errors are enough used to connect these two good regions. The fitting results must be checked if they are reasonable. It shows the most possible kick error between the 1st and 2nd good regions is the misalignment of R3QF7 with dx = 0.68 mm. There are three possible quadrupole errors between 2nd and 3rd good regions. The most reasonable single kick error is R4QF7 with dx = -1.41 mm. The R4QD8 with dx = 3.58 mm could be a solution but it seems too large and was eliminated from the survey and alignment viewpoint. Two possible quadrupole misalignment errors located between the 3rd and 4th good regions. The reasonable single kick error is R5QD3 with dx = 0.26 mm. The other possible error R5QF2 with dx = -0.02 mm seems only improving the fitting result a little.

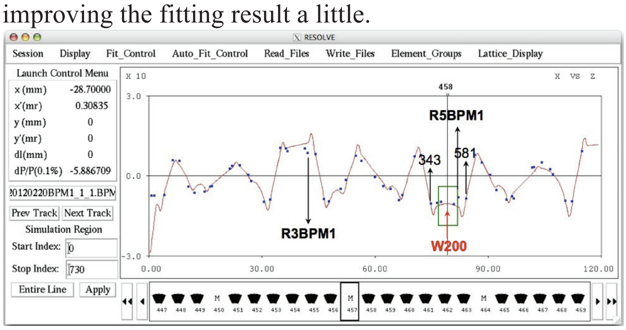

Figure 8: The result after error finding is achieved by RESOLVE.

Table 1: Possible Errors Analyzed by RESOLVE

Good region(s)	Possible error(s)
1st	Energy mismatch (dP/P = -0.6%) Launching condition (x'_0 = 0.3 mrad)
1st, 2nd	Misalignment of R3QF7 (dx=0.68 mm)
2nd, 3rd	Misalignments of quadrupoles R4QD6, R4QF7 (dx=-1.41 mm), or R4QD8
3rd, 4th	Misalignments of quadrupoles R5QF2 or R5QD3 (dx=0.26 mm)

DISCUSSIONS

The RESOLVE program at NSRRC is resurrected now. It is prepared for helping the coming first turn beam commissioning of TPS. We have applied it on the TLS storage ring for testing purpose. The result of experiment and analysis has been presented in this work.

Generally the first turn beam is tested with the on-axis injection condition, which requires higher strengths of kickers. If we use the kicker K4 for the on-axis injection, we need to tune the BTS transfer line such that the beam condition at the exit of injection septum makes the injection beam passing through the center of K4. Another possible on-axis case is using kickers K3 and K4 with higher driving strengths to compensate the injection offset x = -28.7 mm.

Because the TLS is daily operated for users, the driving kickers to higher strength for on-axis injection test may cause the performance risk of the TLS top-up mode operation. Consequently we are only allowed to do the off-axis injection test for RESOLVE analysis.

RESOLVE is a fundamental model-based accelerator debugger [2] by analyzing the beam trajectories so that possible errors can be found and corrected. There are some other machine debuggers such as the MIA [4] combined with a model to do the machine analysis up to higher orders. For the stored beam case, the LOCO is usually used for the lattice calibration [5]. It analyzes the large data of response matrix fitted by adjusting parameters i.e. possible errors in accelerator model.

Currently the light source accelerators are designed to achieve the ultra small emittance. The corresponding strong focusing brings the high field sextupole magnets. It causes the increasing of nonlinear beam dynamics. The tools and philosophy of accelerator debuggers are required to improve the machine modeling and the nonlinear beam dynamics characters [6].

ACKNOWLEDGMENT

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