

# ORBITKORREKTUR, A JAVA CLIENT FOR TRANSVERSE ORBIT CORRECTION IN PETRA-III

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## Abstract

PETRA-III is a 3<sup>rd</sup> generation synchrotron light source dedicated to users at 14 beam lines with 30 instruments in the Max von Laue Hall and 10 beamlines in newly constructed Extensions in North and East which are under installations. PETRA-III is operated with several filling modes such as 60, 480 and 960 bunches with 100 mA or 40 bunches with 90 mA at an electron beam energy of 6 GeV. Transverse orbits are corrected to a reference orbit, which is based on BBA measurements taking into account requirements of the beamlines and results of the dispersion correction. Histograms from 244 BPMs are displayed by means of this Java Client OrbitKorrektur. The orbits may be corrected using the Effective Correction Method with a few correctors or can be corrected using the SVD Method with proper singular Eigen values using theoretical response matrices from an Optic Server of used Optics. In this application additional features are implemented for better observation and analysis of orbits. Furthermore it can also be used to do many additional jobs, such as showing corrector set currents, loading golden and reference orbits, local bumps, displaying the first turn data during commissioning etc.

## INTRODUCTION

PETRA-III [1] is a 3<sup>rd</sup> generation synchrotron light source commissioned with electron beam energy of 6 GeV and 100 mA stored current at betatron tune values of 37.12 and 30.28 in 2009. It has a large circumference of 2304 m which is considerably larger than any existing light source around the world. The machine consists of arcs and several straight sections. The so-called long straights which have a length of 108 m are located in the North, East, South and West. In between two long straights are arcs and a short straight section with a length of 64.8 m. The magnetic structure is a simple FODO lattice. The part that extends from the middle of one long straight to the middle of the adjacent short straight is the basic building block of the machine. Since this section is just one eighths of the machine it is called an octant. The magnetic arrangement of one octant is mirror reflected at the middle of the short straight. Electrons are injected in the South-East (SE) and travel clockwise around the machine. The octant extending from North-East to East was modified breaking the fourfold symmetry and is called as new octant (built in the building *Max von Laue Hall*). It consists of nine Double Bend Achromat cells (DBA). Eight of them provide space for one 5 m or two 2 m long insertion devices (ID).

The two 2 m IDs are inclined towards each other by 5 mrad. This scheme allows operating two independently tunable undulators in a single straight section with beam paths sufficiently separated for individual beam line optics. The ninth straight section is suitable for the installation of an insertion device up to a length of 20 m. The horizontal beam emittance is 1 nm.rad while a coupling of 1% amounts to a vertical emittance of 10 pm.rad. The machine is dedicated to users for experiments from 14 beam lines with 30 end-stations in the Max von Laue Hall. The storage ring has been further modified in 2014 in the North and East quadrants to incorporate 10 new beam lines including a Super Luminescent beam line from dipole radiation. PETRA operates with several filling modes, such as 480 and 960 bunches with a beam current of 100 mA or in the Timing mode with 40 or 60 bunches with 90 – 100 mA. The new light source needs careful magnet alignments, orbit stabilization and closed orbit and dispersion corrections. A prerequisite for the small vertical emittance are tight tolerances on the spurious vertical dispersion that is mainly created by the misalignment of the sextupoles. The closed orbit deviations result from field errors arising from magnetic element positioning errors. The most severe effects come from misalignment of quadrupole magnets, where the resulting dipole field is proportional to both gradient and alignment errors. The closed orbit distortions have been simulated with the alignment tolerances and field errors. Since the integrated quadrupoles strength in the new octant is two to three times higher than in the old octants the alignment requirements are accordingly tighter.

For the initial design condition and without magnet errors the particles move along the so-called “Design Closed Orbit” with designed energy. Generally this orbit is centred in the magnets and Beam Position Monitors (BPMs). The offsets of the BPMs adjacent to quadrupoles are measured with a Beam Based alignment (BBA) to allow the beam passing through the centre of the quadrupoles. Variations of the initial conditions, alignments and magnet field errors lead to a deviation from the “Design Closed Orbit” and oscillate around a distorted closed orbit. Off energy particles take shorter or longer paths around this closed orbit as per the deviation from the designed energy. Transverse orbits are corrected to a reference orbit, which is based on BBA measurements taking into account requirements of the user beamlines and results of the dispersion correction.

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Figure 1: The OrbitKorrektur Java Client as a GUI.

## ORBITKORREKTUR JAVA CLIENT

The Orbitkorrektur program is a Java Client (Fig. 1) used for slow orbit correction of PETRA-III using the Singular Value Decomposition (SVDcor) [2] or Most Effective Orbit Correction (Effcor) Methods [3]. The details of these methods or mathematical procedures are not described here. They are not part of the client program but of the Optics server. The program is a complex structure of many supportive Java applications, and communicate with many different types of servers using the TINE [4] network, Libera [5] server for BPM orbit readings, REFORBIT server for golden orbit, Central Magnet Server (MCS) for magnet currents etc. The main application is a Device Manager where all initialization is done with P3-OrbitKorrektur.xml file and are linked with AcopTransport [6] applications. Two Histograms are used to display of any combination of horizontal/vertical orbits and corrector currents. One of the monitor can be programmed to show Turn by Turn data. The prime function of the program is to correct the orbits to golden orbit, which is the resultant of BBA based orbit and BPM offsets or to any reference orbits as saved earlier. This is performed by using 244 BPMs and 210 horizontal and 189 vertical correctors. The details of Twiss Functions and the theoretical response matrices are available in the optic server as used at the time of correction calculations and applications. During the orbit correction one can opt for a global or a local orbit correction by selecting a range for the BPMs. Similarly, one can choose the type of correction scheme whether it is Effcor or SVDcor. After the calculation of the corrector strengths, the Corrector Table is populated with corrector names and the calculated strengths in terms of magnet set currents in Amperes. During normal operation for users the BPM Table is shown with state of BPMs in Fast Orbit Feed Back (FOFB) system. This client has many features and uses the subsystems as explained below.

### The Device Panel

This is the main class and is used for updating the data variables through Update (Observable o, Object obj). The data are connected with TINE asynchronous links via

initialization files in Device Manager. In the first initialization ACOP-Observables are defined and send to proper Histograms for display which are then further controlled by the operator by mouse adapter. The orbits are displayed in micro/millimeters. The histograms can also show corrector strengths in units of Amperes. Provision is made to show the status and betatron functions of the BPMs and correctors. One can decide to enable or disable single BPMs or correctors for the orbit correction.

### Reference Files

The reference files are managed by the FILEIO class for loading and saving the machine status as a file by the help of the File Sequencer [7]. The File Sequencer maintains the reference and golden orbits files. These orbits are displayed in the Histograms over orbit display panel. This procedure helps in importing the golden orbits at undulator sections from MATLAB.

### Device Data for BPMs and Correctors

The BPMs get recent data from the Libera server in nanometers [8]. The beta functions, dispersion functions and phase advances are available for all elements from the optics server. This makes available of response matrices and preset corrector strengths from optic server for selected orbit to be corrected at BPM positions and wait for Orbit Correction to be executed.

### Orbit-Korrektur

The Orbit Correction (Orbit-Korrektur) is mainly associated with two functions. At first the new corrector strengths are calculated for the selected orbit. In a second step a chosen fraction of the calculated correction is applied to the correctors. The correction is calculated by the optics server using the theoretical response matrices for the actual optics. Depending upon the type of correction SVDcor/Effcor, the range of BPMs to be used, and the optics, the server returns the calculated strengths of the magnets to be applied for orbit correction to golden orbit/reference orbit etc. The most recent orbit correction can be undone if required. The process of setting the magnet currents to the magnets using the Central Magnet Server are carried out by PS.Bumpfahren /PS.Zielfahren [9] protocols which insure that the changes are applied simultaneously.

### Optic Server

The optic server is used to store all types of magnetic optics used in operation of PETRA-III. The loaded optics is assigned by the PETRA Global optics parameter. This server plays an important role to solve the orbit correction procedure or bump protocols with supplied BPM orbits and return correctors strengths. In the server different service routines are sorted by equipment functions and properties. These are described in the following subsections. Mostly these are invoked by Remote Procedure Calls (RPC).

The data of this server begin always with a header structure which contains general data like a machine identifier, actual optics, and an error string. The result of the call is zero for successful execution or errors code otherwise.

**Equipment Function OPTICS** This function gives information of the optics with many defined properties to get Twiss functions, elements names etc.

**Equipment Function ORBCOR** This function is utilized for orbit correction with many defined properties to get orbits, kicks, currents, corrector names etc.

**Equipment Function BCOEFF** The bump service calculates the coefficients for closed bumps of 3 or 4 correctors and allows storing and reading arbitrary/special bumps. The coefficients corresponding to a bump are either fixed or recalculated for the actual optics.

**Equipment Function K2I2K** Under this property all routines are collected to transfer magnet strength to power supply currents and vice versa. The data are transferred by an array of circuit data structures used for bumps. Together with the information of machine and year it is possible to convert the values for a given energy.

### *Bumps*

This program can create 3 – 4 corrector bumps at selected azimuthal position. But in practice this function is less used as another better capable program to play with bumps in PETRA control room is available.

### *First Turn, Single or Multiple Injection*

These classes are in verge of testing for fully functionality.

### *Display and Alarm Reports*

As an observer, this program keeps track of FOFB operation during Top Up mode. It displays the readiness of this client for slow orbit correction or status of FOFB and Undulator Gaps. It also shows the variation of injection magnets pulse amplitudes as well as the synchronization of BPMs with system/machine clocks. These alarms help in proper utilization of this client.

### *Libraries Used in OrbitKorrektur*

The following libraries are used in the main OrbitKorrektur program:

MstApp11.jar, DeviceManager.jar, Optics.jar, orbitUtil.jar, acopbeans.jar, caj-1.1.5.jar, Tine.jar, CamInstrumentation.jar, Fileutilities.jar, Jca-2.3.2.jar,

Jdoocs.jar, Jmf.jar, Logutility.jar, Logviewer.jar, OrbitUtility.jar, Printlikemstapp.jar, Seqserverlib.jar, Sequencer.jar, simpleTINEWrapper.jar, svnkit.jar, TangORB-6.0.7.jar, Timing.jar.

## CONCLUSION

The orbit correction program is successfully used for slow orbit correction of PETRA-III since 2009 and used in upgrade of PETRA-III magnetic lattice with new extensions in North and East. This is capable of loading different optics with low and high beta functions for user's choice at undulator sections and with different beam energies such as 5 or 6 GeV by using 244 BPMs and 210 Horizontal /189 Vertical corrector magnets. The orbit correction can be carried out locally with a few BPMs or globally with all available BPMs utilizing the Effective Correction with a few correctors or SVD with proper selection of Eigen values in the plane of correction. Only, the relevant features are discussed here where the program has many more capabilities to perform.

## ACKNOWLEDEMENTS

The authors gratefully acknowledge and would like to thank Rainer Wanzenberg and Reinhard Bacher for their constant encouragements and guidance.

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