EFFECT OF MAGNETIC ELEMENT ALIGNMENT ERRORS ON ELECTRON BEAM DYNAMICS IN THE TRANSPORTATION CHANNEL OF THE NSC KIPT NEUTRON SOURCE DRIVEN WITH LINEAR ACCELERATOR

Andrey Zelinsky, Peter Gladkikh, Anatoliy Kalamayko, National Science Centre Kharkov Institute of Physics and Technology, Kharkiv, Ukraine

Abstract

In the paper, the results of beam dynamics simulation in the transportation channel of the NSC KIPT neutron source taking into account the errors of the electromagnetic elements alignment are presented. It is show that the values of RMS alignment errors such as 200 mkm in transverse planes and 200 mkrad in angle installations lead to the essential shifts of the beam at a neutron target and, therefore, to the essential beam losses at the vacuum chamber walls. To avoid the losses one should provide additional electron beam correction and to increase the accuracy of the equipment alignment.

INTRODUCTION

Neutron source is a hybrid facility, which combines high-current electron accelerator and subcritical assembly. Photonuclear reactions, induced by hard electromagnetic radiation emerging at retarding of the beam of relativistic electrons in the target from heavy element, are used to generate primary neutrons. Transport channel are used for electron beam transportation from linear accelerator to the neutron production target. The special scanning magnets provide the uniform beam distribution on the target surface. Due to high electron beam intensity and nuclear safety requirements it is extremely important to provide accurate delivery of the electron beam to the neutron generation target. The results of the beam dynamics simulation in the transportation channel taking into account the errors of the electromagnetic elements alignment are presented in this paper.

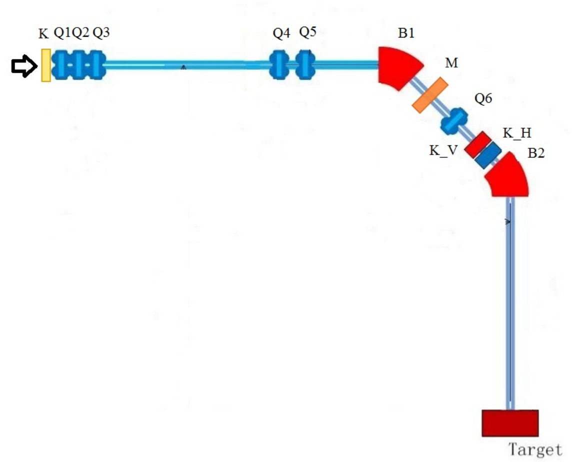

Figure 1: The layout of the NSC KIPT Neutron Source transportation channel: B1-B2 are 45 degree bending magnets, Q1-Q6 are focusing quadrupoles, K,V – K,H are scanning bending magnets, K is dipole corrector, M is beam position monitor.

TRANSPORTATION CHANNEL LAYOUT

The electron beam transportation channel from the linear accelerator to the target should meet the following requirements:

- transportation of the high current electron beam from the driving linear accelerator to the subcritical assembly with minimal particle losses;
- electron beam size at the neutron generating target should be of about 3 mm in both transversal directions with small value of the beam divergence;
- electron beam density distribution at the target of 64×64 mm should be uniform.

The layout of the transportation channel is shown in Fig. 1 [1]. After accelerator electron beam is bended in the vertical plane by achromatic arc with bending angle 90° (two bending magnets B1-B2, 45°bend in each magnet). Different focusing modes are realized by triplet (Q1, Q2, Q3) and doublet of quadrupole lenses (Q4, Q5). The position of the electron beam center is measured by a beam position monitor located after the first bending magnet (B1). To correct the position of electron beam on the neuron target is used dipole corrector magnet (K) located before triplet of the quadrupole lenses.

The beam sizes and dispersion function in the transport channel is shown in Fig. 2.

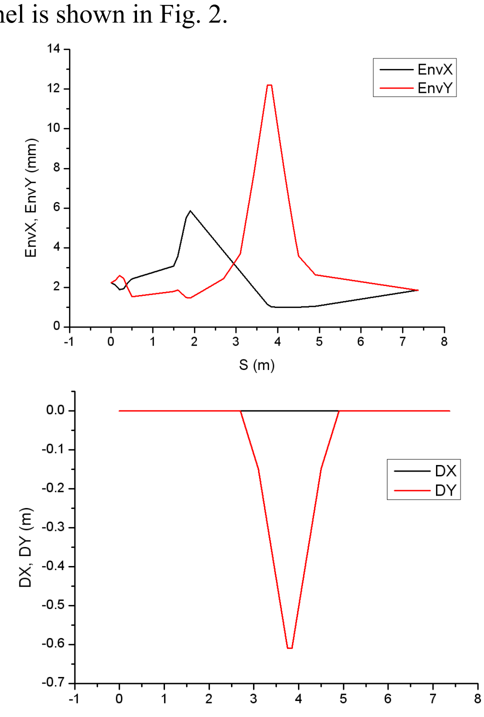

Figure 2: The beam sizes and dispersion function in the transportation channel.

ISBN 978-3-95450-182-3

SIMULATION OF THE ALIGNMENT AND FIELD ERRORS

For the simulations of the alignment errors effect it was supposed that the electron beam at the entrance of the transportation channel has Gaussian beam density distribution functions in both horizontal and vertical directions with the same RMS sizes (1 mm and 1 mrad) and with energy spread of 2%.

The following RMS alignment error values and magnetic field installation errors were used for all transportation channel electromagnetic elements that are quadruple lenses and bending magnets:

- Transversal position displacement is 200 µm;
- Angle rotations in three planes are 0.2 mrad;
- RMS relative field errors are equal to 10^{-4}.

All alignment error values are summarized in Table 1.

Table 1: Alignment Errors

Plane shift	RMS (µm)	Angle shift	RMS (mrad)
dx	200	xs	0.2
dy	200	ys	0.2
ds	200	xy	0.2

Figure 3 shows the results of RMS beam position displacement calculations have been made with MAD code and with error values mentioned above.

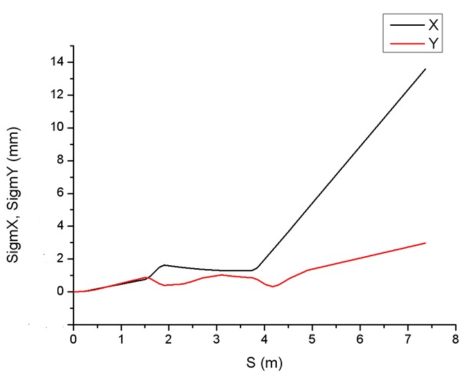

Figure 3: RMS beam position displacement along transportation channel.

As one can see in Fig. 3 the RMS beam position displacement in the horizontal plane is about 2 mm at the beam position monitor M and about 14 mm at the neuron generating target. The RMS beam position displacement in the vertical plane is about 3.5 mm at the neutron generating target and about 1.5 mm at the beam monitor M.

Taking into account that RMS beam size at the beam position monitor is about 7 mm the uncertainly in beam position determination in vertical plane can be quite big.

CORRELATION OF THE BEAM POSITION

The results of simulation of correlation between the beam displacement at the beam position monitor and at the neutron target in both planes is shown in Fig. 4. The correlation coefficient for the horizontal plane is about 0.6, and about 0.8 for the vertical plane. Due to this correlation, it is possible to determine beam position on the neutron target from its position on the monitor with certain accuracy.

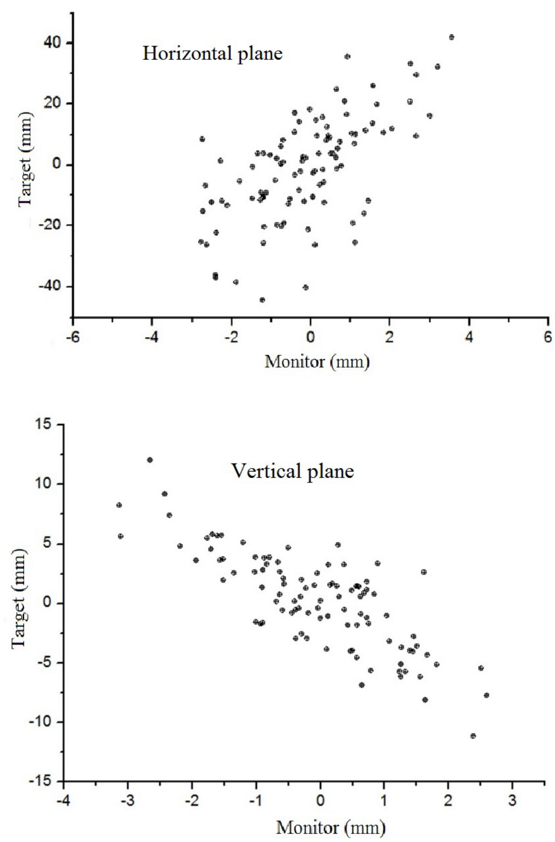

Figure 4: Correlation of the beam position at the beam position monitor and the neutron generating target.

Let us suppose that the electron beam position at the neutron target was displaced with dipole corrector (K) in the horizontal plane for two RMS beam displacement value (29 mm). The beam profile at the target for this case is shown in Fig. 5.

The correction of beam position with dipole corrector (K) in the horizontal plane produces horizontal dispersion, which cannot be compensated in the channel (there are no other bending magnets in the horizontal plane). Despite the fact that dispersion value produced by the dipole corrector (K) is very small, the end part of transportation channel has strong defocusing effect in horizontal plane due to effect of the quadrupole lens (Q6) in the center of the bending arc, which provides nonchromaticity of the transportation channel. The horizontal dispersion on the neutron target can reach 0.4 m and the beam at the neutron target becomes a strip shaped with RMS size in horizontal plane equal approximately to 5 mm and in vertical plane 2 mm (See Fig. 5). In this case, the beam could fall out of the neutron target and damage the wall of the vacuum chamber. That can lead to the loss of vacuum and emergency situation at the subcritical assembly facility.

ISBN 978-3-95450-182-3

To avoid such situation in the future facility operation the further studies of the transportation channel focusing modes are needed.

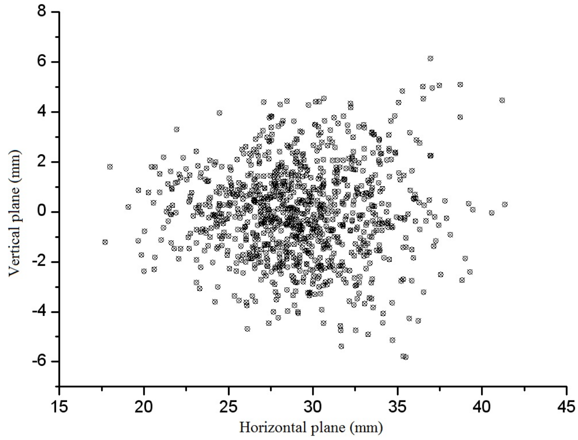

Figure 5: The beam profile at the neutron target for the case of the horizontal beam displacement at the beam monitor equal to 29 mm (2 RMS beam displacement value) in the horizontal plane.

CONCLUSION

There is a significant correlation of beam positions at the beam position monitor M of the transportation channel of the Neutron Source and neutron generating target. Measurements of the beam position on the monitor allow to determinate the beam position at the target.

The dipole corrector (K) provides the possibility to set the electron beam at the center of the neutron generating target.

The large vertical RMS size of the beam at the azimuth of the beam monitor (M) requires special actions for accurate measuring of the beam the position.

Large horizontal beam size at the neutron target requires the further development of a special operation mode to provide use of the scanning system for the uniform beam distribution at the target surface.

REFERENCES

[1] I. Karnaukhov, A. Zelinsky, W. Liu “Proposals for electron beam transportation channel to provide homogeneous beam density distribution at a target surface”, Proceeding of IPAC2011, San Sebastian, September 4-9, Spain 2011, TUPC039, pp. 1084-1086, http://www.JACoW.org

ISBN 978-3-95450-182-3