

MASTER'S THESIS

Beam orbit stability control in modern synchrotron light source facilities

Author:

Juan Gutiérrez Navarro

Supervisor: Ilya Agapov, M.Sc.
Bindu Sharan, M.Sc.

Examiner: 1. Prof. Dr. Herbert Werner
2. Dr. Annika Eichler

May 18, 2022

Title:

Beam orbit stability control in modern synchrotron light source facilities

Project Description:

A Synchrotron light source is a type of x-ray source based on an electron storage ring.

At DESY in Hamburg, the PETRA IV project is upgrading the third-generation light source PETRA III to a fourth-generation light source with ultra-low emittance in order to reach the diffraction limit. Synchrotron light sources are used for scientific and technical purposes. The applicability of this technology extends across a wide range of scientific disciplines, such as physics, chemistry, biology, materials science, medicine, environmental science, and nanotechnology [1].

Synchrotron light storage rings are designed to achieve very small electron beam sizes. This allows synchrotron radiation to be as bright as possible. It is necessary to maintain tight tolerances in electron beam stability to make use of these small beam sizes. To achieve such stability, closed orbit control is important in the design and operation of light sources. Electron orbit fluctuations increase electron beam size and degrade photon beam brightness, while slower orbit deviations require frequent realignment of experiments at the end of photon beam lines [2].

Beam stability is one of the most important requirements in synchrotron light sources. Ambient vibrations and electrical noise cause orbit distortions which have to be counteracted by an orbit feedback [3]. In the case of PETRA IV, it will have a fast orbital feedback system (FOFB), with more than 700 beam position monitors and about 200 fast correctors [1].

The general objective of this work is to analyze the perturbations of the storage ring and simulate their effect on the feedback system. For this purpose, it will be first necessary to implement a model of the particle motion through the lattice with feedback system that keeps the trajectory within tolerable margins. Then, a model of the expected perturbations with the data obtained from seismic measurements at the ring will be include, And finally the performance of the feedback system will be evaluated.

Tasks:

1. Literature review
2. Create a software infrastructure in Python, with tools for the implementation of subsequent simulations of particle accelerators. For this purpose, new functionalities

will be implemented with the pyAT library. The necessary documentation will be prepared to make the infrastructure available to other users.

3. Identify the expected sources of disturbance. This will include experimental work on seismic measurements, data evaluation as well as analysis of pre-existing seismic data.
4. The data obtained in the previous step, will be input into the simulation model of the feedback system and the effect of perturbations analyzed.

References

- [1] C.G. Schroer et al. PETRA IV: upgrade of PETRA III to the Ultimate 3D X-ray microscope. Conceptual Design Report. Deutsches Elektronen-Synchrotron DESY, Hamburg, 2019.
- [2] J. Safranek. Orbit control at synchrotron light sources. Conf. Proc. C, 991004:240–244, 1999.
- [3] Gajendra Kumar Sahoo, Klaus Balewski, Winfried Decking, and Yongjun Li. Closed orbit correction and orbit stabilization scheme for the 6 gev synchrotron light source petra iii. EPAC-2004, Lucerne, pages 2302–2304, 2004.

Supervisor: Ilya Agapov, M.Sc.
Bindu Sharan, M.Sc.

Examiner: 1. Prof. Dr. Herbert Werner
2. Dr. Annika Eichler

External: DESY

Deutscher Titel: Stabilitätsregelung der Strahlenbahn einer Lichtquelle

Start Date: 01.04.2022

Due Date: 30.09.2022

02.05.2022, Prof. Dr. H. Werner

Hereby I declare that I produced the present work myself only with the help of the indicated aids and sources.

Hamburg, May 18, 2022

Juan Gutiérrez Navarro

Abstract

To complete

Contents

1	Introduction to particle accelerators	2
1.1	How Particle Accelerators Works	2
1.2	Particle-Beam Dynamics	2
1.2.1	Charged Particles in an Electromagnetic Field	2
1.2.2	Equation of Motion	2
1.2.3	Beam Steering Magnets	2
1.2.4	Particle Trajectories and Transfer Matrices	2
1.2.5	Dispersion and Momentum Compaction Factor	2
1.2.6	Beta Function and Betatron Oscillation	2
1.2.7	Tune and Optical Resonances	2
1.2.8	Chromaticity of Beam Optics and its Compesation	3
1.3	Summary	3
2	Orbit correction	4
2.1	Fast Orbit feedback	4
3	System and correction simulation	5
3.1	Feedback structure	5
3.2	Noise model (correlation)	5
3.3	Performance system modelling	5
4	Conclusion and Outlook	6

Introduction

To complete

1 Introduction to particle accelerators

This chapter will introduce the basic principles of the operation of a particle accelerator and its main components. In the second part, it will be introduced the particle beam steering from a linear beam optics approach.

1.1 How Particle Accelerators Works

To complete

1.2 Particle-Beam Dynamics

To complete

1.2.1 Charged Particles in an Electromagnetic Field

To complete

1.2.2 Equation of Motion

To complete

1.2.3 Beam Steering Magnets

To complete

1.2.4 Particle Trajectories and Transfer Matrices

To complete

1.2.5 Dispersion and Momentum Compaction Factor

To complete

1.2.6 Beta Function and Betatron Oscillation

To complete

1.2.7 Tune and Optical Resonances

To complete

1.2.8 Chromaticity of Beam Optics and its Compesation

To complete

1.3 Summary

To complete

2 Orbit correction

To complete

2.1 Fast Orbit feedback

3 System and correction simulation

To complete

3.1 Feedback structure

3.2 Noise model (correlation)

3.3 Performance system modelling

4 Conclusion and Outlook

To complete