

# **Project description:**

## **Beam orbit stability control in modern synchrotron light source facilities**

Juan Gutiérrez Navarro

April 18, 2022

### **1 Introduction and problem statement**

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 a feedback system that keeps the trajectory within tolerable margins. Then, the model of the expected perturbations with the data obtained from seismic measurements at the ring will be included. And finally the performance of the feedback system will be evaluated.

## 2 Objectives

The objectives of the work are:

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

## 3 Methodology and work plan

The work will be done on an adjustable schedule according to class hours. There will be a weekly meeting with the DESY tutors in which the progress of the project and next steps will be discussed.

The project will be divided into the following 4 stages, and the duration of each one has been estimated:

1. Familiarization with accelerator physics and feedback concepts (from November 2021 to February 2022). The objective of this phase is to obtain the necessary

theoretical knowledge in particle accelerator physics, machine operation and control system theory for the further development of the project. It also includes familiarization with the software for modeling storage rings and beam transport lines.

2. Analysis of error sources at PETRA IV facilities (from February to the end of March). This more practical phase is expected to carry out seismic measurements on the ring to measure the transfer functions from the vibration source to the beam.
3. Simulation of PETRA systems (from April to the end of May). Simulations will be used to study the effect of disturbances in the feedback system.
4. Documentation preparation (June).

## 4 Resources

This is the list of resources estimated to be necessary to carry out this work:

- Laptop.
- Python as a programming language.
- Accelerator Toolbox using its Python interface (pyAT).
- Hardware and software necessary to perform seismic measurements on the ring provided by DESY.
- Books and papers related to the topic.

## 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.