METROLOGY OF THE NESTOR FACILITY EQUIPMENT

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Abstract

Development of X-ray generator NESTOR in the National Science Center Kharkov Institute of Physics&Technology will let significantly extend the scientific program of investigations that are carried out in NSC KIPT, will allow to increase an amount and improve quality of experimental researches in the field of physics and chemistry.

In this work, tolerances for accuracy installation of the lattice elements of the complex are defined. Fiducialization of dipole magnets and quadrupole lenses was completed. The methods of lattice element position measurement were detected and ways of their realization were defined. These allow to realize project parameters of NESTOR facility and, first of all, generated X-ray beam intensity.

INTRODUCTION

The "NESTOR" (New-Electron STOrage Ring) project facility based on scattering of intense laser beam with relativistic beam of electrons circulating in a storage ring, the Compton back-scattering, can produce intense X-ray radiation, suitable for research in various fields of science and technology [1].

Using DeCA code [2] the calculations of RMS value of reference orbit displacement in NESTOR facility storage ring due to element alignment errors were carried out. Results of calculations showed that acceptable values of electromagnetic element alignment accuracies for the NESTOR facility are the following:

In transverse x direction is $\Delta x = 1\times10^{-4}$ m,

In transverse z direction is $\Delta z = 1\times10^{-4}$ m,

In longitudinal direction is $\Delta s = 3\times10^{-4}$ m,

Transverse element tilt is $\Delta xz = 2\times10^{-4}$ rad,

Longitudinal element tilt is Δxs, $\Delta zs_x = 2\times10^{-4}$ rad.

To provide such accuracy one should estimate and provide the total error budget such as:

- Accuracy of magnet axis determination is 40-50 µm;
- Accuracy of element survey target coordinate determination is 60-80 µm;
- Accuracy of element alignment is 60-80 µm.

Total error budget: 70-100 µm.

The alignment errors in vertical z direction have the most crucial effect on the value of reference orbit displacement.

For survey and alignment procedure at NESTOR facility we developed a survey coordinate net [3]. The coordinate net is formed by 14 horizontal survey targets. Wall targets form 4 storage ring axes *T1-T6, T11-T7, T3-T10, T4-T8,* 2 axes of a linear accelerator *TL1-TL3, T2-T5* and injection axis *TL2-T9.* Projections of each axis at the plane of circulating electron beam are coincided with corresponding axis of NESTOR electron beam passing. Axis *T1-T6* is X coordinate of proposed coordinate system and axis *T3-T10* is *Y* coordinate of the system. So, the beginning of the coordinate system *O* is at the reference position of the first bending magnet of the NESTOR facility storage ring and coincides with crossing of *T1-T6* and *T3-T10* axes. Layout of the coordinate system is shown in Fig.1.

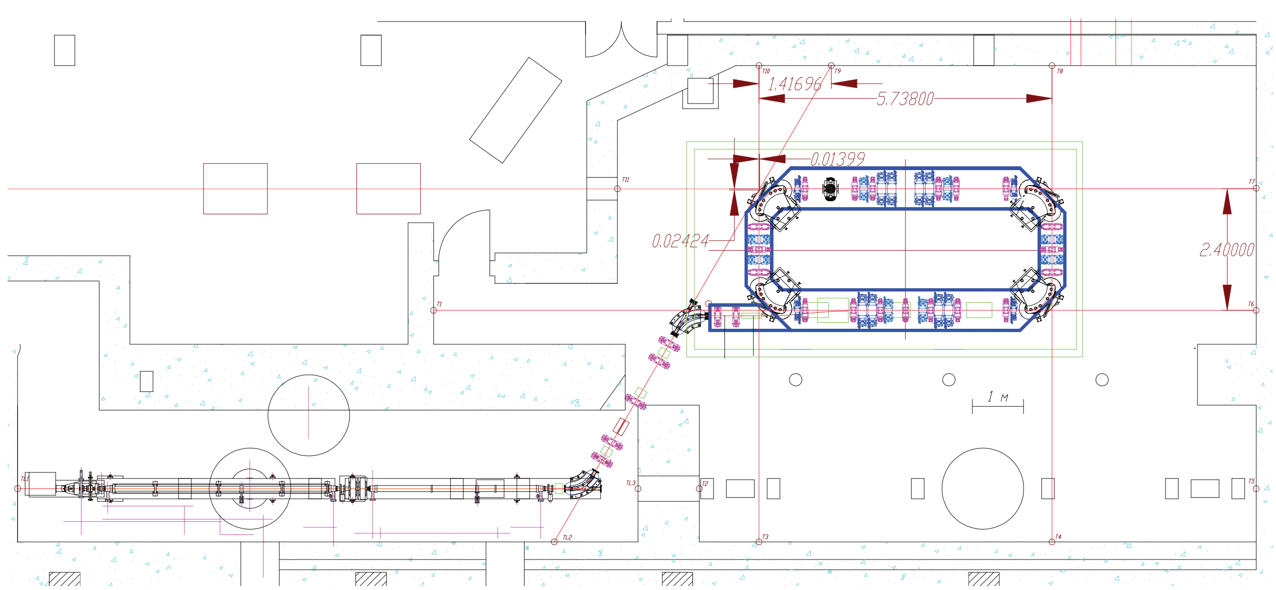

Figure 1: Layout of the NESTOR facility coordinate net.

COORDINATE SYSTEM

The 19.05 mm ball targets with specific supports were used to develop NESTOR coordinate net [3]. The targets were installed and coordinate net were balanced in a way as it is shown in Fig. 2.

Angular measurements were made with theodolites 3T2KP of 2" accuracy. Theodolites were installed at the top of the storage ring bending magnets at the middle points at the special tables that provide horizontal adjustment in *x-y* plane Laser distance meter LMS100 of 5 µm accuracy was used to measure distance between targets *T6-T7* and *T8-T10* that determined the distance between storage ring axes. Leveling is provided with Leica NA-2 of 1 mm/km accuracy.

The procedure of the coordinate net installation, adjustment and balancing provided the accuracy of the wall target and storage ring axes installation equal to 20-30 µm.

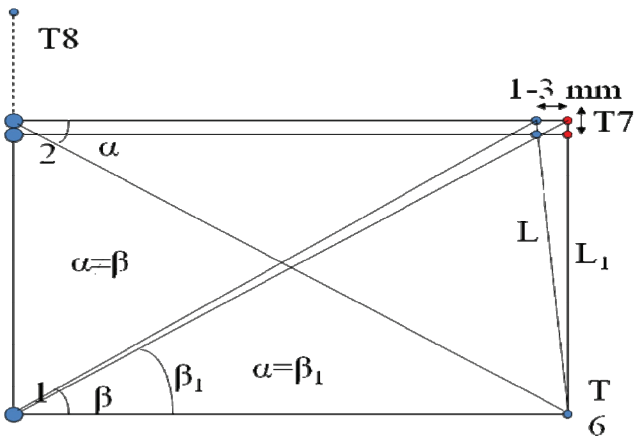

Figure 2: Procedure of the NESTOR coordinate net balancing.

FIDUCIALIZATION OF DIPOLE MAGNETS

The dipole magnet is electro-magnetic element that creates charged particle guiding magnetic field and is used to determine the reference trajectory of the charged particle beam. The dipole magnets of the NESTOR facility transportation channel have the bending radius of 500 mm, angle 60°, and the minimum value of the field in the gap of about 0.4 T at the injection energy of 60 MeV.

Magnetic measurements of the magnets were carried with Hall detectors that were moved at a special way along dipole magnet poles. The effective lengths of the magnet fields and field distribution along the magnet axese were measured. Then, transverse distribution of the magnetic field where measured. Measurements have showed that the effective angles of rotation of the first and second magnets are 60.0° ± 0.03° and 60.0° ± 0.03° respectively, that is in a good agreement with the design parameters.

During the fiducialization process, the distanses between the virtual element items (magnetic axis, edge of the effective magnetic field) and the actual element items (target balls) must be accurately determined.

For fiducialization of dipole magnets of the NESTOR transportation channel it was necessary to match the position of 2 survey targets on the top part of the magnet yoke with the input and output of the electron beam reference orbit and edges of the effective magnetic field. The middle target position should be matched with position of two tangential lines to the electron beam reference orbit cross section put to the point of effective magnetic field edge. These survey targets are shown in Fig. 3. with red arrows. Theodolite was set in such way that the middle target divided angle between enter and exit targets to equal angles. From these measurements it became apparent that the magnets are made with high accuracy and with a good agreement with design project. This procedure was completed and the magnets are positioned at their project positions. The accuracy of the magnet fiducialization was about 40-50 µm. The results of the measurements were confirmed by the commissioning of the NESTOR transportation channel in November 2012 [4].

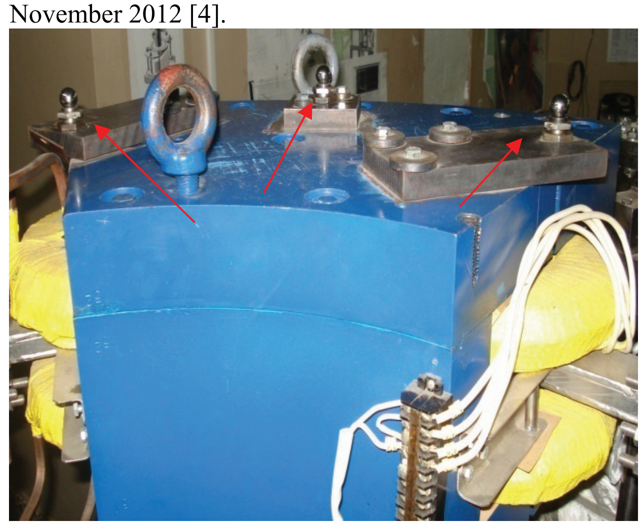

Figure 3: Target balls of the transportation channel dipole magnets.

NESTOR facility storage ring dipole magnets have the rotation angle 90.0° and the effective bending radius of 500 mm, the maximum magnetic field in the gap is 1.5 T and gap 36 mm. The maximum coil current is 300 A. Magnetic measurements used the same Hall detectors as for the case of transportation channel dipole magnets, that where moved along the reference trajectory. The magnets have gradient field, therefore they should be installed with high accuracy. For the magnet fiducializations on the top of magnet yokes 2 survey targets corresponding to the input and output of the electron beam at the reference orbit and edge of effective magnetic field azimuth were installed with a cylindrical support on a platform attached to the yoke. The targets are 19.05 mm diameter balls. It allows any time to check the current positions of the magnets. For installation of large dipole magnets in the operation position, we used special tool, that was positioned exactly at the bottom pole of the magnet. In the

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frame three balls of the same radius are placed and with the help of two theodolites, previously installed at the tangential lines of the 90 degree magnet. Dipole magnet of storage ring with target balls is shown in Fig. 4. The accuracy of the target installations is about 20-30 µm.

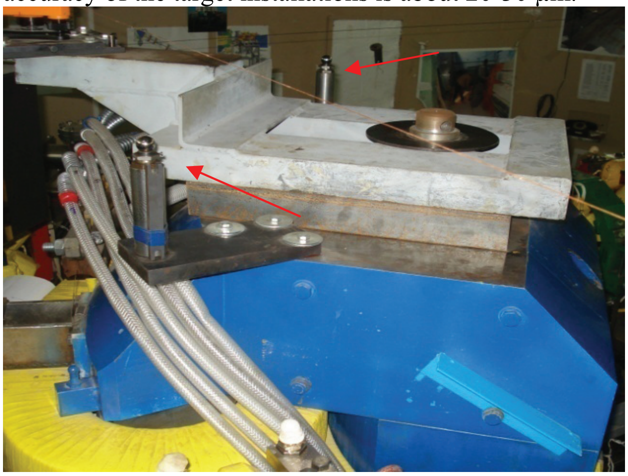

Figure 4: Dipole magnet of storage ring (target balls is shown arrows).

FIDUCIALIZATION OF QUADRUPOLE LENSES

Quadrupole lenses should be installed in a such way that the orbit of the particles coincides with lens magnetic axes. The displacement of the lens at a distance ΔR, calculated relative to the trajectory of the particles, resulting in the displacement of the beam from the reference orbit. Before starting fiducialization of quadrupole lenses the magnetic measurements were carried out with a coil that rotates in the aperture of the lens, and simulates the design position of lenses on the storage ring and the injection channel. From the measurements, the harmonic content of the lens magnetic field was determined. After magnetic measurements 4 survey targets were mounted on quadrupole lens top. The targets are balls with a radius of 19.05 mm.

The median plane of the lens was transferred to the target balls. Distances between the balls were measured with special tool and data were written to the lens passport. The angels of metrology points of quadrupole lenses were measured in relation to magnetic axes. Installations of quadrupole lenses in the design position were made with theodolite 3T2KP and ball targets, which are placed in the aperture of the lens. Aligning elements in a vertical plane were made using the geometric leveling that is less complicated than the radial alignment, but both of these procedures were tested using only one theodolite. The whole procedure of the lenses fiducialization provides the target position determination corresponding to the lens magnetic axis equal to 20-30 µm. A quadrupole lens during fiducialization procedure is shown in Fig.5. The installation procedure provides quadrupole installation with accuracy equal to 60 µm. Fig. 6 shows installed electromagnetic elements of the NESTOR storage ring.

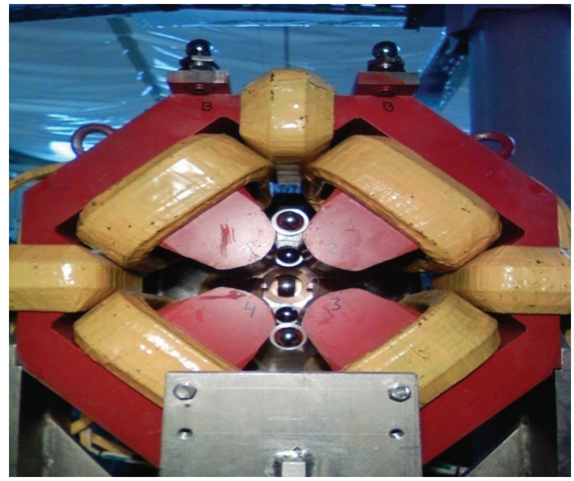

Figure 5: Quadrupole lens during fiducialization procedure.

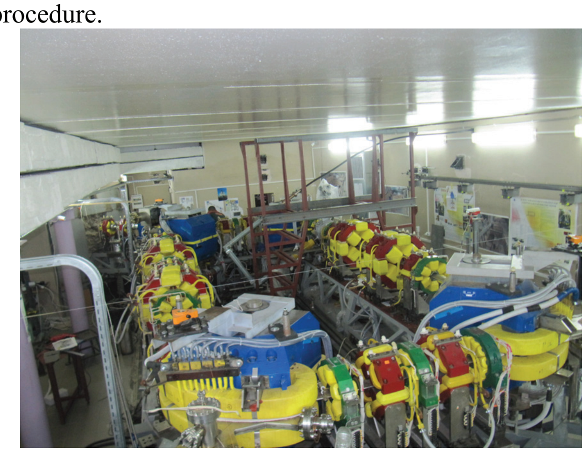

Figure 6: Storage ring of NESTOR facility.

CONCLUSION

NESTOR facility coordinate net was developed. The procedure of dipole and quadrupole magnets fiducialization with use of high precision theodolite, as well as magnetic measurements was designed and carried out. The process was optimized and magnetic elements error budget of 100 mkm in the vertical and in the horizontal planes has been provided.

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