Survey & Alignment of Pohang Light Source

Ae-Hee Maeng, Kwang-Won Seo and Seung-Chan Lee
Pohang Accelerator Laboratory
POSTECH, Pohang, Kyungbuk 790-784, KOREA

ABSTRACT

Pohang Light Source(PLS) which is operated by Pohang Accelerator Laboratory(PAL) of Pohang University of Science and Technology(POSTECH) is the third generation synchrotron radiation source. The project was initiated in April 1988, and completed in December 1994.

As a method to achieve the required positional accuracy of a few tenths of a millimeter for the PLS machines, we have introduced various precision surveying instruments and techniques. For linac alignment, we applied an optical tooling technique to a prealignment process, and developed a laser alignment system of a He-Ne laser and Fresnel zone plates for final alignment in the accelerator tunnel. We introduced a noncontact 3-dimensional measuring system with theodolites, conventional surveying technique with survey network for storage ring alignment, and a GEONET program for data analysis and database management. A smoothing analysis using a low-path filtering method was developed for estimating the electron beam orbit and offset error of the magnets in the storage ring. The positional errors of 0.15mm in rms value has been obtained in positioning the quardrupoles and sextupoles of the storage ring.

In this presentation described are; linac alignment, storage ring alignment, the estimation of positional errors, smoothing analysis, survey network and so on.

I. INTRODUCTION

The Pohang Light Source"[1], the first third generation synchrotron radiation source in Korea, is a national users facility which is operated by the PAL, POSTECH. The PAL is located in Pohang city. The Pohang city, which is regarded as one of major science cities, is located about 400 km southeast of Seoul. The PLS project was initiated in April 1988, and completed in December 1994 with the excess achievement of its commissioning goals, running at 2.0 GeV electron energy and stored current of more than 300mA. Now two beamlines, one for VUV and the other for x-ray, serves domestic and international users, starting from September 1995. And three more beamlines will be available by the beginning of 1996.

The PLS is composed of a 2 GeV linac, a storage ring and beamlines. Allowable positional errors(rms) are 0.25mm for the accelerating columns of the linac, and 0.15mm for the quadrupoles and sextupoles of the storage ring. Considering various accelerator surveying technology[2][3][4], we decided to introduce an optical tooling technique, a laser alignment system of He-Ne laser and Fresnel zone plates, a 3-d non-contact measuring system by theodolites, and conventional surveying techniques using precision instruments such as theodolites(T3000 or E2), mekometer(ME5000) and level(N3). In relate to the instruments, we have designed and fabricated various kinds of precise jig and fixtures. A GEONET was chosen for data analysis and database management[5]. In order to estimate an effect of floor settlement on the actual electron beam orbit and offset errors of magnets in the storage ring, we have studied various smoothing schemes and developed a smoothing analysis using a low-path filtering method. This smoothing was applied to the PLS storage ring magnet alignment successfully in August 1995[6].

II. LINAC ALIGNMENT

The PLS 2.0 GeV linac is a full energy injector to the storage ring. The linac which consists of 42 SLAC type accelerating columns and 6 quadrupole triplets is 150m long. Accelerator tunnel is located 6m below the ground level. The allowable relative positional error of the accelerating columns is 0.25mm(rms)

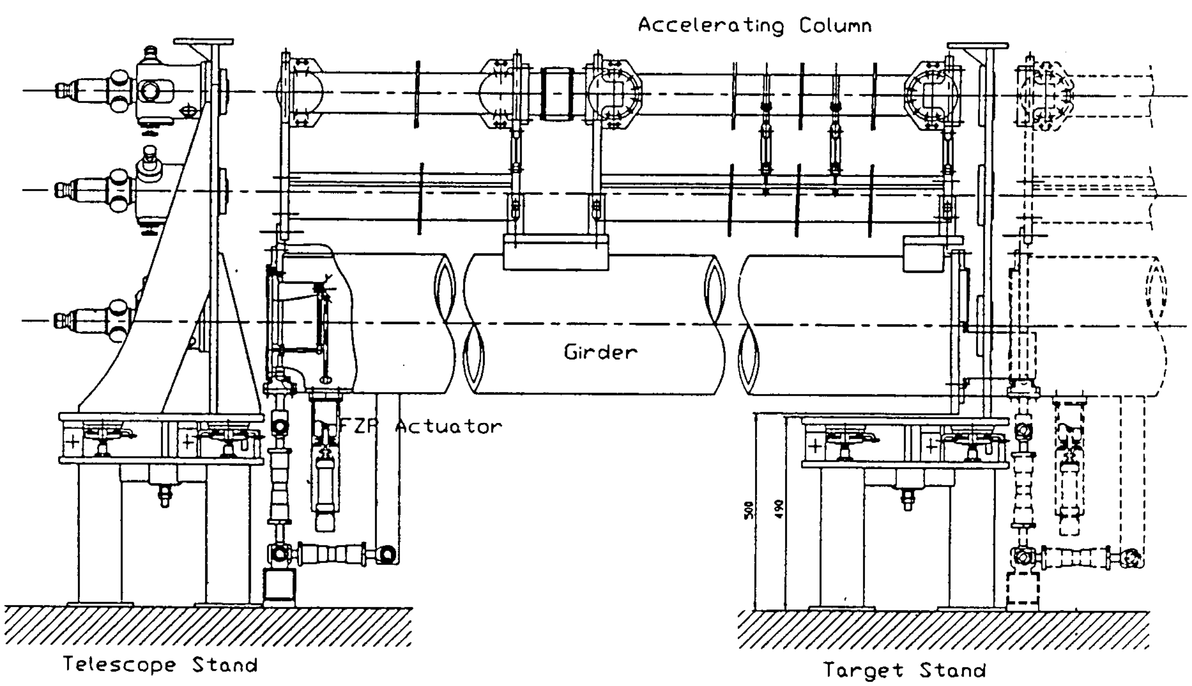


Fig. 1 Linac Prealignment

The accelerating columns were prealigned in the assembly room. Prealigning process consists of three steps; 1) the straightness check and adjustment of accelerating columns, 2) the true position check between the center of accelerating column and two optical tooling holes in support plates, 3) the alignment of optical tooling holes and Fresnel zone plate. Optical tooling instruments such as jig transit and tilting level, and precision measuring instruments of dial indicator and height master were used for the above first and second step. The straightness of the accelerating column was adjusted within 0.10mm. And as shown in figure 1, the optical tooling holes and the Fresnel zone plate were aligned to the lines of sight which were established by the prealignment stands of telescopes and targets.

The linac was prealigned to the positional errors(rms) of 0.07mm vertically and 0.11mm transversely. The positional errors consist of offset errors and reading errors. The offset errors resulted from the straightness, the true position, and the alignment error. The reading errors were estimated about 1:200,000 which is generally regarded as the errors in the optical tooling technique.

The girder assembly which had been prealigned was moved into the linac tunnel, and aligned to the reference line on the floor. Then the offsets of Fresnel zone plates were measured accurately and rapidly using a laser alignment system. The laser alignment system measures the offsets with the precision of a few hundredths of a millimeter by analyzing the pattern of the laser beam, which is diffracted by the Fresnel zone plate, using an image processing system. A schematic drawing of the laser alignment system and a typical pattern of diffracted laser beam are shown in figure 2.

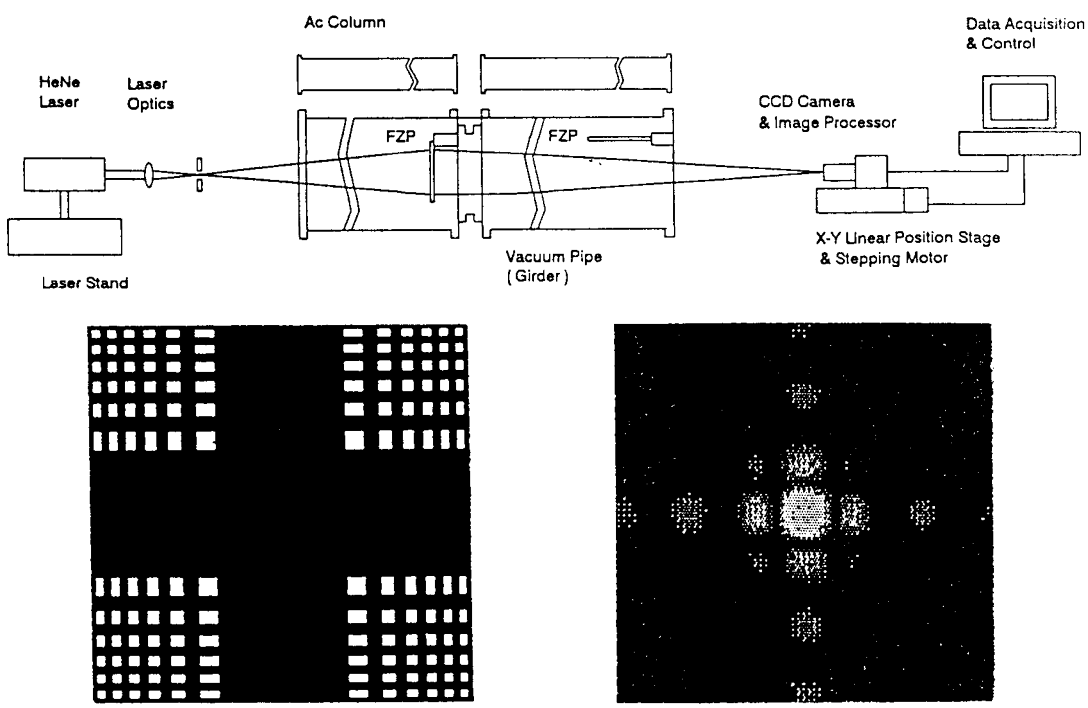


Fig. 2 Laser alignment system and FZP Diffraction Image

Since the alignment of linac was completed with the positional error(rms) of $\triangle x$=0.02mm, and $\triangle y$=0.02mm respectively in March 1994, the status of linac alignment has been checked periodically with the laser alignment system, and proved stable within the required accuracy of 0.25mm. A slight increase of positional error which has been monitored during the last one and half year may be caused by the effect of an inequable settlement of tunnel floor.

III. STORAGE RING ALIGNMENT

The PLS storage ring has a 12-period Triple Bend Achromat(TBA) lattice. Its circumference is 280.56m. There are 36 bending magnets, 144 quadrupoles and 48 sextupoles. The allowable positional errors(rms) for quadrupoles and sextupoles are $\triangle x$=0.15mm and $\triangle y$=0.15mm.

Storage ring alignment process consists of magnet fiducialization, vacuum chamber prealignment, girder rough-setting, magnet rough-setting, fine positioning and smoothing analysis.

Magnet fiducialization is the process of establishing a machine coordinate, which is expressed by four fiducial posts on the top surface of magnet using a CMM. Figure 3 shows a quadrupole and its fiducial posts.

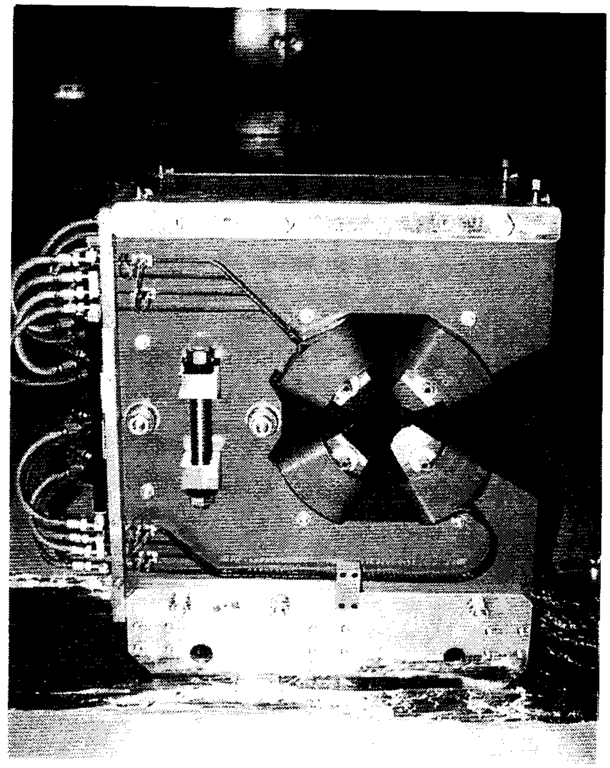


Fig. 3 Quadrupole and its fiducial posts

Vacuum chamber prealignment is the process of establishing a girder coordinate and aligning vacuum chamber to the girder. Each vacuum chamber was aligned within the maximum offset of 0.5mm. A non- contact 3dimensional measuring system with about 0.1mm of accuracy was used in this prealigning process as shown in figure 4. By measuring and bundling the reference holes of beam position monitor(BPM) and the fiducial posts on the girder, the offsets of vacuum chamber were determined and aligned within the offset of 0.5mm.

Girder rough-setting is the process of bringing the vacuum chamber and girder assembly into the storage ring tunnel and setting it to the designed position on the basis of a storage ring tunnel survey network. Each girder was aligned within the offset of 0.5mm for horizontal and vertical direction respectively.

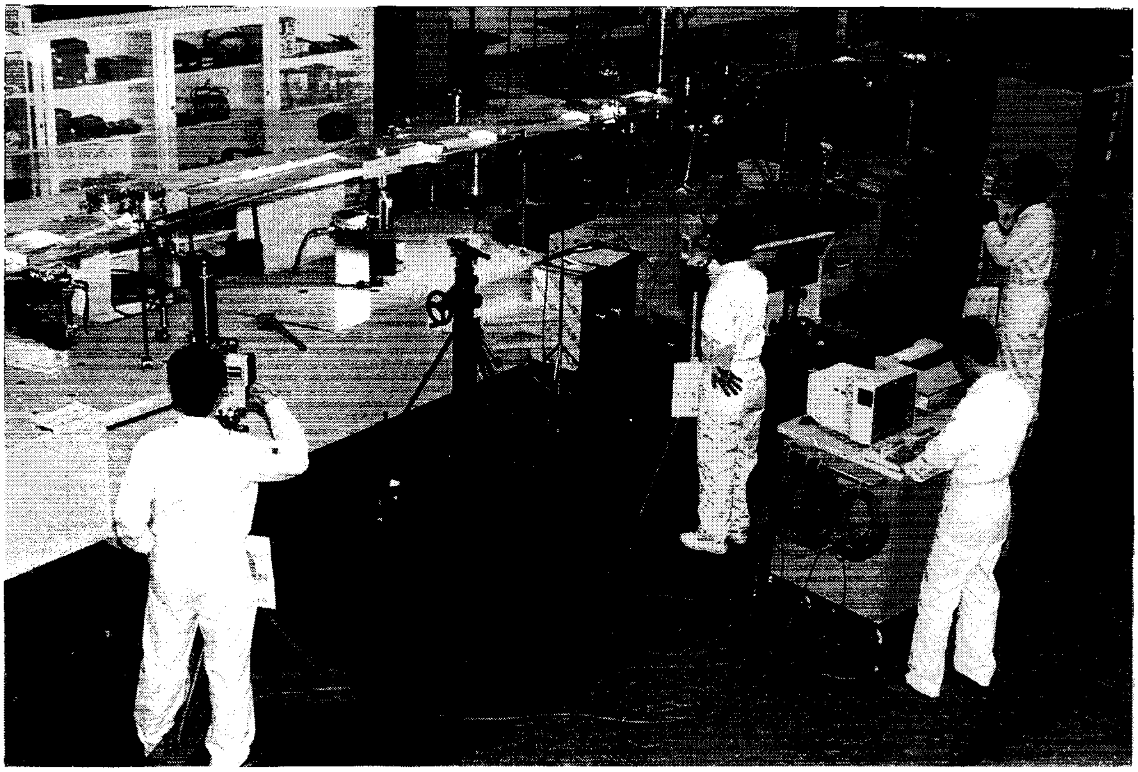


Fig. 4 Vacuum chamber prealignment

Magnet rough-setting is the process of installing the magnets using 6 strut mechanisms. The magnets are aligned horizontally as accurately as possible by an intersection method using two theodolites. The gaps between vacuum chamber pocket and magnet pole tip are closely monitored during leveling process.

Magnet fine positioning process which consists of surveying and adustment were repeated 4-5 times until the positional errors becomes within tolerance. Figure 5 shows the direction surveying. A theodolite is mounted on the survey monument of wall bracket using an adapter. The adapter was fabricated after Taylor Hobson sphere and Kern centering mechanism. Figure 6 shows a direction and distance survey network.

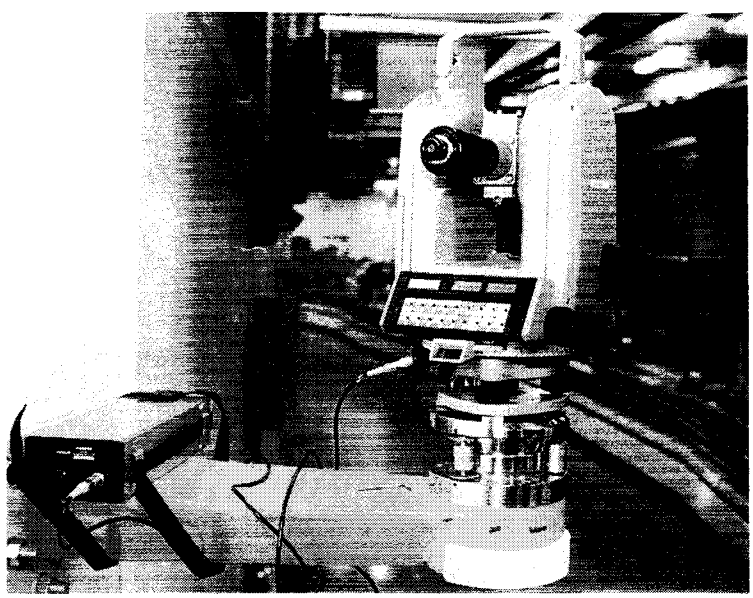
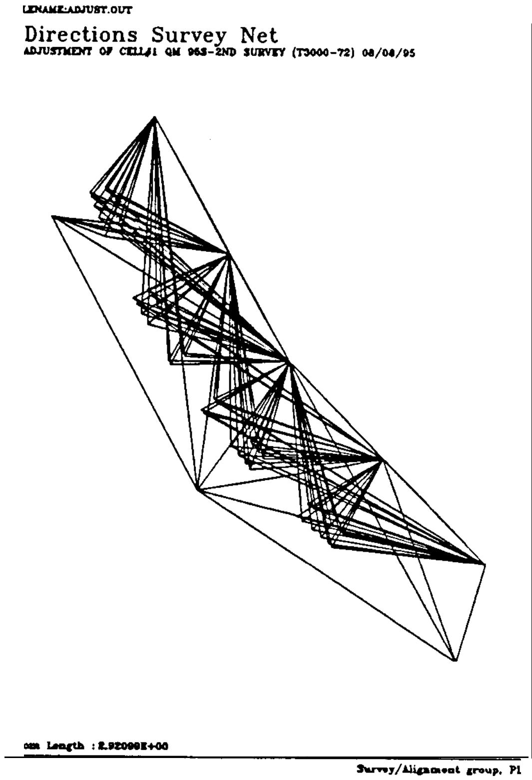
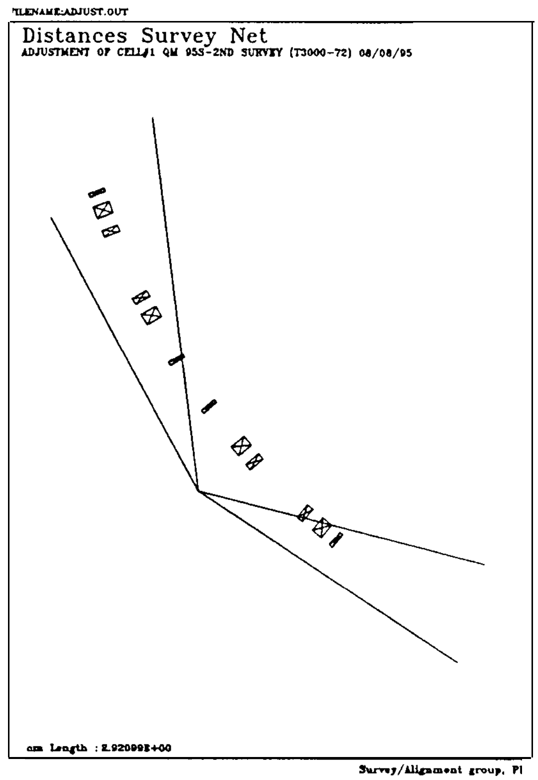


Fig. 5 Direction surveying in the tunnel





direction distance

Fig. 6 Direction & distance survey net for quadrupole alignment

A positional error in magnet alignment consists of a positioning error and an offset error. The former, which represents reading error in the form of standard error ellipse, was calculated by GEONET program, and the latter, which indicates alignment status, is the statistical observation of magnet offsets from designed path. As figure 7 shows, the major axis values(a) of absolute error ellipses in quadrupole surveying dated on August 24, 1994 were between 0.05mm and 0.08mm. Distances among fiducial posts which were measured during magnet fiducialization were integrated for error ellipse analysis. The positional errors(rms) of $\triangle x$=0.14mm and $\triangle y$=0.08mm were obtained in August 1994 as shown in Table 1.

TABLE 1. Estimation of Positional Errors in PLS Storage Ring Magnets as of August 1994 (unit:mm)

Magnets	Positional Errors	
	$\triangle$x(rms)	$\triangle$y(rms)
Quadrupole	0. .39	0.075
Sextupole	0.149	0.074
Bending Magnets	0.186	0.078

Fig.7 Standard error ellipses of quadrupole surveying

Smoothing analysis is the process of estimating the electron beam orbit of the storage ring as closely as possible in the form of smoothed curve by analysing the offset values of quadrupoles from the designed path. The offset errors of magnets are estimated on the basis of the smoothed curve. A smoothing analysis using a low-path filtering method was developed for estimating the electron beam orbit and the offset error of magnets in the storage ring.

The smoothing analysis was applied to estimating the offset errors of magnets for the survey of August 1995. It was found that quadrupoles were deviated as much as $\delta x_{max}=-1.0$mm and $\delta y_{max}= -0.85$mm for horizontal direction and vertical direction respectively from the designed electron beam orbit of the storage ring. And, estimating the offset error of quadrupoles on the basis of the designed path, we got the offset errors(rms) of $\triangle x=0.39$mm and $\triangle y=0.37$mm. On the contrary, applying the smoothing analysis, we got the maximum deviation of $\delta x_{max}=-0.27$mm and $\delta y_{max}=0.22$mm, and the offset errors(rms) of $\triangle x=0.13$mm and $\triangle y=0.12$mm. The results of smoothing analysis are summarized in table 2.

TABLE 2. Estimation of Offset Errors by Smoothing Analysis in PLS Storage Ring Magnets Alignment as of August 1994 (unit:mm)

Magnets	Offset Errors on the Basis of Designed Path		Offset Errors on the Basis of Smoothed Curve	
	△x(rms)	△y(rms)	△x(rms)	△y(rms)
Quadrupole	0.388	0.365	0.127	0.118
Sextupole	0.385	0.344	0.131	0.070
Bending Magnets	0.467	0.385	0.181	0.113

IV. SURVEY NETWORK AND TUNNEL DEFORMATION

The survey network of the PLS is composed of a surface net and tunnel nets. These are linked with one another that they provide the global coordinates of the PLS.

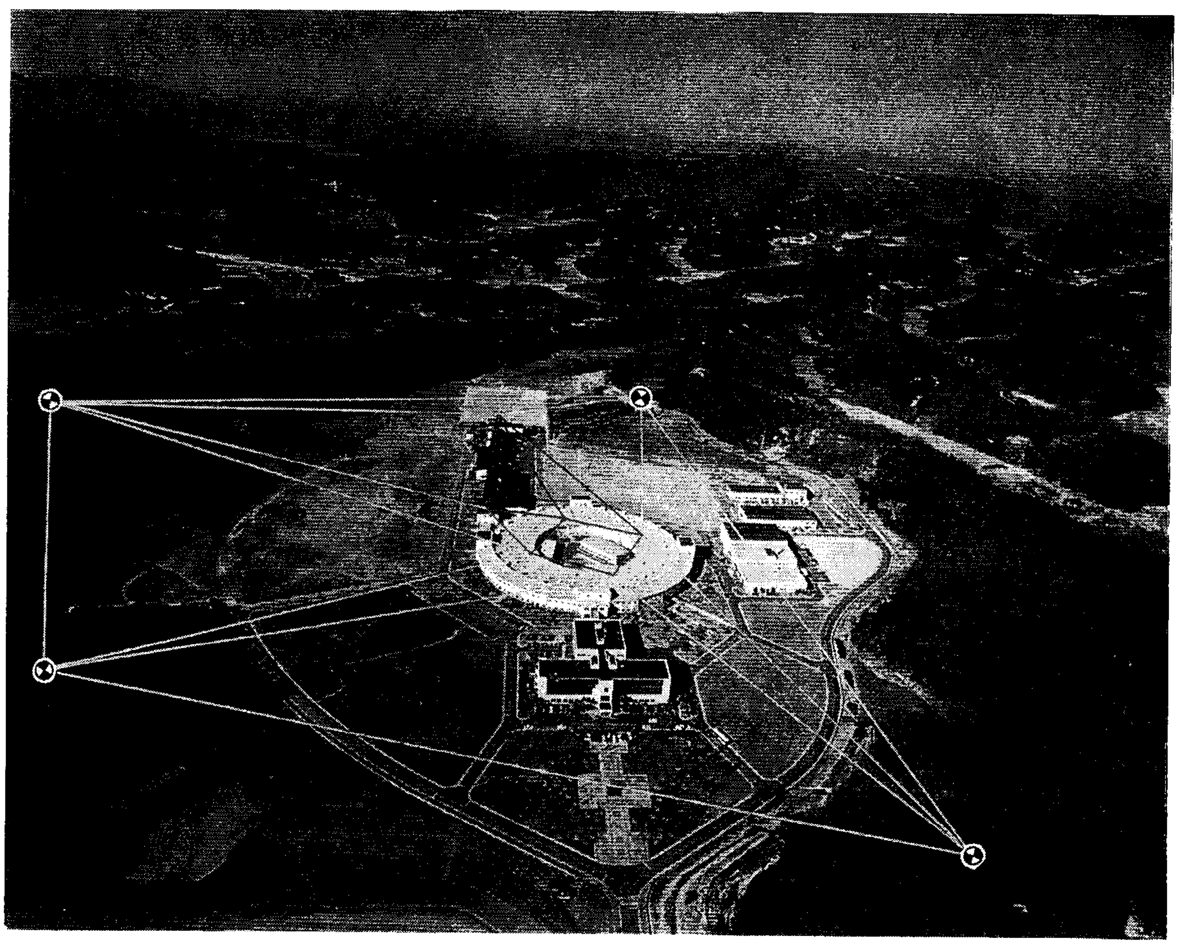


Fig. 8 PLS surface net

The surface net consists of 10 geodetic control points; four of them are located on the top of hills around the PAL, and six are on the roof of buildings as shown in figure 8.

The tunnel nets are composed of a storage ring net, a linac net and a beam transfer line net in the viewpoint of location. There are two kinds of tunnel net; the TNET of which the control monument are installed on the inner wall controls horizontal location, and the ENET of which the control points are embedded in the tunnel floor controls elevation. The absolute error ellipses of the surface net were estimated as 0.20-0.40mm in the major ellipse axis values. And those of the TNET of the storage ring were 0.2-0.3mm as shown in figure 9.

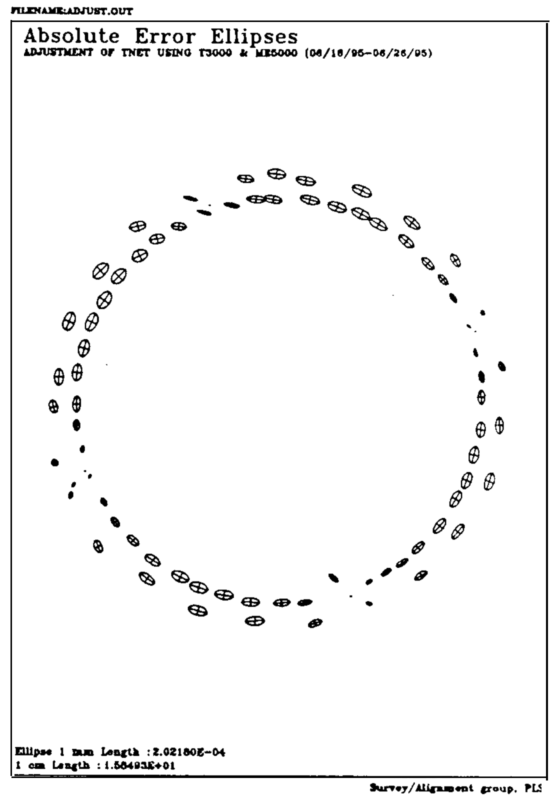
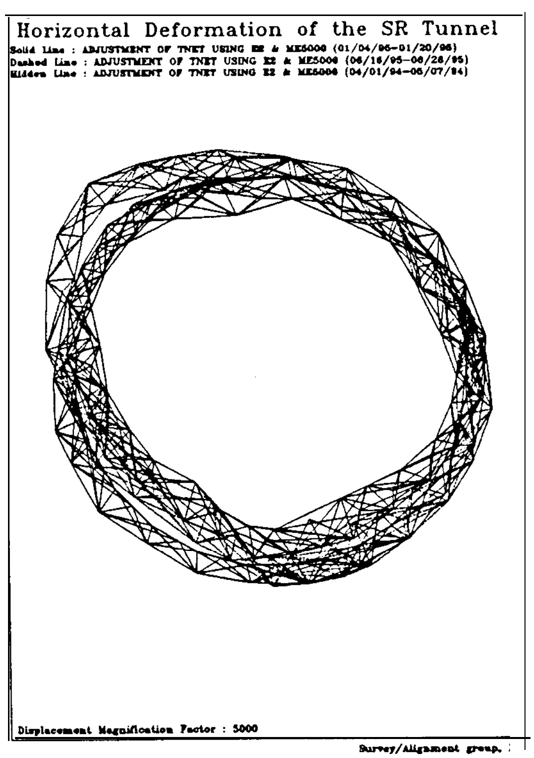
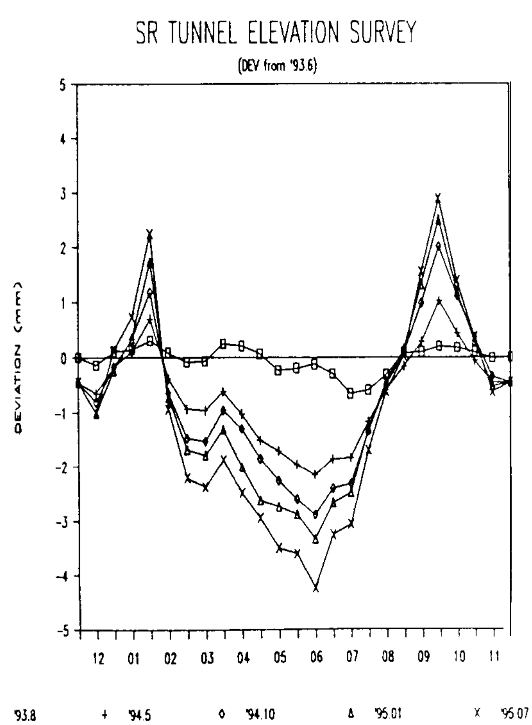


Fig. 9 Absolute error ellipses of strorage ring TNET





horizntal deformation

vertical deformation

Fig. 10 Deformation of the storage ring

Figure 10 shows that the storage ring tunnel has been settled inequally about 3.0rnm per year, and deformed horizontally as much as the maximum value of about 1.0mm. The tendency of this deformation was found having been reflected in vertical and horizontal offsets of the storage ring magnets.

ACKNOWLEDGMENT

In preparing this paper we have heavily relied upon the work of our colleagues who have made their utmost efforts in accomplishing the goal of the PLS project. Without the work of our seniors who have made great contibutions to the art of state technology of accelerator surveying, we could not have enjoyed the pleasure of a success. We would like to thank Professor Zhang Yen of IHEP, Dr. Robert Ruland of SLAC, Mr. Horst Friedsam of ANL, Dr. Franz Löeffler of DESY and Mr. Michel Mayoud of CERN, for their advices, helps and encouragement of this work. Thanks are also due to Professor B.G. Kim who led the way while we were in the awkward situation. This work was supported by the Korean Ministry of Science and Technology(MOST), and Pohang Iron and Steel Company(POSCO).

REFERENCES

1. *Design Report for Pohang Light Source,* PAL, January,1992
2. R.B. *Neal, The Stanford Two-Mile Accelerator,* W.A. Benjamin, Inc., 1968, pp.95- 162, 821-885
3. Michel Mayoud, *Geodetic Metrology of Particle Accelerators and Physics Equipment, CERN,* Proc. of the First International Workshop on Accelerator Alignment, SLAC, July 31-August 2, 1989, pp.128-140
4. F. Löeffler, *The Alignment of the DESY-Accelerators An Overview,* Proc. of the Second International Workshop on Accelerator Alignment, DESY, Sept. 10-12, 1990, pp.69-88
5. H. Friedsam, R. Pushor and R. Ruland, *GEONET-A Realization of an Automated Data Flow for Data Collecting, Processing, Storing and Retrieving,* Proc. of the First International Workshop on Accelerator Alignment, SLAC, July 31-August 2. 1989, pp.141-151.
6. J.G. Yoon and *S.C.* Lee, *Smoothing Analysis of PLS Storage Ring Magnet Alignment,* to be Presented at the 4th International Workshop on Accelerator Alignment, KEK, Nov.14.-17,1995