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Master Thesis (2012)
A Software Solution for the Alignment of the HIE-ISOLDE Accelerator at CERN

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Abstract
The goal of this thesis was the creation of a software solution that uses image capturing devices for the alignment and monitoring of the currently developed HIE-ISOLDE particle accelerator upgrade at CERN to measure fiducial points on the accelerator components in a global frame. For the development of the software for the calculation of the observation frame, a suitable system of local coordinate systems for calibration measurements needed to be developed. Additionally, the design and implementation of an adjustment system with observation equations and unknown parameters that are suitable to describe the transformations between the different systems and code to transform points from one system to another were also part of the thesis work.

The existing ISOLDE and REX-ISOLDE particle accelerators at CERN receive a major energy and intensity upgrade that requires the replacement of most of the existing ISOLDE post-acceleration facilities by a superconducting linear accelerator (Fig., top). Within the frame of this upgrade, the described alignment system (Fig., bottom) for the components of the accelerator was developed at the BE-ABP-SU (surveying) section of CERN in the frame of the Master Thesis. Based on positive experiences from other CERN installations, the alignment system will mostly consist of image-based sensors (BCAM devices) that monitor fiducial targets on the accelerator components. These sensors make it possible to minimize the time and required personnel for the alignment of the accelerator extension and also allow the analysis the observations in an on-line monitoring system in a later development stage.

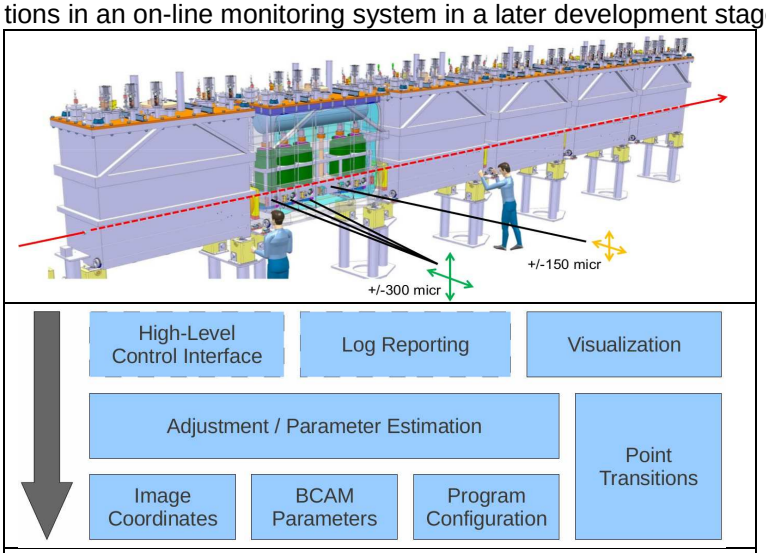

Fig.: (Top) Design of HIE-ISOLDE CERN Particle Accelerator. (Bottom) Design of the developed Alignment- and Monitoring Software

Knowing the exterior orientation of the BCAM sensors is a critical for the image based observations. The BCAM sensors offer an isostatic mounting system that allows the conservation of the exterior orientation during the calibration. When the positions of the mounting balls are known precisely, the BCAM parameters are available in the frame in which the mounting balls are given. During the design process of the alignment hardware, metrologic tables have been developed which provide mounting balls for BCAM devices on a common rigid body. The tables will be placed between the cryo-modules and provide a foundation for the BCAMs. The position and orientations of these tables in a global frame provides the foundation of the observation frame for the monitoring of the fiducial marks. Superconducting elements of the accelerator need to be cooled down to 4 Kelvin; this limits the choice of possible target types for the components inside the accelerator. Besides the low temperatures, the whole cryo-module will be under a working vacuum of 10e-8 mbar at all times. Since the targets are inside the modules and the BCAM sensors are outside, the observations need to be taken through small, thick windows. The influence and possible correction of the systematic observation errors that are generated by the windows have already been studied in the surveying section; formulas to model the influences of the windows exist and were implemented in the software.

After the design an implementation of the software, a validation phase that compared the results of the reconstruction calculations to reference measurements followed. For this purpose, a model setup with real hardware and realistic plate distances was installed. The positions of points on the plates were measured by a laser tracker that can very precisely determine point positions. The same points were measured locally on the tables and transformed into the measurement frame of the laser tracker to compare the reconstruction results with the reference measurements.