SURVEY AND ALIGNMENT FOR BEPCII STORAGE RING

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1. ABSTRACT

The BEPCII will be constructed for both high energy physics (HEP) and synchrotron radiation (SR) researches. It is an upgrading scheme from BEPC with two rings, e^+ ring and e^- ring, built in the existing BEPC tunnel. This paper will describe the required survey and alignment tolerances, the survey concept, instrumentation to position storage ring beam components, typical cell alignments.

2. ALIGNMENT TOLERANCES

In order to achieve a successful startup of the BEPCII storage ring (shown in Fig. 1), the following relative alignment tolerances are defined by the accelerator physicists.

Table 1 Tolerable displacements for storage ring magnets (components)

	Horizontal ΔX (mm)	Vertical ΔY (mm)	Beam Direction ΔZ (mm)	Pitch $\Delta\theta_x$(mrad)	Yaw $\Delta\theta_y$(mrad)	Roll $\Delta\theta_z$(mrad)
SC magnet	0.15	0.15	0.2	0.1	0.1	0.1
B	0.2	0.2	0.2	0.2	0.2	0.1
Q	0.15	0.15	0.5	0.5	0.5	0.2
S	0.15	0.15	0.5	0.5	0.5	0.5
BV, BH	0.3	0.3	1.0	1	1	0.5
BPM	0.15	0.15	0.5			
RF	0.15	0.15	0.5			
Kicker	0.3	0.3	1.0	1	1	0.5
Lambertson	0.3	0.3	1.0	1	1	0.5

The circumference of storage ring can't deviate from its design value by more than 5mm; the difference between two rings has to be set within 4mm.

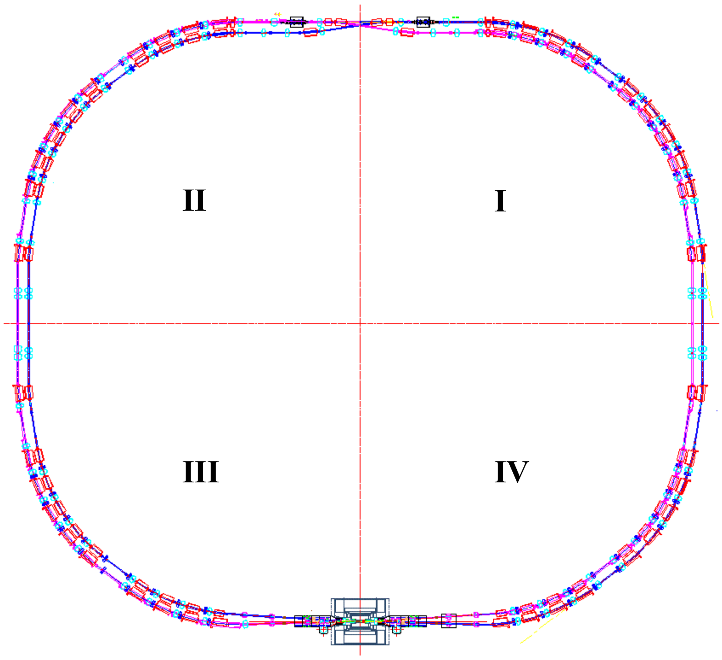

Fig. 1 General layout for BEPCII storage ring

3. SURVEY CONCEPT

One of the most important factors in the successful operation of the machine is alignment quality, which ensures the stability of the particle beams. The primary goal of the survey and alignment of the BEPCII storage ring is to align the magnets within 150μm of their designed position precisely. To accomplish the task, a network of monuments is established and their positions are measured with respect to one another. Using the monuments as reference points, positions of magnets and other beam components are measured and aligned.

Uneven drop will occur in the storage ring floor due to different floor loading, ground moisture variations and seasonal variations. Therefore, monument positions and the magnet positions will have different changes.

The monument measurements and coordinate value calculations should be carried out periodically and the magnet locations will be surveyed and aligned at regular intervals.

The BEPCII accelerator consists of three main components, the linac (200 meter long), the transport line (90meter long) and the storage ring (circumference 237.5m), which will be constructed in the pre-existing BEPC tunnel. In order to position all the beam components in a great accuracy along the beam orbit, it is necessary to design and set up a network, which could keep the Linac, the transport line and the storage ring in correct position relative to each other.

The control network is composed of the horizontal network and the elevation network. The horizontal network comprises the ground and the tunnel control networks.

3.1 Ground control network

The ground control network, which was used for BEPC, is made up of 6 concrete monuments (Figure 2) embedded in the bedrock. Among them, two are the connections to the tunnel network in the LINAC (L101, L102), two are the connections to the transport line (T65P, T65E), the others are to the storage ring (R7, R23). Windows on relative ratchet wall were prepared when tunnel being constructed.

Total station instrument TDM5005 is used to measure the ground control network. For the vertical transfer technique, the precision optical plummet is needed. With an accuracy expecting program, an accuracy better than 1mm can be achieved with distance accuracy of 0.7mm and angle accuracy of 2 sec.

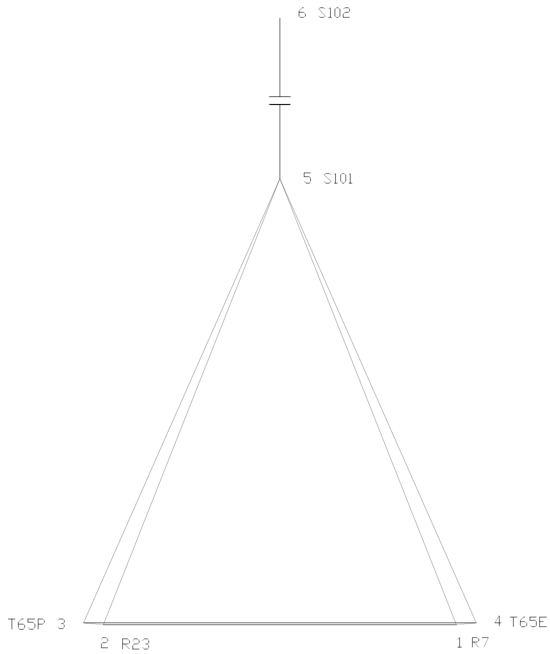

Figure 2 Sketch of the ground network

3.2 Tunnel network

The tunnel network is made up of braced quadrilaterals through the tunnel of each accelerator subsystem, which will be used for the global positioning of all beam components in each accelerator subsystem. For the storage ring, 36 monuments are imbedded in the concrete floor (including two ground network monuments), and the target is just above the floor surface. Its cross-section is shown in Figure 3. The other 72 points are set on the wall. This three dimensional layout improves the network geometry and provides the necessary control points for elevation network.

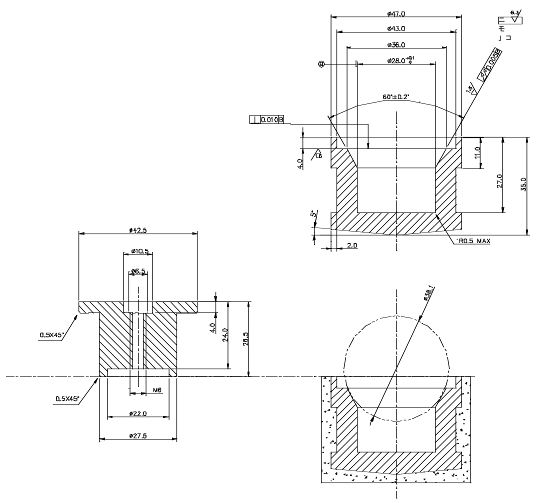

Figure 3 Cross-section of tunnel monument

The tunnel network is measured by SMX4500, a laser tracker, with its software SMXInsight.

The measurements are carried out in 35 stations nearby each floor monument, shown in Figure 4. At least two floor monuments and wall references of each side, backward and forward will be measured. 6 common points exist between any two neighbor stations. The simulation of such a network with the distance measured accuracy of 0.05mm shows that the maximum transverse deviation of less than 0.08mm could be achieved.

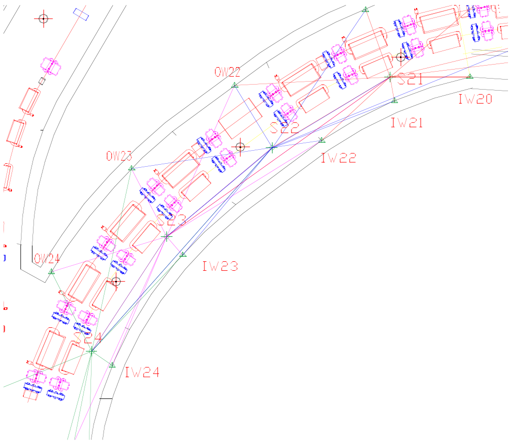

Figure 4 Tunnel network

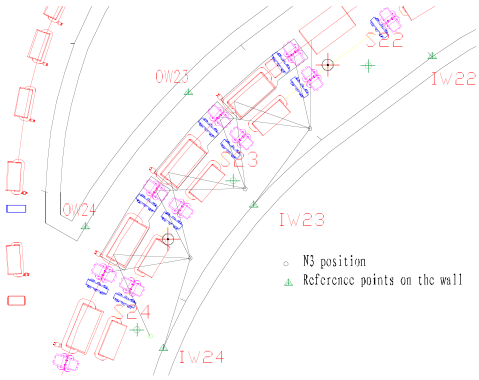

Figure 5 Elevation network

3.3 Elevation network

All the reference points on the inner wall 1.7meters high from the floor composes the elevation reference network schematically shown in Figure 5.

After all the beam components are carried out and the tunnel is cleaned, the level of tunnel floor will be measured. The middle height along the ring floor will be taken as the start point of the level. In order to inspect the floor deformation, all the tunnel monuments will be surveyed when doing the elevation network survey by using the Wild N3 sight level and a relative accuracy (rms) better than 0.1mm is expected.

4 TYPICAL CELL ALIGNMENTS

4.1 Fiducialization

Each quadruple, sextupole and dipole magnet has fiducial cups welded on top of the laminations or side of the yoke. 1.5 inch SMX4500 reflector is used as targets for these fiducial cups. During the magnet mapping process the location of each fiducial cup is determined using SMX4500 reflector.

4.2 Magnet alignment

All the beam components are measured with respect to the known monument positions. The local magnet coordinate system with respect to beam orbit is illustrated in the figure 6.

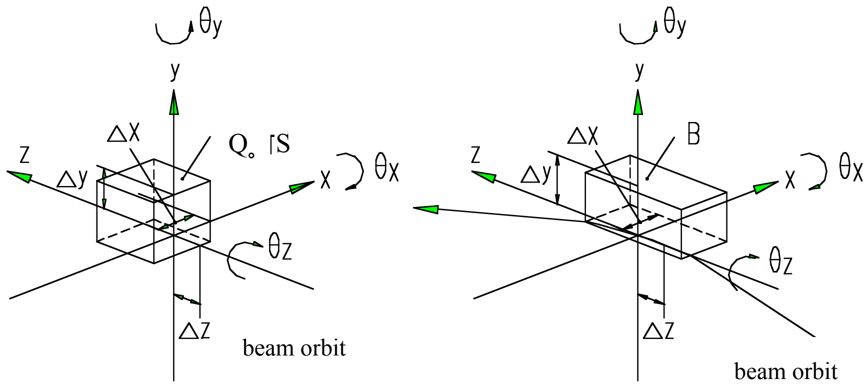

Figure6 Local magnet coordinate system

To perform the precision alignment, five-step procedures are applied.

4.2.1 Prealignment procedure for quadruple, sextuple and dipole magnets

For the purpose of matching the vacuum chamber dividing scheme, a 2-girder system in one cell is used. There are more than 3 fiducial plates on the girder surface. The SMX4500 reflector with a adapter could be put on the plates.

The magnets, vacuum chamber and BPM, which are put on the same girder, will be prealigned by using SMX4500 and N3 in a preparation room, shown in Figure 7. With the work being done in a preparation room rather than in the tunnel, it can be carried out more efficiently, with higher quality in a rather short period of time. Thereby speeding up of installation program can be expected.

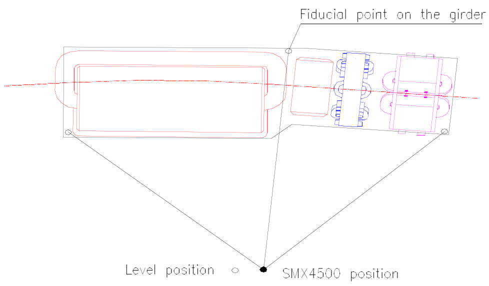

Figure 7 Prealignment for quadruples, sextuple and dipole magnets

4.2.2 Prealignment for BPM and Vacuum Chamber

After dipole, quadrupole and sextupole magnets are prealigned, the quadrupole and sextupole's top halves will be removed. The vacuum chamber and BPM are mounted and aligned to the girder with respect to BPM fiducial point. Then the top halves of magnets are restored.

4.2.3 Marking the beam line on the floor

The position of dipole magnets and magnets on the end of each girder (Q or S) is derived from tunnel network control points using SMX4500. Each position will be marked on the top surface of copper rods embedded in the tunnel floor by the precision of ±1.5mm. The base plate position of the girder will then be drawn on the tunnel floor using the position markers as reference.

4.2.4 Positioning girders

Each prealigned girder is brought into the ring tunnel and roughly positioned by using the location markers. Then it is leveled by Wild N3. Tilt is controlled with a bubble level. A tolerance within ±2mm in relation to the neighboring reference points is expected.

Magnet positions on each end of the girder are measured and then adjusted to a rms 0.15mm of the designed position with respect to neighboring reference points utilizing SMX4500.

4.2.5 Smoothing alignment

After girder alignment, a confirmation survey is carried out to determine whether the magnets are within the required tolerances. The survey is independent of the tunnel monuments, constituted from the quadruple magnets themselves. If the magnets are found to exceed the required tolerance, the process is repeated.

5 ERROR BUDGET

The tolerance for the storage ring's beam components is set within 150μm. The accuracy of items involved are designed as follows:

The magnet center to the magnet fiducial point	0.05mm
The tunnel network locally	0.08mm
The magnet fiducial point to the tunnel network	0.06mm

The total value:

$$M_F = \sqrt{0.05^2 + 0.08^2 + 0.06^2} = 0.11mm$$

6. ACKNOWLEDGEMENT

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7. REFERENCE

[1] The Precision Survey of BEPC Storage ring, Y.Zhang, IHEP China

[2] Survey and Alignment at the Advanced light source, Gary F.Kvebs, Lawrence Berkeley Laboratory

[3] Positioning the Spring8 Magnets with the Laser Tracker, C.Zhang, S.Matsui, J.Ohnishi, Spring8

[4] The Alignment of the Advanced Photon Source at Argonne National Laboratory, Horst Friedsam, Argonne National Laborator