NETWORK MEASUREMENTS AT THE HEAVY ION SYNCHROTRON SIS AT GSI

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1. Introduction

The Heavy Ion Synchrotron SIS (see Figure 1) forms together with the Linear Accelerator UNILAC and the Storage Ring ESR the accelerator complex of the Gesellschaft für Schwerionenforschung in Darmstadt. It accelerates heavy ions up to Uranium to 1 Gev/amu. The accelerators and beamlines have been surveyed and aligned using the TASA method [1,2,3].

For SIS a network was established in order to survey the synchrotron with the TASA method. Goal of a diploma thesis was to establish an alternative network for a Laser Tracker instrument and to reach error ellipsoids below 30 μm. In this paper a comparison of the two methods is given.

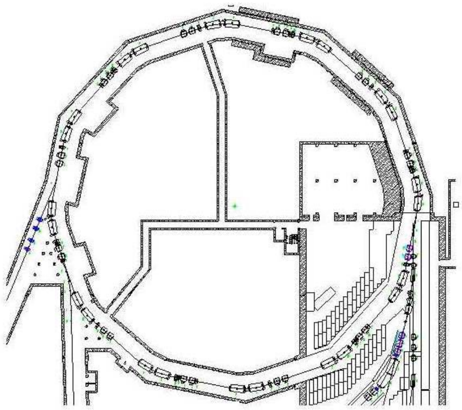

Figure 1 – The Heavy Ion Synchrotron SIS   Figure 2 – Fixed consoles welded on the magnets

2. TASA System

It is based on the following principles

- Use of a Total Station with a combitarget for angle and distance measurement (see Figure 3)
- Mobile pillars (see Figure 5)
- Taylor-Hobson Centering with an adapter from Kern to Taylor-Hobson (see Figure 4)
- Fixed consoles welded onto the magnets/diagnose boxes (see Figure 2)
- Two fiducial points and the roll angle

and uses the following instruments

- Total Station LEICA TC2002K
- LUCAS SCHAEVITZ Inclinometers (roll angle)
- Electronic Atmosphere sensors.

Figure 3 Combitarget

Figure 4– DESY Adapter

Figure 5 – Mobile Pillars

25 reference points define the reference network: 11 mobile pillars, 12 instrument consoles fixed at the magnets and 2 at the walls. The distance between the reference points is between 5 and 13 m. Figure 6 shows the network configuration. To stabilize the network we included the height differences between the reference points by leveling. The data were adjusted using the PANDA software.

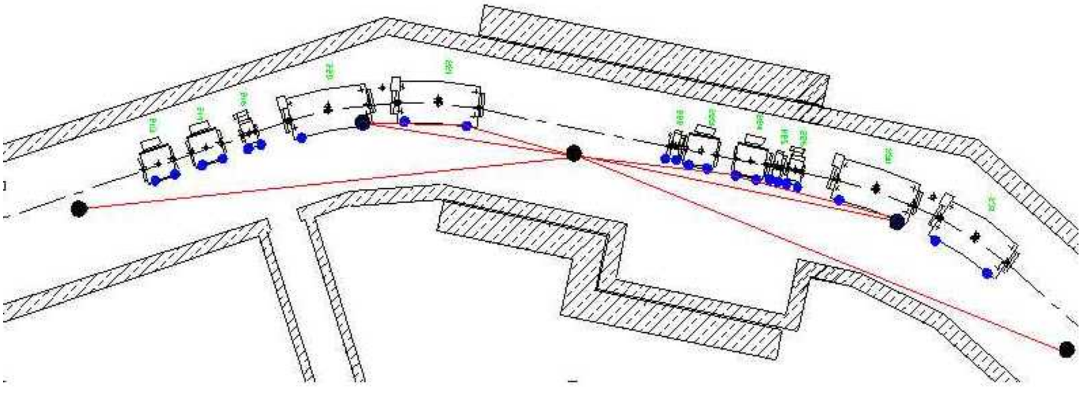

Figure 6 – Section of the TASA Network

3. Laser Tracker System

We used the Tracker SMX 4500 freely stationed around the ring. Targets are 1.5’’ SMR’ s with an adapter to the 3.5’’ Taylor-Hobson norm (Figure 7). The network was formed by the previously mentioned fixed magnet consoles and the mobile pillars. The data were taken according to the following principles

- Short measurement distances
- Every network point was targeted at least three times.
- Each measurement was done in two faces
- Additional leveling data are taken by NA3000

To stiffen the network we used additional nests on the floor and at the walls. Figure 8 shows the network configuration. The data were adjusted using the bundle adjustment program LEGO [4].

Figure 7– Tracker target with adapter and nest

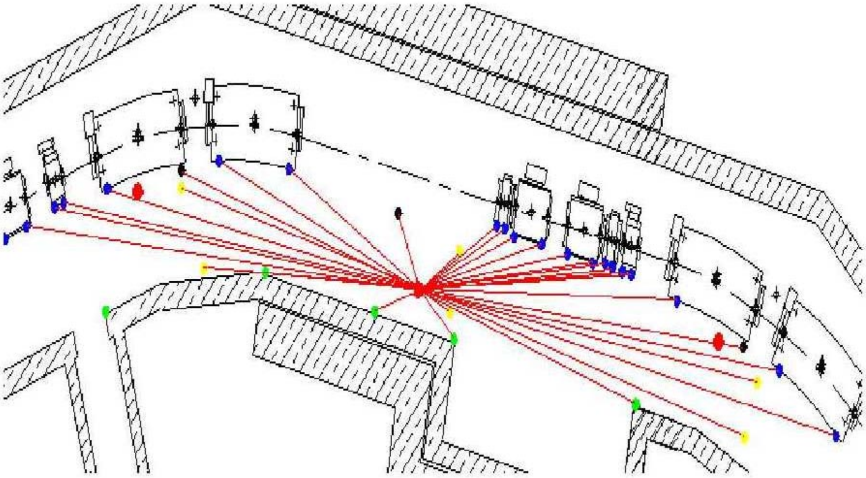

Figure 8 Section of the Tracker network

4. Results

Table 1-3 show the results. Table 1 gives the TASA network measurement results. The standard deviation for the adjusted coordinates are typically 0.1 mm for the adjusted coordinates.
Table 2 gives the Tracker results. The standard deviations of the angular observations include an offset of the target of 5 µm. Nevertheless all values are better than the values obtained with the Total Station.

Table 1 – Results of the TASA Measurement

Standpoints	Netpoints	Observations	Degree of freedom
25	161	901	397
standard deviation of observations			
Horizontal angle σ_{Hz} [mgon]	Vertical angle σ_{Vz} [mgon]	Distance σ_S [mm]	Height differences σ_d [mm/km]
0,87	0,75	0,08	0,61
standard deviation of coordinates			
X - Axis σ_X [mm]	Y - Axis σ_Y [mm]	Z – Axis σ_Z [mm]	3D – Error (Helmert) σ_{HP} [mm]
0,10	0,11	0,07	0,17

Table 2 – Results of the Laser Tracker Measurements

Standpoints	Netpoints	Observations	Degree of freedom
24	276	3110	2214
standard deviation of observations			
Horizontal angle σ_{Hz} [mgon]	Vertical angle σ_{Vz} [mgon]	Distance σ_S [mm]	Height differences σ_{Hd} [mm/km]
0,13+ArcSin(5µm/s)	0,22+ArcSin(5µm/s)	0,01	0,6
Standard deviation of coordinates			
X - Axis σ_X [mm]	Y – Axis σ_Y [mm]	Z - Axis σ_Z [mm]	3D - Error (Helmert) σ_{HP} [mm]
0,01	0,01	0,06	0,06

The standard deviations of the horizontal coordinates (adjusted with the program LEGO) are 0.01 mm, roughly a factor 10 smaller than the values reached with the Total Station. The value for the vertical coordinate z is with 0.06 mm much worse. The reason for this is the inaccurate levelling of the Laser Tracker. This is confirmed by the relatively large standard deviations of the rotational parameters R_x and R_y in Table 3. More levelled data or network points at the walls had been necessary to improve these values.
We took all available data (obtained by Laser Tracker, Total Station and NA3000) as input for a LEGO run. The results are given in Table 3. As expected the standard deviation of the vertical coordinate improves to 0.04 mm due to the better levelled TC2002 data, but the intended 30µm could not be reached.

Table 3 –Results of the adjustment of all data

TASA & LASER TRACKER – Measurements			
Standpoints	Netpoints	Observations	Degree of freedom
49	276	3986	3065
Standard deviation of observations LASER TRACKER / TC2002K			
Horizontal angle σ_{Hz} [mgon]	Vertical angle σ_{Vz} [mgon]	Distance σ_S [mm]	Height differences σ_{Hd} [mm/km]
0,125+ArcSin(5µm/s)/ 0,75	0,22+ArcSin(5µm/s) / 0,75	0,01 / 0,08	0,6
Standard deviation of coordinates			
X - Axis σ_X [mm]	Y - Axis σ_Y [mm]	Z - Axis σ_Z [mm]	3D - Error (Helmert) σ_{HP} [mm]
0,01	0,01	0,04	0,04
standard deviation of rotation parameters LASER TRACKER / TC2002K			
σ_{Rx} [“]	σ_{Ry} [“]	σ_{Rz} [“]	
0,7 / -	0,7 / -	0,2 / 0,9	

5. Conclusion

Table 4 gives a comparison of the two methods. Since the Tracker measurements are done automatically only one person is needed. That reduces the man power. Time consumption for both methods is about the same, although much more network points were used with the Laser Tracker method. As a consequence of the larger number of network points the homogeneity of the results is better.

Table 4 – Comparison of the methods

	Laser Tracker	TASA
Accuracy of the Observations	+	-
Accuracy of the Coordinates	+	-
Homogeneity of the Results	+	-
Time Consumption	+	-
Man Power	+	-
Number of Network Points	-	+
Software	-	+
Data Evaluation	-	+
Instrument Reliability	-	+
Instrument cost	-	+

6. References

[1] H. Wirth, G. Moritz, A new Standard method for the Surveying and Alignment of Beamline Facilities at GSI, IWAA 95, Tsukuba, Japan

[2] H. Wirth, G. Moritz, The most flexible Instrumentation for Surveying and Alignment: A high Precision Total Station controlled by modern Software, IWAA 95, Tsukuba, Japan

[3] I. Pschorn, H. Paluszek, G. Moritz, Implementation and first Results of the Survey and Alignment of the Accelerators Facilities at GSI, IWAA 97, Argonne, USA

[4] C. LeCocq, LEGO: A Modular Approach to Accelerator Alignment Data Analysis, IWAA 97, Argonne, USA

7. Acknowledgement

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