SURVEY AND ALIGNMENT FOR THE SYNCHROTRON LIGHT SOURCE ELETTRA

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ABSTRACT:

ELETTRA is a third generation light Source currently under construction in Trieste, Italy, which will be commissioned in 1993. As a high brilliance machine, ELETTRA is designed for extremely small emittance, which causes a high sensitivity to alignment errors. First results and the general alignment method, as well as the instruments, survey tools and applied software, are described.

1. INTRODUCTION

A (preliminary) proposal for the alignment of ELETTRA was presented at the 'Second International Workshop on Accelerator Alignment' in 1990 [2]. At that time, in June 1991, we started the construction of the main building. In the mean time the construction of ELETTRA has made considerable progress (Fig. 1). The main instruments for survey and alignment were delivered in the second half of 1991 and the manpower of the Alignment Group increased in the meantime from one to five. The tasks which have been performed, were the survey of the global network, the survey of the storage ring network and the pre-alignment of the transfer line and the storage ring. In performing these operations, our team gained the skill for the alignment work. Furthermore all the instruments were tested and calibrated and the tools and software programs were adapted to our tasks.

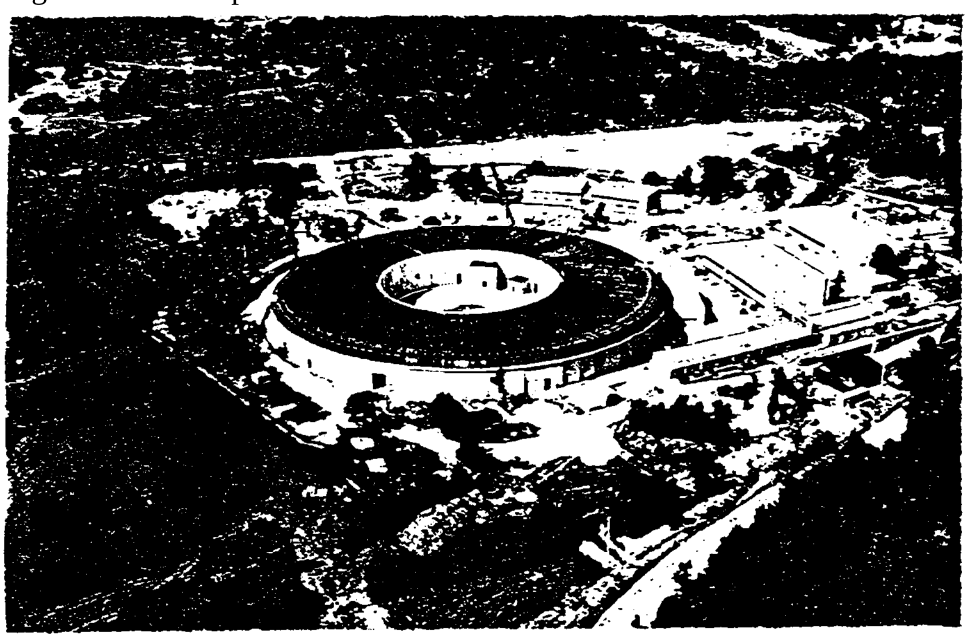

Fig. 1. View of ELETTRA

ELETTRA consists basically of three parts: the linac, the transfer line and the storage ring. Since the linac is located under ground, the beam orbit of the storage ring is 3.9 meters above the linac axis. The beam is accelerated by a 1.5 GeV linac to its final energy and transported via a transfer line, which includes 3 horizontal and one vertical bending section, to the inner side of the storage ring and injected from there in the horizontal plane.

ELETTRA is a third generation light Source. As a high brilliance machine, the storage ring is designed for extremely small emittance, which causes a high sensitivity to alignment errors. The storage ring is approximately circular in the shape and has a circumference of 259.2 meters. In order to reach the correct RF-frequency, the absolute accuracy of the circumference should be ± 2 mm.

The ring is built up by 24 bending magnets, 108 quadrupoles and 72 sextupoles. Since the bending magnets are combined function elements, it has to be treated with the same care for the alignment as a quadrupole. To reduce the effects of alignment errors on the machine performance, very tight positioning tolerances were requested, which are listed in table 1. The positioning errors there have to be understood as 1 standard deviation of a Gaussian distribution truncated at 20. Fig. 2 explains the definitions of the positioning errors.

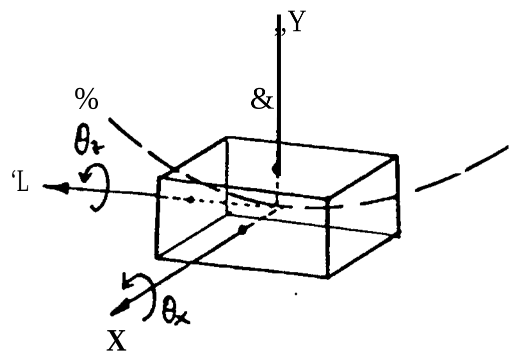

Fig. 2. Definition of positioning errors

Table 1
Positioning tolerances for the storage ring magnets [1]

tolerance [mm,mrad]	bending	quadrupole sextupole
Δx	0.1	0.1
Δy	0.1	0.1
Δz	0.25	0.5
$\Delta\theta_x$	1.0	1.0
$\Delta\theta_y$	0.25	0.25
$\Delta\theta_z$	0.25	0.5

2. NETWORK AND GENERAL ALIGNMENT METHOD

In order to keep the linac, the transfer line and the storage ring in correct relative position to each other, five monuments were placed on the rocks (Fig. 7). One additional monument M9 was placed at the roof close to the linac entrance. In addition there are 2 fixed columns at the horizontal deflection points of transfer line in order to define the orbit of the transfer line.

In the storage ring tunnel 24 column basements were installed below the false floor for the positioning of the movable columns. These positions and 2 monuments located in the central open area of the storage ring build the survey network of the storage ring. There are 6 small windows in the internal wall of the storage ring tunnel in order to measure from the central monument to 6 columns and 6 reference points on top of the bending magnets. Furthermore there are two holes in the floor which guarantee a vertical line of sight between the storage ring tunnel and the transfer line tunnel.

For the alignment of ELETTRA we chose to separate the horizontal coordinates (2D) from the vertical ones (1D). After distances and angle measurement, the horizontal coordinates were calculated by using the least square method.

After the bending magnets of the storage ring have been aligned, all the magnets in the straight sections between two adjacent bending magnets were aligned.

3 SURVEY EQUIPMENT

Our survey equipment includes two electronic theodolites Wild T3000 with a REC modular system, a Distomat Wild DI2002, a calibrated invar scale bar, an optical plummet wild NL, two precision levels Wild N3, with two 2 m invar staffs, a Mekometer Kern ME5000 with a portable computer Psion, a Rank Taylor Hobson micro-alignment telescope with several targets, two comer cube prisms in a centring full sphere with a diameter of 88.9 mm, a stationary and a portable 386 PC and a Macintosh.

The Kern GDF21K basement and CERN hydraulic universal support with a male piece were the two parts of our centring system (Fig. 3). They were adopted for all the monuments, the columns and references fixed on top of the bending magnets, of both the transfer line and the storage ring.

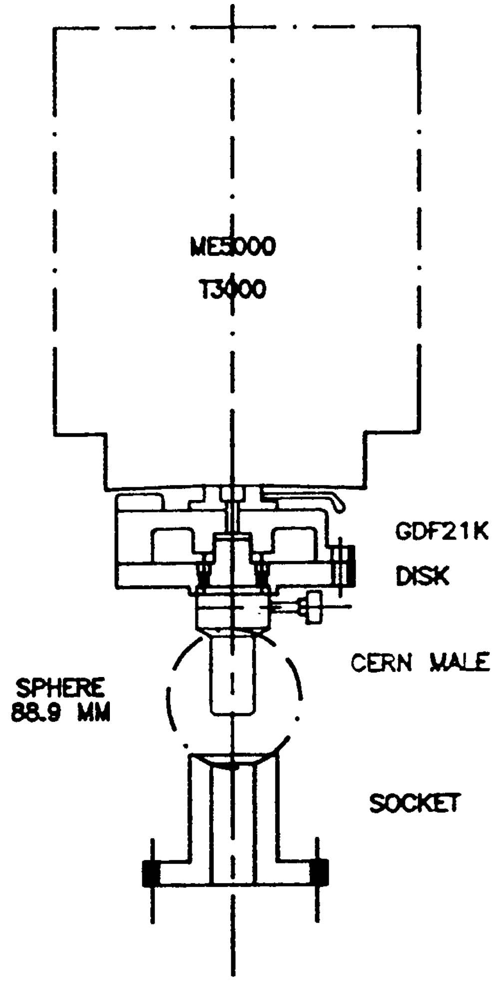

Fig. 3. Centring system

The Mekometer ME5000 with its original target and two corner cube prisms was re-calibrated on the CERN interferometer calibration bench, before the pre-alignment of the storage ring network in January 1993 was started.

The Distomat DI2002 is a convenient instrument to measure distances with the electronic theodolite Wild T3000 over a range from a few meters up to several hundred of meters. The accuracy of the instrument was about 1 mm rms, when station and target were both in the horizontal plane. It was also used to mark the positions of component supports on the floor. We noticed that the Distomat DI2002 is elevated 60 mm above the T3000 telescope axis. Particularly for short distances, when the station and the target were in different heights, the distance offset correction 6 has been taken into account of (Fig. 4).

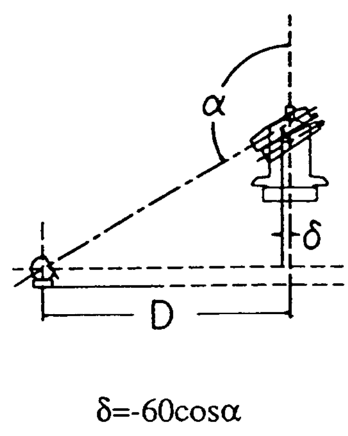

Fig. 4. DI2002 offset correction

The Distomat DI2002 was calibrated by our Mekometer ME5000. The two precision levels have been frequently checked and the distance from the station to the two targets was kept constant in order to eliminate errors coming from the bubble level and the focusing.

The measurement data of Wild T3000 and DI2002 were stored in the Wild REC module. They were loaded into 386 PC by a Wild GIF12 data reader. The measurement data of the ME5000 were stored in a Psion portable computer with Promeko software and then transferred into a 386 PC via a COMMS link. Both data were processed by several programs, most of them written in FORTRAN. The measurement data of precision level N3 were processed by Excel software. Then calculation with the Panda software was performed. By means of a computer code, the calculated horizontal coordinates were then transferred into an adjustment file in local coordinates. Its plot file was transferred into autocad.

4 FIDUCIAL REFERENCES AND ADJUSTMENT SYSTEM

Two fiducial references, sockets (Fig. 3), were accurately (20μ to a mechanical reference) fixed on each bending magnet using a 3D measurement system. The fiducial reference was placed on the tangent of the beam orbit , therefore they could be used as a finale network for aligning all the components in the straight sections.

A mechanical support and adjustment system (made of steel) has been developed for the precise positioning of the bending magnets in the Elettra storage ring (Fig. 5). The weight of the bending magnet is about 6 tons. A central screw was used which acts as a jack for adjusting the vertical position. Screws in the horizontal plane are used to perform the lateral and longitudinal movement of the bending magnet. A small block is holding the central screw and acts on two semi-spheres which force the base to slide between two plane surfaces. In this case a point contact on the surface is avoided. The open block guarantees the free movement of the central screw and a high resolution in the horizontal adjustment (20μ). To keep the system as compact as possible a limited range of 10 mm for the horizontal plane and 20 mm for the vertical direction was chosen. Therefore it was necessary to align the support plate to be aligned to 2 mm horizontally and 3 mm vertically.

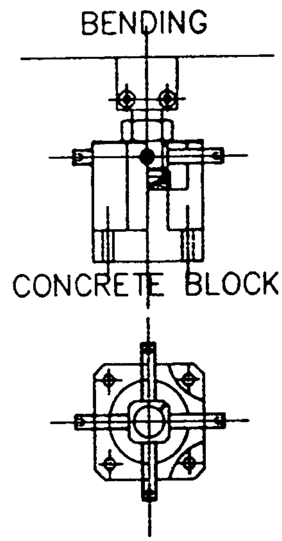

Fig. 5. Mechanical support and adjustment system

Three of these supports are holding one bending magnet (Fig. 6). Support number one in figure 6 is adjustable in the transverse and the longitudinal directions, number 2 is only adjustable in the transverse direction but free to move in the longitudinal direction and number 3 is free to move in the horizontal plane. All three supports are individually adjustable in the vertical direction.

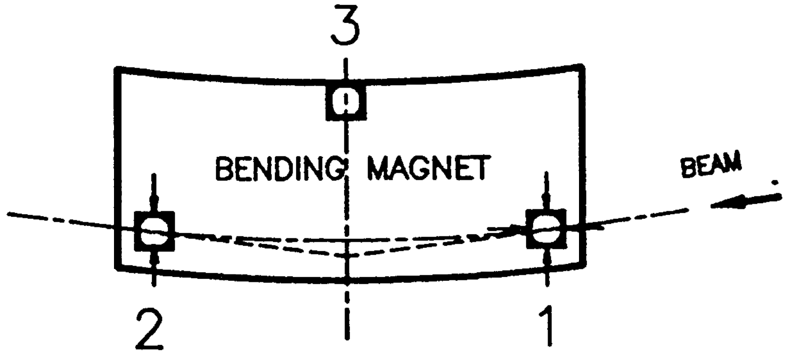

Fig. 6. Arrangement of the bending magnet supports

Two fiducial cone references and one horizontal plane reference were positioned on top of each quadrupole and sextupole during the magnetic measurement. The two cone references were aligned to the magnetic axis by a micro-alignment telescope with 30 μm accuracy. The plane reference was used for levelling by means of a bubble level to 40 μm/m accuracy.

5 ALIGNMENT PROCEDURES

In order to specify the survey network of the ELETTRA storage ring, several simulations have been performed by means of the Panda software. Different accuracies of distance and bearing measurements, the number of measurements and the number of windows in the internal wall of the storage ring were compared. The method to survey the horizontal network by distance and angle measurement has been chosen because the ELETTRA storage ring is located in a rather narrow tunnel, and particularly also because the quadrupoles are too small to place instruments on top of them. For the accuracy of the instruments we have taken the values from the literature which are 3 cc for the Wild T3000 and 0.14 mm for the Kern ME5000 as a standard deviation.

As a result of the simulations, the survey of the horizontal network of the storage ring is done in the following way: The distance and bearing measurements are performed from each network point to the adjacent two points in forward and backward direction. To meet the accuracy required for the circumference, six additional distances from the centre monument to six reference points on top of the magnets will be measured also. In this way a standard deviation of 80 μm can be reached for the final network.

The standard deviations of the budget for the ELETTRA storage ring quadrupoles are then the following:

magnetic centre to socket	$\sigma_1 = 30\ \mu m$
roll	$\sigma_2 = 25\ \mu m$
socket to SR network reference	$\sigma_3 = 40\ \mu m$
SR network reference to adjacent one	$\sigma_4 = 80\ \mu m$

$$\sigma_{total} = \sqrt{\sigma_1^2 + \sigma_2^2 + \sigma_3^2 + \sigma_4^2} \qquad \sigma_{total} = 100\ \mu m$$

Which means that our objectives for the alignment can be reached.

After ground breaking, 5 monuments were installed on the rock and were measured in position in order to form the global network (Fig. 7). Before closing the linac and transfer line tunnel, 4 datum marks were embedded in the floor and their positions were also measured. In addition there are also two holes in the roof of the tunnel which allow to measure the positions of the datum marks in reference to the global network also in the future. To the define the electron orbit, two columns were installed close to the deflection point of the transfer line.

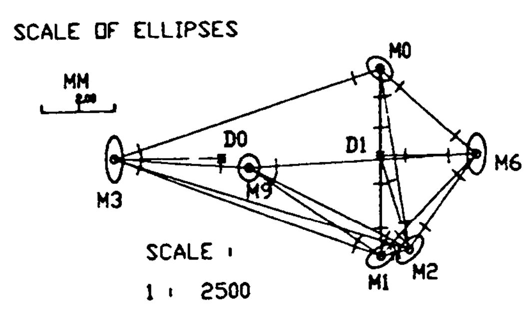

Fig. 7.Global network with error ellipses

The 23 vertical references and the 24 basements for the portable columns of the storage ring, as well as the 24 vertical references for the experimental beam lines were implemented into the floor during the floor construction. The elevations of the basements were adjusted to 1 mm accuracy.

The magnets of the storage ring are supported by 84 concrete blocks, with a steel plate of 20 mm thickens placed on top of them, which is aligned to 5 mm accuracy by using the two monuments which are in the centre of the storage ring building. The magnet supports with the adjustment systems were screwed to this steel plate. In order to position the plates within 2 mm accuracy in the horizontal plane, 48 sockets were temporarily fixed on the 24 plates.

After having installed the 24 bending magnets, the storage ring network was measured and adjusted by 3 iterations. The progress of the procedure is shown in figure 8, where the transverse deviations of all reference points is shown for the three iterations.

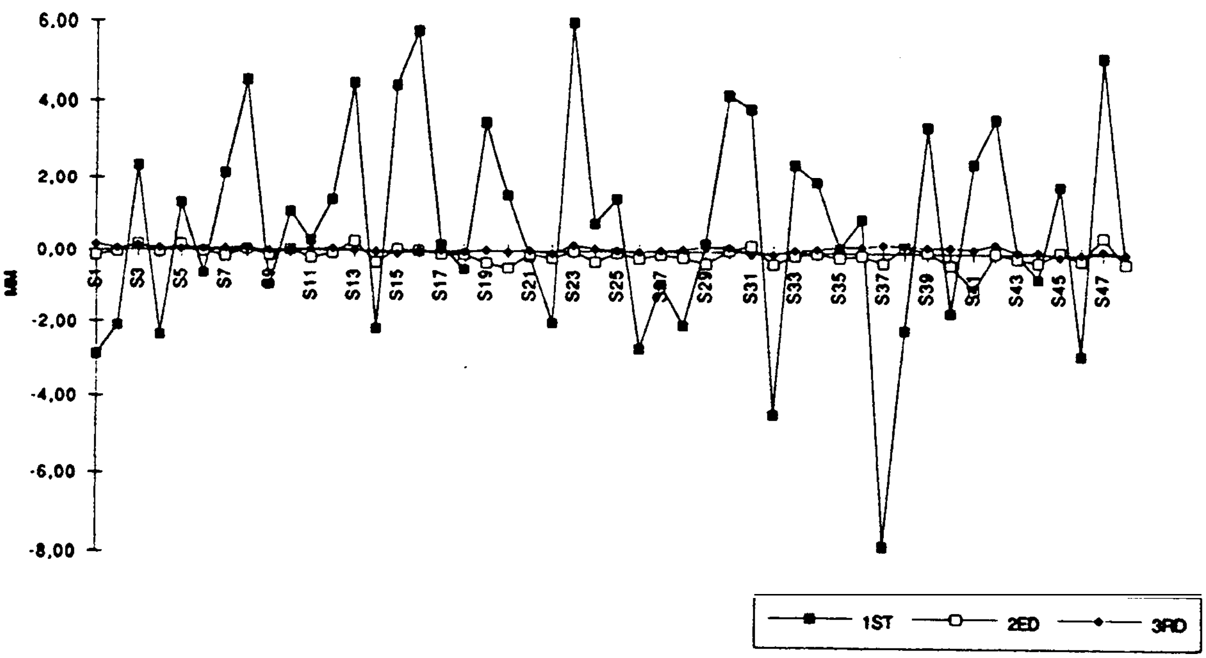

Fig. 8. Transverse magnet positioning for the three iterations of measurement and adjustment

6. CURRENT STATUS

Pre-alignment

The final network of the storage ring is made up by 74 stations. For both positions of the theodolite, 294 bearings have been measured, and in addition 162 distances were measured with Mekometer and taken into account for the calculation. The maximum major axis of the 95% confidence error ellipses was 0.16 mm as shown in figure 9.

After the re-calibration of the Mekometer at CERN, a standard deviation of 0.16 mm could be reached for the accuracy. The standard deviation of the error for the electronic theodolite T3000 was 2.5 cc.

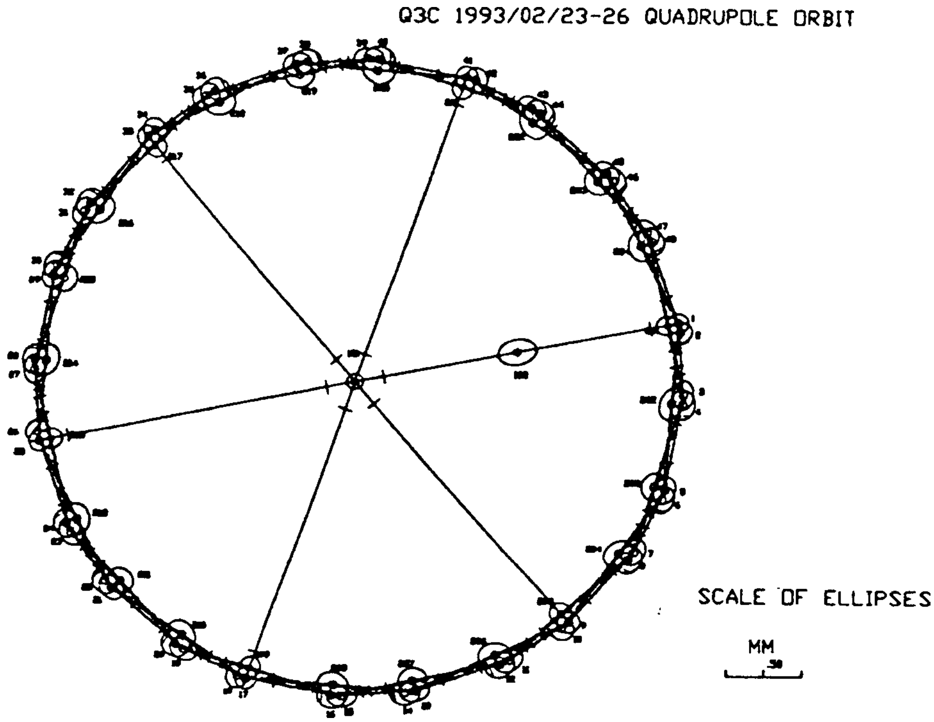

Fig. 9. The 95% confidence error ellipses of the SR network

The transverse deviations of the storage ring network after the second adjustment are shown in figure 10. All the bending magnet references were positioned within 3.2 mm in both, transverse and longitudinal directions. The height of the references was always adjusted to ±0.1 mm for each iteration.

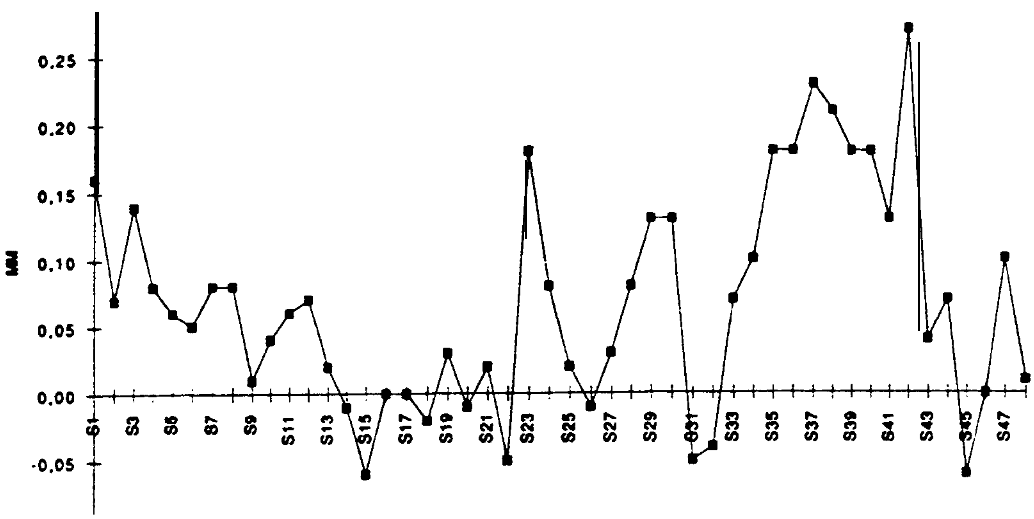

Fig. 10. Transverse deviations of the SR network after the pre-alignment

Network for Beam lines

The network for the synchrotron radiation beam lines consists of two parts. First there are 24 vertical references placed close to the outer wall of the experimental hall, at the extension of the straight section of the storage ring. They have been embedded in the floor of the experimental hall during construction and their elevations were measured with ±0.2 mm accuracy. Furthermore there are 72 horizontal position marks which are inserted into the floor with an accuracy of a few mm, also at the extensions of the straight sections. The horizontal coordinates, of both the vertical references and the horizontal marks were surveyed with 1 mm accuracy by using the storage ring network, before the shielding wall has been put into position. They will be useful for the pre-alignment of the synchrotron radiation beam lines in the future

7. FUTURE TASKS

Final alignment and smoothing of the storage ring

The pre-alignment of the quadrupoles and sextupoles in the storage ring is now going on. The assembly of the machine, including the radiation protection walls will be completed in September. After this, the final alignment and the smoothing of the storage ring will be performed.

Survey and pre-alignment of beam lines

Several front ends of the experimental beam lines and some complete beam lines will be installed already before start of commissioning of the storage ring. The survey and the pre-alignment of all the components of the beam line to a few mm accuracy will be a part of tasks in the future for the alignment team. The final alignment of the beam line components will then be performed by using the synchrotron light itself.

Investigation of the stability

The third generation synchrotron radiation light source is more sensitive to quadrupole movements[5] than high emittance machines. Care has been taken in choosing a suitable site and in constructing the proper foundation and support system. The influence of vibrations will be investigated during the operation of the machine in the next years.

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REFERENCES

[l] Alignment Tolerances for Storage Ring and Transfer Line Magnets, A.Wrullich, ST/M-TN-90/26, Sincrotrone Trieste

[2] ELETTRA Alignment (Preliminary), F.Wei, Sincrotrone Trieste, (the Second International Workshop on Accelerator Alignment , DESY, 1990)

[3] The survey Network Simulation for the ELETTRA Storage Ring, Fuqiang Wei (Sincrotrone Trieste, ST/M-TN-92/6)

[4] “Magnetic Measurement and alignment of the ELETTRA Storage Ring Quadrupole, Sextupole and Steerer Magnets”, D.Zangrando and R.P.Walker, ST/M-93/4

[5] “Technological Challenges of Third Generation Synchrotron Radiation Source”, M,Comacchia, H.Winick, SLAC-PUB-5164, Jan. 1990.