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SURVEY NETWORK OF NESTOR FACILITY

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Abstract

For successful operation of X-ray source NESTOR it is necessary that all the focusing elements should be installed in design position according to the designed lattice, which should provide a low emittance value and small beam size at the interaction point . Accuracies of NESTOR electromagnetic elements installation are 100 mkm in the transverse coordinate, 200 mkm in the longitudinal coordinate and 200 mrad for all three rotation freedom degrees. To achieve these objectives coordinate net, which allows us to align the elements, was designed and developed in the hall of the NESTOR storage ring. The whole process is controlled by means of optical instruments and theodolite 3T2KP with angular accuracy of 2" and laser meter system LMS - 100, which measure the distance with micron accuracy. The final errors budget consists of the accuracy of the measuring instruments, the quality of elements manufacture and assembling. A well-planned methodology allows to realize the design parameters of the X-ray generator "NESTOR" and was proved by experiments of the facility.

INTRODUCTION

The feature of the «NESTOR» project (New-Electron STOrage Ring) [1] is the proposed method for radiation generation, that is scattering of intense laser beam by relativistic electron beam circulating in a compact storage ring (Compton backscattering). To use such method one can receive intense X-ray radiation, suitable for researches in various fields of science and technology. Design parameters of X-rays generated by the source " NESTOR " are:

- Generated photon energy range is 6 - 900 keV,
- The intensity of the generated radiation is 10^{12} - 10^{13} photons / (s * mrad) .

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 the errors originated from different sources, calculate the total errors budget and provide methods that can reduce the errors budget to the required by the project. The main error sources in the compact storage rings that is NESTOR storage ring are:

- Accuracy of magnet elements axis determination;
- Accuracy of element survey target coordinate determination (fiducialization error);
- Accuracy of element alignment.

To provide the appropriate accuracy error value of each source one can provide the required by project value of the total element alignment accuracy.

In this article the total budget of errors will be presented. It will be shown how to develop the survey network for electromagnetic elements installation in the calculated position and to verify the functionality of the whole system after installation of the storage ring vacuum chamber. Layout of the NESTOR X-ray source facility coordinate system is shown in Fig.1.

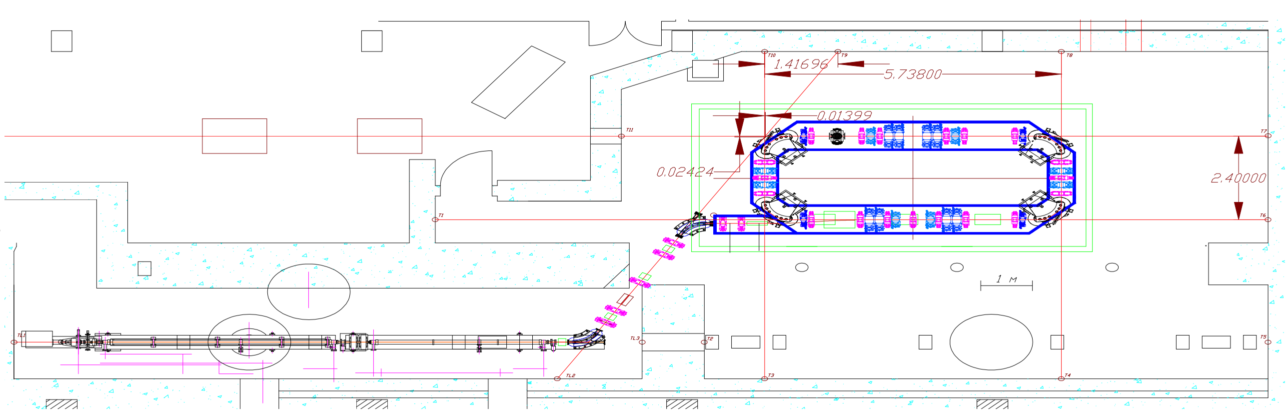

Figure 1: Layout of the NESTOR facility coordinate system.

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METHOD OF MAGNETIC ELEMENTS FIDUCIALIZATION AND ERROR BUDGET

To provide the accurate and convenient procedure of the magnetic elements originate alignment and further facility operation it necessary to determine the coordinates of the survey targets at each electromagnetic element in accordance to the virtual magnetic axis of the element (fiducialization of the magnetic elements). After that one can install the element in design position with use the survey targets of the elements only.

At NESTOR facility the targets for alignment of the magnetic elements are the spherical metal balls with mirror surface of $19.05^{-0.03}$mm diameter. The view of survey target is shown in Fig. 2.

Figure 2: View of the spherical survey target.

Registration of the target position with use of the spherical mirror balls is done with optical high accuracy theodolite 3T2KP of angular accuracy of 2"D. During the survey measurements one should put the light source at the optical axis of the theodolite and register the reflection of the target mechanical center. At NESTOR survey measurements we can not put the light source at the optical axis through the center of the equipment tube. However, if one shifts the light source away from the tools axis, the measurement error will be determined by the light source position in the measurement plane. Applied measurement scheme does not involve measurements in two planes at the same time. So, if light sift does not lead to the big measurement errors it is easy to realize the method constructively. The process the light source allocation for the survey measurements is shown in Fig. 3.

For the measurement plane error is determined according to the following expression:

$$h = 0.5\frac{R \cdot S}{D}$$

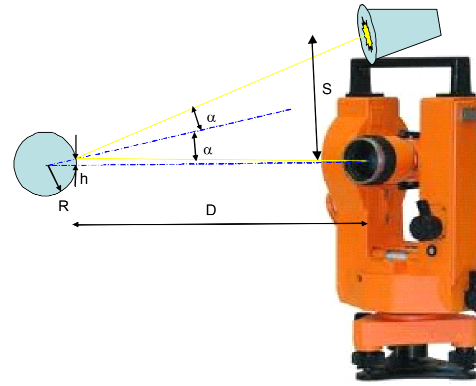

Figure 3: Targeting layout for spherical mark. S is sifting distance of the light source away from the tools optical axis; R is survey target radius; D is distance to the target; α is angle of incidence and reflection of the target ; h is target position error.

For example, for fiducialization and equipment alignment the typical values are the following:
S = 2 mm;
R = 9.5 mm;
D = 1500 mm
And, therefore the error value is equal to 0.007 mm. Targets are installed at the magnets and work both as horizontal and vertical survey marks simultaneously. However, the process of targets installation at the magnet is separated by installation in one plane at a time. At the first stage the target is aligned in the vertical position. This process assumes that there are check plates in the magnet gap. Furthermore, spherical targets installation in horizontal plane in accordance with certain reference surfaces in the magnet gap is taken place. These two steps are repeated again.

Thus, the fiducialization process is separated at two stages with two freedom degrees and implies retargeting of theodolite or leveling from the spherical target located in the aperture of the magnet to the other spherical target, with further adjustment of its position. Fiducialization algorithm assumes the following errors:

1. Error of spherical target targeting in the aperture of the magnet:
Optics error 2" with the basis of 2 m equal to 10 mkm;
Reflection error with the basis of 2m equal to 5 mkm ;
2 . Retargeting error with the basis of 2 m equal to 10 mkm;
3 . Spherical target targeting error:
Optic error on the basis of 2 m equal to 10 mkm; Reflection error on the basis of 2 m equal to 5 mkm.
Rms error is 20 mkm.

For hight measurements retargeting error is 7 mkm. This error is caused by using a 10" level during level shifting out of the central aperture plane to the horizontal plane of a survey spherical target. Thus, the chosen method of magnets fidicialization provides the RMS accuracy of the leveling measurements of 20 mkm.

Thus, the calculated error budget consists of:

- accuracy of the element magnetic axis measurements equal to 50 mkm that includes

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quality of magnetic elements assembling, quality of magnetic element poles machining, quality of the rotating coil manufacture, accuracy of the magnetic axis measurements etc;

- fiducialization error equal to 22 mkm,
- retargeting error equal to 20 mkm.

So, the total error budget is about 60 mkm. This error budget does not include the error of the survey net development and measurements.

SURVEY NETWORK

For the NESTOR facility lattice elements installation, it is necessary to equip each magnetic element with ball survey targets that are stationary or removable. For NESTOR facility the targets are stationary and are integrated to the element [3]. Survey targets are used to determine the position of elements in the survey coordinate system of the complex. The survey coordinate system of the NESTOR facility consists of 12 wall ball targets (Fig. 1). Two targets form a 60° axis of the injection beam transportation channel (TL2, TL9 in Fig.1). Targets T1, T3, T4, T6, T7, T8, T10, T11 form the rectangular survey coordinate net. The coordinate net is formed and adjusted with use of four theodolite sockets that are installed at 90°dipole magnets and distance meters. Equipment for development of horizontal and vertical coordinate net is shown in Fig. 4 – 6.Distance meters move along the rail installed between targets T6-T7 and T-8-T10.

Distance meters LMS- 100 have distance measurement accuracy of about 1 mkm. Theodolite 3T2KP having angular accuracy 2". Level of Leica company on a portable tripod with the height measuring system LIR- 7 is used to measure the exact distance in vertical direction [4].

The method of the coordinate system targets installation and adjustment are the same as it was described above. So, the accuracy of the targets coordinates measurements are 50 mkm (taking into account distances between theodolites and targets) and the total error budget is about 76 mkm. Taking into account the errors of personal during measurements the total RMS errors will be about 100 mkm that satisfy the design requirements and was confirmed with the first experiments at the facility [5].

Figure 4: Rails along the wall to move the reflector laser system LMS- 100.

Figure5: LMS-100.

Figure 6: Level of Leica company, on a portable tripod with the measuring system LIR- 7.

CONCLUSION

The developed survey and alignment system provides effective and cheap procedure of equipment installation and precise positioning for compact facility of Compton X-ray source NESTOR. The system uses traditional triangulation method and provides the accuracy of technological equipment alignment equal to 100 mkm.

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