NSC KIPT EXPERIENCE IN USE OF LASER TRACKER LEICA AT 401 IN EQUIPMENT ALIGNMENT OF 100 MEV/100 KW ELECTRON LINEAR ACCELERATOR OF "NEUTRON SOURCE" DRIVER

O. Bezditko, A. Zelinsky, I. Karnaukhov, M. Moisieienko, A. Mytsykov,
NSC KIPT, Kharkov, Ukraine

Abstract

For successful operation of electron linear accelerator that is driver of NSC KIPT "Neutron source" it is necessary that all the acceleration sections and all the electromagnetic elements should be installed in design position according to the designed lattice. Accuracies of all electro-magnetic elements installation are 150 mkm in transverse positions and 200 mrad for all three rotation directions. The whole process, fiducialization and developing of coordinate net, is controlled by Laser tracker Leica AT 401. Well-planned methods allow to realize uniform irradiation of neutron-generation target.

INTRODUCTION

According to the design, to provide required electron beam parameters at the target, accuracies of NSC KIPT 100 MeV/100 kW electron linear accelerator electromagnetic element installations are 150 mkm in the transverse coordinate, 200 mkm in the longitudinal coordinate and 200 mrad for all three rotation freedom. The whole installation and alignment process is controlled by Leica Absolute Tracker AT401 [1]. The electromagnetic system of the linear accelerator consists of quadrupole lenses, quadrupole triplets, bending magnets and scanning magnets.

Leica Absolute Tracker AT401 is a portable coordinate measuring machine (CMM) that allows extreme precision over ultra large distances. It is able to be powered by its own internal battery and is able to work in the most demanding environment, yet maintains the highest level of precision and the largest ever work envelope. All accuracies are specified with Leica Geosystems precision 1.5" Red Ring Reflectors and a measurement mode of 2 seconds per point under stable environmental conditions.

Full range is specified as 1.5 to 80 meters away from the laser tracker within a vertical range of +/- 45°. All accuracies are stated in maximum permissible error (MPE).

Absolute Angular Performance:
Resolution: 0.07 arc Seconds
Accuracy (MPE): +/- 15 µm + 6 µm/m (+/- 0.0006" + 0.00007″/ft)
Repeatability (MPE): +/- 7.5 µm + 3 µm/m (+/-0.0003″ + 0.00004″/ft)
Inclination Setting Accuracy (2σ): +/- 1 arc second
Absolute Distance Performance:
Resolution: 0.1 µm
Accuracy (MPE): +/- 10 µm (+/- 0.00039″)
Repeatability (MPE): +/- 5 µm (+/- 0.0002″)

Red Ring Reflector and the Leica Absolute Tracker AT401 are shown in Fig 1.

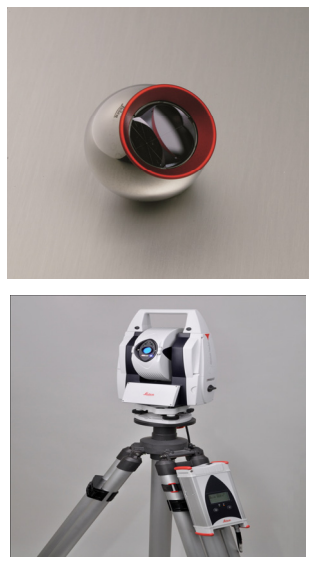

Figure 1: Red Ring Reflector and the Leica Absolute Tracker AT401.

ACCELERATOR COORDINATE NET

For linear accelerator electromagnetic element installations a survey coordinate net was developed. The coordinate net was formed by 23 survey targets, that were installed on the walls and in the floor of accelerator tunnel and 4 survey targets were installed in the experimental hall. 23 survey target design is like nest with magnet for the red ring reflector installation. To develop the coordinate net it is necessary to identify and fix the coordinates of all survey targets along the accelerator tunnel in vertical plane considering the electron beam reference orbit as a longitudinal horizontal coordinate axis. The vertical coordinate axis is axis of the electron beam and the neutron-generating target interaction. The facility coordinate system "0" point is intersection of these two axes.

The process of the survey targets coordinate measurements and fixations was carried out by the laser tracker with move station method [1]. The move station method was used between every two neighbouring sections consist of at least 3 (or more) survey targets. Measuring coordinates of 3 survey targets in the previous group is necessary and sufficient for the transition to the measurement of the positions of the targets in the new group. Taking into account the number of survey targets (23) NSC KIPT 100 MeV/100 kW has 7 sets of target for the move station method. The process of coordinate determinations is shown Fig. 2.

ISBN 978-3-95450-182-3

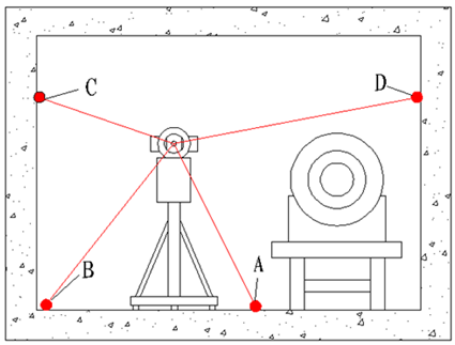

Figure 2: The process of survey target coordinate determinations.

Using this method, the cloud of all survey target point coordinates for all 7 groups of survey targets was obtained in the neutron-generating target coordinate system, where the coordinate X is longitudinal coordinate of the accelerator axis, Y is transverse coordinate that perpendicular to the longitudinal one, Z is vertical coordinate of the neutron generating target axis interaction with electron beam.

The longitudinal coordinate axis X was set with installation of basic survey target nests at the back wall of accelerating tunnel and opposite wall of the experimental hall of the NSC KIPT Neutron Source Facility.

Initial transverse coordinate Y was set with installation of basic survey target nests at the both left and right sides walls of NSC KIPT Neutron Source experimental hall before final installation of the top moveable biological shielding.

The vertical coordinate system axis at real facility realization was determined as the central axis of rotation of rotating top part of biological shielding. Using the coordinates of two support rollers of top rotating part of biological shielding and radius of the rotating plate that is 1365.65 mm the coordinate of the vertical axis was determined and set as the basic in the Leica coordinate system for further measurements.

The final accuracy of the coordinate system basic point installation to the mechanical center of the neutron generating target is better than 1 mm for all three transverse coordinates.

The accuracy of the survey target coordinate determinations in the set neutron generating target coordinate system is about is 50 mkm for all survey targets.

FIDUCIALIZATION OF THE ACCELERATOR ELECTROMAGNETIC ELEMENTS

The basic elements of the NSC KIPT 100 MeV/100 kW linear accelerator are electron gun, prebuncher, buncher, injection section, 4 chicane magnets, 9 regular accelerating sections, 5 focusing triplets, 6 quadrupole lenses of the transportation channel, 2 of 45 degree bending magnets of the transportation channel, 2 neutron generating target scanning magnets. All elements, mentioned above were design and manufactured by IHEP, Beijing, China. After manufacturing all elements were tested with electromagnetic and mechanical tests but fiducialization and alignment of the individual units has been done in NSC KIPT [2].

To provide alignment of the equipment with required accuracy (within 200 mkv in transverse coordinates) the fiducialization of the chicane bending magnets, quadrupole focusing triplets, quadrupole lenses of the transportation channel, bending magnets of the transportation channel, scanning magnets of the transportation channel has been done. The alignment of the electron gun, prebuncher, buncher, injection section and regular accelerating sections was done on the base of mechanical measurement data of manufacturer.

Quadrupole Lenses

Quadrupole lenses of the transportation channel of the electron beam are used for focusing of the electron beam to obtain the required beam geometric dimensions at the neutron generating target (see Fig. 3).

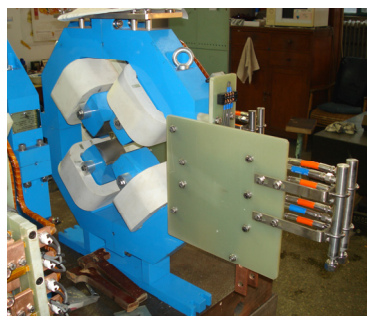
Figure 3: NSC KIP 100 MeV/100 kW linear accelerator quadrupole lens.

The quadrupole lenses, the quadrupole triplets, the bending magnets and the scanning magnets manufactured on high-precision machines. Manufacturing accuracies of yoke and poles of the electromagnetic elements are equal to 50 mkm. It gives the possibility to use the yoke and pole surfaces as a basic planes and points for the mechanical element center axis determination and set of the local element coordinate system for the element fiducialization. At first, the front and back yoke planes were measured with laser tracker. After constructing of two vertical planes and averaging the position of the vertical center element plane was determined. Second, the coordinate of quadrupole poles were measured and four points were projected onto the median vertical plane. Then two vectors were constructed between the projected points, the intersection of the vectors determines the absolute center of the lens, where the coordinate system was placed. In this coordinate system the coordinates of the survey target nests (Fig. 3) were measured and tabled for further use during quadrupole lenses alignment at accelerator. The accuracy of the quadrupole lenses fiducialization is about 70 mkm.

Fiducialization of Accelerator Dipole Magnets

NSC KIPT 100 MeV/ 100 kW linear accelerator first chicane bending magnet, 45 degree transportation channel

ISBN 978-3-95450-182-3

bending magnet and vertical scanning magnet are shown in Fig. 4.

Figure 4: NSC KIPT 100 MeV/100 kW linear accelerator first chicane magnet, 45 degree bending magnet and vertical scanning magnet.

As one can see the nest for the survey targets installed at the top of rectangular yokes of the chicane and scanning magnets and at special vertical support of the sector transportation channel magnet.

The procedure of the elements fiducialization was similar to the procedure of the quadrupole fiducialization with difference of dipole poles number and shape. The accuracies of the fiducialization for all dipole magnets were better than 70 mkm.

Fiducialization of Quadrupole Triplets

Quadrupole triplet is shown in Fig. 5.

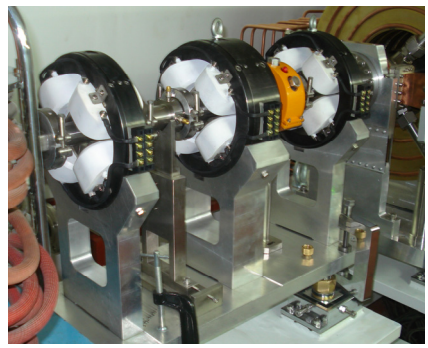

Figure 5: NSC KIPT 100 MeV/100 kW linear accelerator quadrupole triplet.

Due to mechanical design of the quadrupole triplets of the linear electron accelerator, the access to the apertures of the lenses is blocked. Since it is impossible to use the fiducialization method described above, it was decided to determine the magnetic center of the quadrupole triplet determining the centers of the circle yokes of the lenses. Thus, the center of the circles of all 3 lenses of one triplet were measured and the value of the displacement of the centers of circles relative to each other was estimated. If the displacement value did not exceed 50 μm, the coordinate system was set into one of the centers of the circle.

ACCELERATOR ALIGNMENT

After accelerator coordinate system was set and balanced, the coordinates of the survey targets were determined and tabled, all accelerator elements were fiducialized and the data was fix the procedure of the equipment alignment has been done. Taking into account the accuracies of the survey target coordinate determinations, accuracy of each element fiducialization and accuracy of element installation itself the total accuracy of the accelerator elements alignment is better than 150 mkm in transverse directions and 200 mrad for all three rotation freedom.

CONCLUSION

NSC KIPT Neutron source facility coordinate system was designed and developed. The procedure of fiducialization of dipole and quadrupole magnets, quadrupole triplets, scanning magnets with use of laser tracker Leica AT 401 was done. The process was optimized and magnetic elements error budget of 150 mkm in the vertical and in the horizontal planes has been provided.

REFERENCES

[1] http://www.leica.com/.

[2] A. Zelinsky, “Test and Commissioning Results of NSC KIPT 100 MeV/ 100 kW Electron Linear Accelerator, Subcritical Neutron Source Driver”, presented at the 8th Int. Particle Conf. (IPAC’17), Copenhagen, Denmark, May, 2017, this conference.