

Alignment for the Synchrotron Light Source ELETTRA

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Abstract

ELETTRA is a Third Generation Light Source currently under commissioning in Trieste, Italy. As a high brilliance machine, ELETTRA is designed for extremely small emittance, which makes the machine very sensitive to alignment errors.

The target goal to the alignment was a transverse positioning error of 0.1 mm rms and an accuracy in the circumference of 2 mm. The alignment method and the achievements are described in the report.

1. INTRODUCTION

In June 1991, we started the construction of the main building. 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. Commissioning of the ELETTRA storage ring began on October 4, 1993. The first 2000 turns were reached in record time on the second day of operation and in just over two months of operation the source surpassed the design current of 400 mA.

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 dipole section, to the inner side of the storage ring and is then injected from there in the horizontal plane in the storage ring.

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.[1] The storage ring is approximately circular in 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 dipole magnets, 108 quadrupoles and 72 sextupoles. Since the dipole magnets are combined function elements, they have to be treated with the same care for the alignment as the quadrupoles. To reduce the effects of alignment errors on the machine performance, very tight positioning tolerances were requested. The positioning errors there have to be understood as 1 standard deviation of a Gaussian distribution truncated at 2σ . [2]

2. SIMULATION

In order to specify the survey network of the ELETTRA storage ring, several simulations have been performed by

means of the Panda software. 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. [3]

As a result of the simulations,[4] 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 are also measured. 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	$\sigma_1 = 30 \mu\text{m}$
roll	$\sigma_2 = 25 \mu\text{m}$
socket to SR network reference	$\sigma_3 = 40 \mu\text{m}$
SR network reference to adjacent one	$\sigma_4 = 80 \mu\text{m}$

$$\sigma_{\text{total}} = \sqrt{\sigma_1^2 + \sigma_2^2 + \sigma_3^2 + \sigma_4^2}$$

$$\sigma_{\text{total}} = 100 \mu\text{m}$$

3. THE FIDUCIAL REFERENCES AND ITS ADAPTER FOR INSTRUMENTS

Two fiducial references, sockets, were accurately (20 μm to a mechanical reference) fixed on each dipole 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 final network for aligning all the components in the straight sections.

Two fiducial cone references and one horizontal plane reference were positioned on top of each quadrupole and sextupole during the magnetic measurement. They 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 $\mu\text{m}/\text{m}$ accuracy.[5]

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

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.

4. THE ADJUSTMENT SYSTEM

A mechanical support and adjustment system (made of steel) has been developed for the precise positioning of the dipole magnets in the Elettra storage ring. The weight of the dipole magnet is about 6 tons. The adjustment system guarantees the free movement of the central screw and a high resolution in the horizontal adjustment (20μ).

Three of these supports are holding one dipole magnet (Figure 1). Support number 1 in Figure 1 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.

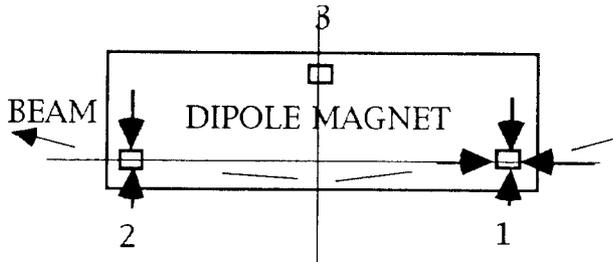


Figure 1. Arrangement of the dipole magnet supports

5. ALIGNMENT PROCEDURES

5.1 GENERAL ALIGNMENT METHOD

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

5.2 Alignment of the global network

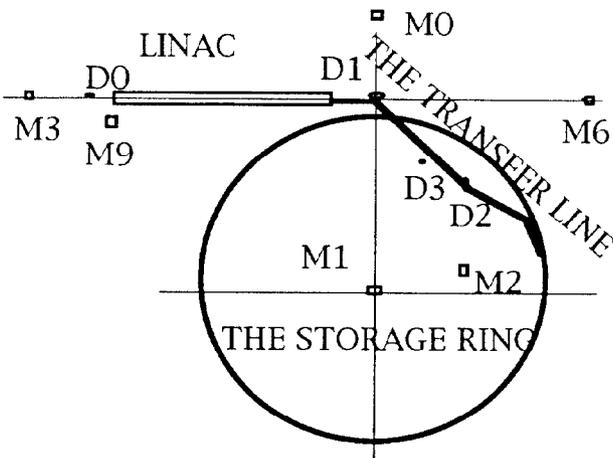


Figure 2 The global network of ELETTRA

After ground breaking, 5 monuments were installed on the rock and were measured in position. Before closing the linac and transfer line tunnel, 4 datum marks were embedded in the floor and their positions were also measured. To define the electron orbit, two columns were installed close to the deflection point D1 and D2 of the transfer line. The 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. (Figure 2).

5.3 Pre-alignment of the storage ring network

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 dipole magnets.

After having installed the 24 dipole magnets, the storage ring network was measured and adjusted by 3 iterations. The height of the references was always adjusted to ± 0.1 mm while the roll deviation was less than ± 0.04 mm/m for each iteration.

5.4 Final alignment of the storage ring network

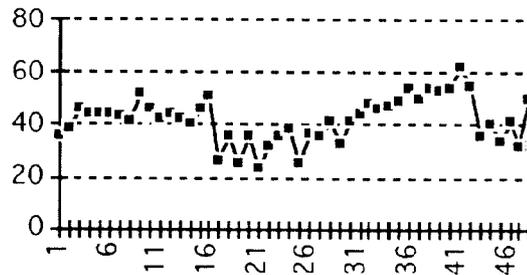


Figure 3 The transverse deviation (in unit of 10^{-2} mm) of the storage ring network (July 1993)

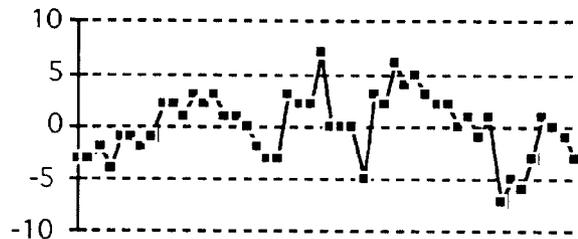


Figure 4. The vertical deviation (in unit of 10^{-2} mm) of the storage ring network (June 1993)

For the final alignment of the storage ring 48 references on the dipole magnet of the storage ring were used as datum. 206 bearings and 156 distances have been measured and have been taken into account for the free network calculations. An extremely high accuracy, a standard deviation of 1.5 cc for

the bearing measurements and 0.06 mm for the distance measurements, was reached. The maximum major axis of the 95% confidence error ellipses of the measurements was 0.07 mm. The transverse deviation of the storage ring network after the final alignment is shown in Figure 3.

It is clear in Figure 3 that the average radius of the storage ring network was 0.4 mm longer than the ideal value. It would be slightly shorter in the winter considering that it was done in the summer of 1993. The circumference will be kept in 2 mm tolerance.

5.5 Alignment of the magnets of the storage ring

The positioning of the quadrupoles and sextupoles of the storage ring was done in June of 1993. The alignment of the quadrupoles and sextupoles of the storage ring was performed immediately after the final alignment of the storage ring.

The assembly of the machine, including the radiation protection walls was completed in September. After this, the final check of the storage ring network was performed. There was no significant change. Then the 24 dipole magnets were displaced to compensate their individual variation of the magnetic field.

6. ALIGNMENT OF THE BEAM LINE

6.1 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.

6.2 Survey and pre-alignment of beam lines

Three front ends of the experimental beam lines and several beam lines are already installed. The survey and alignment of most of the components of the beamlines were performed by the alignment team using the beam line network. All the beam lines got the photon beam passed through shortly after starting their commissioning.

7. DEFORMATION

The third generation synchrotron radiation light source is more sensitive to quadrupole displacements than high emittance machines. Care has been taken in choosing a suitable site and in constructing the proper foundation and support system.

Following figures show the deformations of the storage ring network:

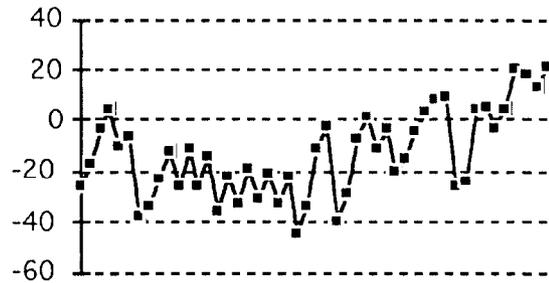


Figure 6 the transverse deformation (in unit of 10^{-2} mm) of the storage ring network from Sep. to Dec. 1993

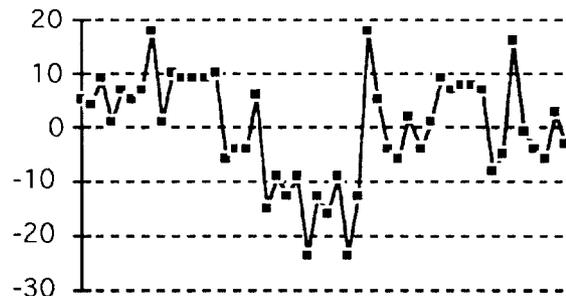


Figure 7 The vertical deformation (in unit of 10^{-2} mm) of the storage ring network from June 1993 to Jan. 1994.

The above figures show that the ELETTRA foundation is very stable. In the first 4 months after the final alignment the deformation everywhere in the storage ring was kept within 0.5 mm. The maximum local deformation is about 0.3 mm in the transverse or vertical direction. The average radius of the storage ring network was 0.2 mm shorter than the prior value as expected.

8. ACKNOWLEDGEMENT

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