

IMPACT OF THE DBA BLOCKS ALIGNMENT ON THE BEAM DYNAMICS OF THE STORAGE RING IN SOLARIS *

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Abstract

Installation of the Solaris synchrotron has been accomplished at the beginning of the 2015. Although the machine is a replica of the 1.5GeV ring at MAX IV in Sweden, the entire group responsible for the installation, was facing numerous problems during the entire installation period. One of the most critical issues that are responsible for the proper functionality of the machine is the survey of the machine. An appropriate alignment of the components in accordance to each other as also to the building provides a good quality of the beam so extensively desired by the beamline's users. This paper presents the results of the alignment in the 1.5GeV storage ring, describes possible critical sectors of the ring that might influence the accuracy of the measurements and juxtapose the results with the values gained during the operational phase of the synchrotron. This comparison enables the identification of the beam losses and extension of the lifetime of the electron beam.

INTRODUCTION

Solaris is a first synchrotron built in Poland, in Cracow. It has been successfully created thanks to the cooperation and help provided by the Swedish scientists from MAX IV Laboratory [2]. Solaris project consists of 600MeV injector and 1.5GeV storage ring. The thermionic RF gun injects the electron beam into the 40 meters long accelerator unit, that contains six accelerating structures, and through the transfer line into the storage ring. The normalized emittance of the beam is approx. 10mmrad and the energy spread is less than 0.2% in the linac, whereas the horizontal electron beam emittance in the 1.5GeV storage ring is 5.98nmrad. Once the beam reaches the 96m long storage ring, it is collimated and ramped up through 12 DBA magnet blocks and RF system into its final energy. Currently, Solaris has two beamlines: one from the bending magnet (PEEM/XAS) and from an elliptical polarized undulator with 120mm period length. Future development of the facility, foresees further extension by building up a new beamlines, that will create wide range of possibilities for the scientist and make Solaris an attractive scientific tool in Poland and Europe.

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DBA OVERVIEW

The 1.5GeV storage ring, consists of 12 double bend achromat magnets (DBA). This is a novel concept, invented by MAX IV laboratory [1] [4], that assumes the integration of several cells of smaller magnets into one block, i.e. Fig. 1. This solution guaranties better mechanical stability, speeds up the installation of the storage ring, enables higher positioning accuracy and eases the maintenance of the magnets. The entire structure has been manufactured by Danfysik AS at Danish Institute of Technology and consists of two main halves of the magnetic structures with the vacuum chamber placed exactly between the two halves. Each half is 4.5 m long structure and weight approx. 3.5 tone. This design, placed on the three alignment feet together with the three concrete blocks, guaranties stability of the structure and eases positioning. An appropriate position in the storage ring can be achieved through the fiducialization process in which a magnetic axis of the achromat is transferred onto the outer body of the magnet. By means of fiducial nests placed on the top of the magnet, the whole structure can be precisely aligned using geodesy equipment such as a Laser Tracker.

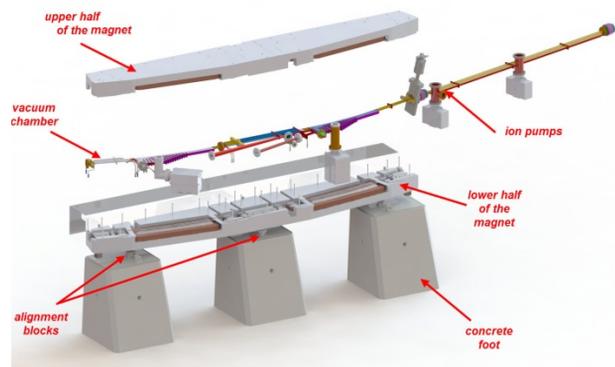


Figure 1: Double Bend Achromat Magnet (DBA) layout.

Injection of the electron beam into the storage ring requires its constant behaviour's observation and, adaptation to the changing conditions. The feedback is given by a set of beam positioning monitors (so called BPM's) placed inside the achromat. Each DBA magnet contains three BPM's: at the entrance, in the centre and on the exit of the magnet. Their task is to measure a beam position inside the vacuum chamber in horizontal and vertical axis, perpendicular to the beam axis movement. The signal is processed using Libera Brilliance and turn-by-turn data.

A unique design of the achromat magnets enables the production of a better light with higher intensity and

stronger collimation that would be useful for the scientific experiments.

STORAGE RING ALIGNMENT

The alignment procedure at Solaris has been done using Leica AT401 laser tracker. The entire alignment procedure has been divided into 3 steps: survey of the building, rough and smooth alignment of the synchrotron components. The survey of the building has provided an information about its layout and shape, which was used as a link between the idealistic 3D model, real shape of the building and machine configuration. Besides of that, it was used as a waypoint for the measuring equipment, in order to locate itself in the 3D space. There were few iterations of each step in alignment sequence. A huge attention has been put especially on smooth alignment, which considered changes in surrounding environment (e.g. air fluxes, temperature changes, ground stability, functionality of the devices). The machine's current position is a result of fourth network iteration, conducted in 2015. The storage ring is aligned to $\pm 120\mu\text{m}$ RMS from the ideal orbit in horizontal plane, and $\pm 60\mu\text{m}$ RMS from the average high of orbit in vertical plane, i.e. Fig. 2.

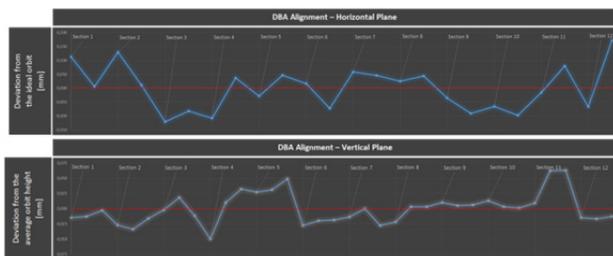


Figure 2: DBA alignment tolerances in horizontal (upper diagram) and vertical (lower diagram) planes.

The storage ring's survey network has been built using 42 laser tracker stations. The instrument stations were located in such a way, to ensure an overlap from one section to the next one. The DBA magnets were adjusted from the centre station and re-shot from the upstream and downstream stations. The DBA magnets position's cross-check, did not reveal any "floating" of the magnet's position over time.

ALIGNMENT VS. BEAM DYNAMICS

DBA magnet blocks alignment

Synchrotron Solaris is currently in the commissioning phase [3] [5]. Due to Solaris specific construction (short linac), electron beam that moves inside the storage ring must be ramped up from the injection energy (525 MeV) to its final energy (1.5GeV). During this process a beam losses have been observed and as also growth of the pressure in particular sections of the storage ring (kicker magnet section, injection section, section no. 09). In those sections, the vacuum level has dropped down to $1.7 \cdot 10^{-7}$ mbar. Besides of that, an enhanced radiation level has been observed next to the 02, 03 (kicker magnet) and 12 (RF cavities) sections.

To eliminate the error, an electron beam orbit has been corrected using correcting magnets inside the achromat magnets. Until some extend, implemented modifications could influence the position of the beam and focused the beam back to the ideal beam trajectory, i.e. Fig. 3. However supply current on the correcting magnets has reached their nominal values and the beam was still vanishing in problematic sections.

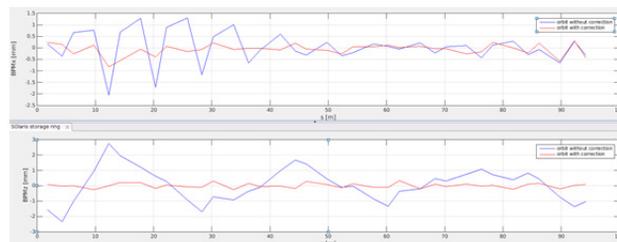


Figure 3: BPM's read-outs from horizontal (upper diagram) and vertical (lower diagram) planes for all 12 DBA magnets without any corrections (blue line) and with correction (red line).

The highest beam deviation is observed in DBA 02 reaching 2mm for the horizontal and 2.8mm for the vertical plane in the middle of the achromat.

A realignment of the particular DBA's position was implemented to improve the orbit. The elements were moved sequential, in accordance to the following steps:

- The kicker magnet has been shifted outside the storage ring (approx. $100\mu\text{m}$) and moved back to its basic position in radial direction.
- DBA magnet in section 02 has been moved in two steps, in the outer side of the ring direction by an $400\mu\text{m}$ offset ($200\mu\text{m}$ in each step) and moved back $-200\mu\text{m}$ to step 1 position.
- The downstream side of the DBA magnet in section 01 was rotated of $100\mu\text{m}$.
- The kicker magnet has been lifted $100\mu\text{m}$ in vertical direction.

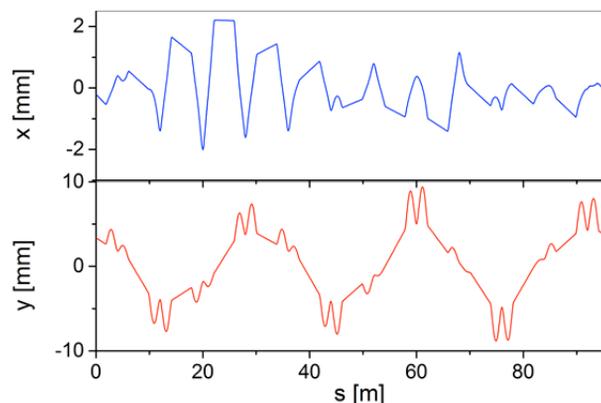


Figure 4: Simulated orbit around Solaris storage ring without any correction.

However, those realignment attempts didn't improve significantly the closed orbit. The simulations of the magnet misalignment were done for better understanding of the closed orbit deviation source, i.e. Fig. 4. According to the simulated situation were 12th DBA were shifted $50\mu\text{m}$

in the horizontal and vertical plane. Additionally, the random misalignment errors were applied to the rest of the magnets assuming 25 μ m RMS horizontal, vertical and longitudinal misalignments and 0.2mrad roll angle errors.

Correcting the alignment of the 12th DBA should improve the closed orbit in the horizontal plane.

For the vertical plane more simulations need to be done to better understand the origin of the closed orbit distortion.

Straight sections alignment

The specific construction of the storage ring requires attention to the straight sections placed between the DBA magnets. In the first commissioning phase, significantly increased level of radiation and vacuum impurity were observed. Deeper analysis revealed that the straight sections were not aligned accurately through which it was bent in roll and pitch axis. Since straight sections do not have any fiducials needed to obtain a proper alignment procedure, commonly used measuring tools were used to straighten the geometry of the sections (e.g. laser level, spirit level) in accordance to the two surrounding DBA magnets. Further measurements did not show any other problem in those sections. However, this aspect must be always taken into consideration, during maintenances of the vacuum chambers and magnets, as also nearby infrastructure.

SUMMARY

The regular verifications of the storage ring component's position, did not show any changes along the time and throughout this, proved that the idea of the integrated magnets is a good and smart solution worth using in a synchrotron technology. Further observations revealed that even minor offsets in DBA's position (within the range of 100 μ m), can significantly change the orbit of the electron beam. Problems with the higher radiation level and higher beam losses, might require further realignment of the particular components. Due to this, all elements must be taken into consideration, to obtain their proper shape and their survey. The issues presented in this paper, signalizes that there are few potential problems that must be checked: fiducialization data for particular components, software mismatch in control system, the sum of all errors that occurred during the survey of the building or misalignment between the vacuum connections.

Further measurements are planned in order to obtain the most suitable electron beam trajectory and to eliminate the possible sources of measurement errors. The knowledge, gained by understanding the behaviour of the electron beam in the storage ring, will be used to find a "golden mean" between the mechanical, electrical and physical divisions of the synchrotron's phenomena.

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