ION OPTICS ALIGNMENT IN THE ELECTROSTATIC DOUBLE STORAGE RING DESIREE

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Abstract

The alignment of the ion optics is always a critical task during the construction of a storage ring. In the electrostatic double ring, DESIREE a somewhat unconventional method has been chosen for the alignment process. In terms of ion optics alignment the quadrupoles are the most important factor for the ion beam acceptance in DESIREE. The goal of aligning all quadrupoles with precision of 0.1 mm was obtained by using precisely positioned footprints combined with measurements with a portable coordinate machine and a level instrument.

INTRODUCTION

DESIREE is a cryogenic electrostatic double storage ring under construction at Stockholm University [1]. The two rings have similar circumference, 8.8 m and a common straight section for merged beam experiments. In each ring the ions are guided by two 160° cylindrical deflectors and four 10° deflectors and focused by four quadrupole doublets. A unique feature with DESIREE is its double ring structure which allows for merged beam experiments with positive and negative ions that are stored in separate rings. In many of the planned experiments weak beams and/or very low reaction rates are anticipated and therefore would benefit from long storage times. In order to reach long storage times in storage rings there are a number of parameters that have to be considered. To minimize collisions between the stored ions and rest gas particles, the particle density in the rest gas, has to be as low as possible. In DESIREE the cryogenic environment (T<20 K) will give very good vacuum conditions ($<10^{-12}$ mbar).

Two other critical parameters are the stability of the HV-power supplies for the ion optics [2] and the positioning of the optical elements with respect to each other. The latter is the scope of this paper. In order to achieve reasonably long life times, ion beam calculations and simulations suggest that the position of the optical elements in DESIREE should not deviate more than ±0.1 mm from the calculated values. The two rings in DESIREE are different around the merging section. In ring 2 the quadrupoles are further apart which causes the acceptance to be much smaller. The acceptance is a measure of the maximum size of the circulating beam. Misalignment of optical elements also reduces the acceptance, and in particular transverse errors of the quadrupole positions. In order to have a reasonable acceptance in ring 2 it is therefore essential to have the quadrupoles well aligned.

The construction of DESIREE resembles that of a cryostat. It has an inner and an outer vacuum chamber and in between these two there will be a thermal screen and 30 layers of super insulation. All optical elements, diagnostics, and detectors are carefully mounted on the bottom of the inner chamber which will be cooled to cryogenic temperatures. Attached to the bottom of the outer chamber are four supports on which the inner chamber rests. The position of the inner chamber can be adjusted both horizontally and vertically with respect to the outer chamber. To improve the mechanical stability of the bottom plate of the inner chamber only the top lid of the chamber was removed during the alignment procedure (see Fig. 4). In this way the 0.5 m high frame will support the bottom plate but on the same time limit the access to the optical elements during the alignment. In order to facilitate mounting and alignment of the optical elements in the inner chamber the work was performed outside the outer vacuum chamber in a temporary installed clean room. Once this work is finished the inner chamber will be installed in the outer chamber together with the thermal screen and the super insulation.

THE ALIGNMENT METHOD

For positioning of the ion optics, the bottom plate of the inner chamber is prepared with a number of footprints (see Fig. 1) where each footprint consists of four areas (Ø=15 mm, depth≈3 mm) that define the vertical position of the footprint and two alignment holes that define the footprints horizontally. Similar alignment holes are found on all base plates of the optical elements. During mounting of the elements two cylindrical pins

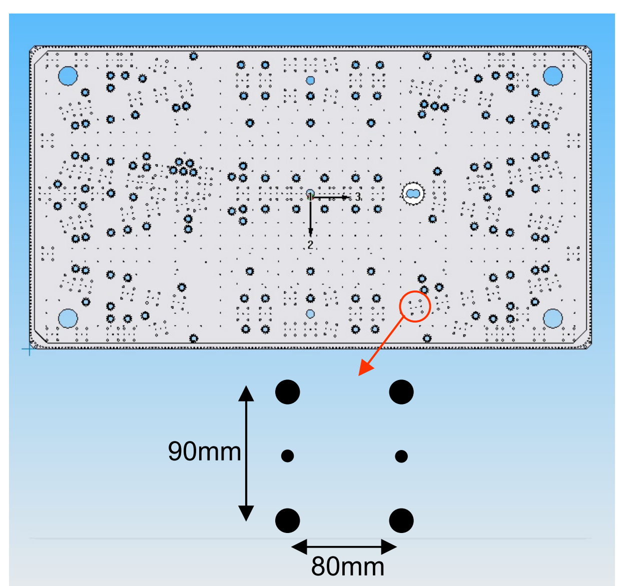

Figure 1: Footprints on the bottom plate.

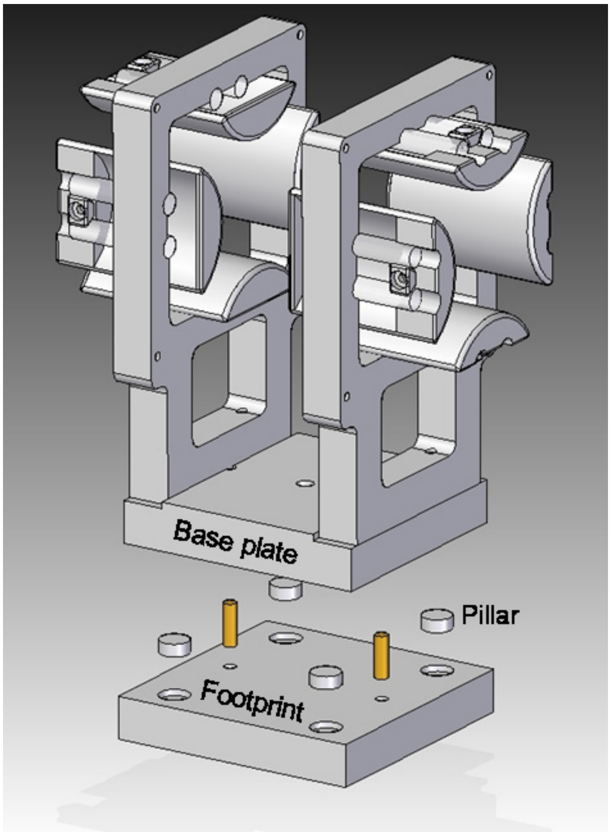

Figure 2: Illustration of the positioning method of the optical elements.

(dowel pins, Ø=6 mm, M6) will guide the base plate into footprint (see Fig. 2). All element base plates rest on four or more free cylindrical pillars (Ø=14 mm) which will define the vertical position of the optical elements.

The alignment procedure was performed in three steps: measurements of the reference points (the footprints, see below) on the bottom plate of the inner chamber, measurements on each individual optical element after assembly and finally measurements on the elements when mounted in their final position in the chamber.

For the alignment two instruments have been used. A conventional level instrument (vertical precision ~±0.05 mm) and a Platinum FaroArm (see Fig. 4). The latter is a coordinate measuring machine with a measuring range of 1.2 m and volumetric maximum deviation of ±0.018 mm. In these measurements a touch probe was used which means that data points are taken automatically when the probe touches the object. By loading the CAD drawings of objects into the FaroArm software a direct comparison between the real object and the CAD drawing can be made during the measurements.

Element Design

Even though the different types of optical elements differ in both shape and size they are designed according to the same principle (see Fig. 3). All use one or several cylindrical sapphire rods (crystalline Al_2O_3, Ø=10 mm, L=20 mm) to electrically insulate the electrodes from ground potential. They are also built on a base plate which contains reference holes for positioning of the element onto the bottom plate of the inner chamber. In order to simplify the construction of the optical elements they are designed without any adjustment mechanics. Instead all machining of the ingoing parts were performed with a very high degree of precision. Together with a very careful assembly combined with coordinate machine measurements it was possible to align the electrodes in each of the 28 optical elements within a precision of ±0.1 mm with respect to the reference holes on the base plate of each element.

To make sure that the position of the electrodes within an element will be maintained during the cooling-heating cycles that will be a reality once the optics are installed in DESIREE, one of the quadrupole doublets was installed in a test chamber and cooled to 20 K. After this cooling test and the quadrupole had returned to room temperature no measureable deviations could be observed.

Element Positioning

Since the bottom plate is a 4.5 m long, 2.5 m wide and 20 mm thick aluminum plate it was foreseen that the bottom plate could not be perfectly flat while resting on its four supports. As a first step the vertical position of all footprints were therefore measured with the level instrument. The footprints close to the supports were leveled to the same height by adjusting the supports and used as a reference for the height measurement of the other footprints. In order to obtain the horizontal position of the alignment holes for each footprint the coordinate measuring was used. To cover all footprints the coordinate machine had to be moved several times. Fixed and temporary reference points (see Fig. 4) were used to be able to relate the coordinate systems to each other after each movement of the arm. To ensure that the movement of the arm did not introduce any systematic errors beyond the expected, the first footprint was checked again at the

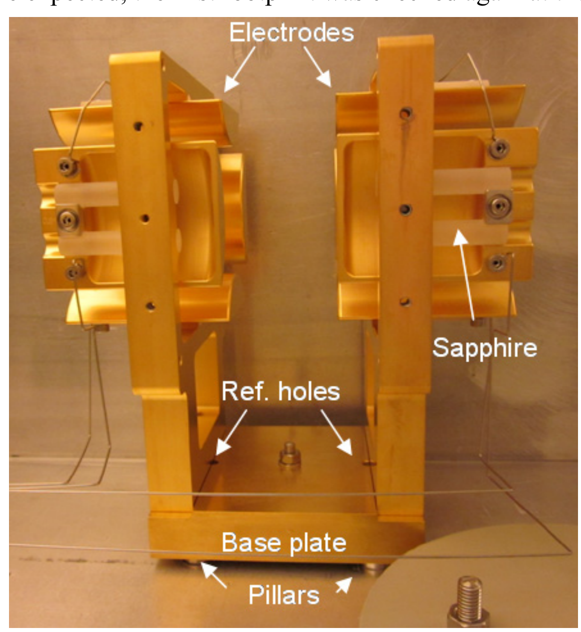

Figure 3: The quadrupole doublet.

Figure 4: Picture from alignment of the quadrupole doublets showing the portable coordinate machine to the left and some of the reference points used during when the FaroArm was moved from one position to another.

end of this series of measurement. Also for the coordinate machine measurements the leveled plane spanned by footprints close the stands were used as a vertical reference. In order to increase the measurement precision of the footprints where the quadrupole doublets will be mounted, the coordinate machine was used also for the vertical measurements on these footprints. These measurements also worked as a reference for the measurements when the optical elements finally were installed on the bottom plate.

In a few cases the alignment holes deviated up to 1 mm from the calculated positions due to mistakes during the machining of the bottom plate. To compensate for these deviations the elements at these positions were adjusted during the construction.

Final Mounting of the Optical Elements

Using the data from the collected footprint and element measurements the exact height of each individual pillar could be calculated. Once the pillars had been manufactured the elements could finally be mounted into the inner chamber starting with the quadrupole doublets. By using the reference points used in the earlier footprint measurements it was now pretty straight forward to measure the position of the quadrupole doublets with the coordinate machine and compare with the numbers from the ion beam calculations and simulations. After a careful mounting and some minor changes on a few of the pillars the alignment of all the quadrupoles were within the ±0.1 mm compared to the theoretical positions which was the limit according to the ion optics calculations.

Based on the experience from the quadrupole alignment it could be concluded that no complementary measurements with the coordinate machine were needed once these elements were installed in the chamber. The earlier alignment on each individual element and their footprints, together with the fact that the alignment of these elements with respect to other optical elements are not that critical for the stored beam, will make sure that they will be positioned with a precision that is good enough.

REFERENCES

[1] R. D. Thomas et al., Rev. Sci. Instrum. 82 (2011).
[2] P. Löfgren et al., EPAC'06, Edinburgh, 2006, MOPCH093, p. 252 (2006); http://www.JACoW.org.