ALIGNMENT STRATEGY OF SESAME

T. Abu-Hanieh, SESAME, P. O. Box 7, Allan 19252, Jordan

A. Lestrade, C. Bourgoin, M. Sebdaoui, Soleil, 91192 Gif sur Yvette, France

Abstract

The synchrotron Light Source for Experimental Science and Applications in the Middle East (SESAME) is now in its final stage. This paper presents the methodology and initial results for mechanical alignment of the booster synchrotron for SESAME. SESAME booster is the old BESY 1 Booster and requires special considerations for alignment. This paper also presents the alignment strategy for the storage ring of SESAME.

INTRODUCTION

SESAME (Synchrotron-light for Experimental Science and Applications in the Middle East) is the first international 3rd generation synchrotron light source in the Middle East region, under construction in Jordan [1]. It will promote peace and understanding through scientific cooperation and bring new scientific fields to the region. As of October 2014, members of SESAME are Bahrain, Cyprus, Egypt, Iran, Israel, Jordan, Pakistan, Palestine Authority, and Turkey. The injector of the facility consists of a 22.5 MeV Microtron and 800 MeV Booster, from BESSY I [2]. The 2.5 GeV main Storage Ring (SR) is completely new. The beam emittance is 26 nm.rad and 12 straight sections are available for Insertion Devices. Seven beamlines are envisaged in Phase I, with three available at the start-up of the new ring. Complete beamlines from decommissioned synchrotrons at Daresbury (UK) and LURE (France) have been donated, as has additional equipment from laboratories in Switzerland and the USA. Some of the Phase I beamlines will make use of this donated equipment and some will be newly built by teams from the region. In the longer-term, up to 18 further beamlines can be added. Fig. 1 shows SESAME building at Allan, Jordan, almost 35km northwest of Amman, it was officially inaugurated on 3rd November 2008.

Figure 1: The SESAME building

ALIGNMENT TEAM

The Survey and Alignment work at SESAME is one of the Mechanical Engineering Group tasks, the group consists of three Mechanical Engineers; one is dedicated for the Survey and Alignment. SESAME has strong collaboration with Soleil Alignment Group; they participate efficiently in developing alignment strategy, designing the alignment network, optimising the network, and being involved onsite missions.

ALIGNMENT NETWORK

The design of the Alignment Network is a very sensitive point to be treated. Such networks are made of a set of fiducials, typically, concrete pillars or steel wallbrackets spread all around the accelerators and beamlines. This design deals with the centring system of the instrumentation, the number and location of fiducials and finally, the cost of such a network.

General Considerations & Layout

The best solution for SESAME is the wall brackets; lower cost and easier to use than pillars. Wall brackets are Steel Wall Brackets used as references with accurate positions; they are used to hold the TDA5005 and its ATR (automatic target recognition) Reflector; they act as absolute and accurate mechanical references, Fig. 2 shows a wall bracket with the centering system of the instruments (designed by Soleil).

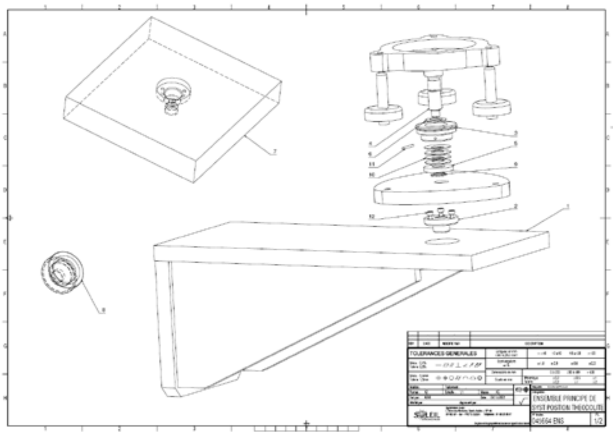

Figure 2: a wallbracket with the centering system

The primary geodetic network is made of 16 wall brackets to be installed on the concrete columns (Fig. 3). These wall brackets will allow tracings and adjustments of any part of the project since they act as absolute and accurate mechanical references.

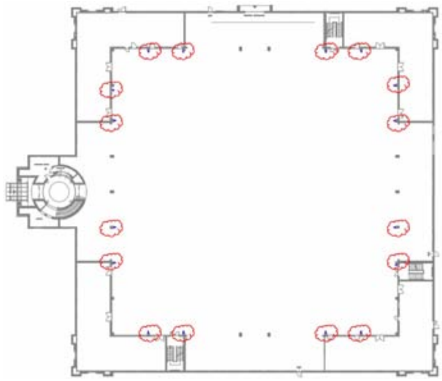

Figure 3: Primary Geodetic Network Wallbrackets

The measurements have been carried out with Leica TDA5005. All available distances and angles between wall brackets to each other were measured (Fig. 4). The distances were corrected through the calibration formula defined by ESRF. The meteorological correction has been applied to the distance measurements (1018hPa, 27°C). The centering system has been used for both, instrument and retro-reflector.

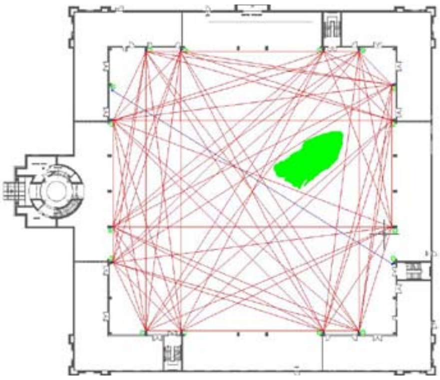

Figure 4: Primary Wall brackets Survey

The calculations of the final wall bracket coordinates were obtained by least square bundle adjustment performed by SOLEIL's software called reseau.m and developed with MatLab®. The general results are as follows: Angle measurements $1\sigma = 0.00045$deg, Distance measurements $1\sigma = 0.15$mm. Two wall brackets from the 16 primary wall brackets have been fixed on the exact diameter of the SR for the line of sight to link the primary and SR networks together through small windows in the shielding walls (Fig. 5).

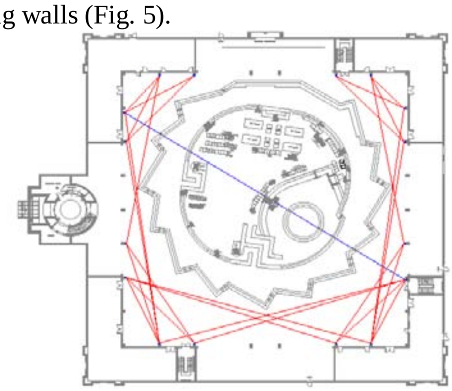

Figure 5: Line of Sight

Theoretical co-ordinates of the project axes

The theoretical definition of the project axes is given by the machine physicists through synoptics; which are tables containing angles and lengths between components. These synoptics allow the coordinates computation of each component in order to locate them accurately (few 0.01mm required) by means of survey instrumentation as the Leica TDA5005. The coordinates computed from the synoptics must fit exactly with the layout drawing of the project. It has been decided with the SESAME team to use all the synoptics information to define the beam orbits.

Fiducialisation on the floor (Brass Nails)

Brass nails will be used to mark the axes of the accelerator on the floor to organize the tracing of the girders later on (Fig. 6). In addition, these nails could be useful for having reference points inside the closed areas (BOO & SR after having realized the shielding) for general purpose.

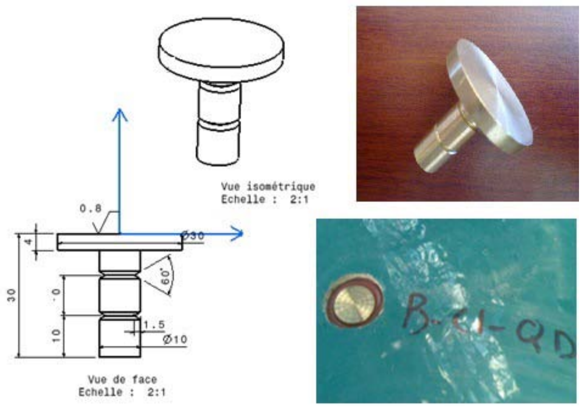

Figure 6: Brass Nails

163 points were traced as follows: two points defining TL1, 18 points for the Booster, 10 points defining TL2, 33 points defining SR, 100 points defining Beamlines; see Fig. 7 for clear view.

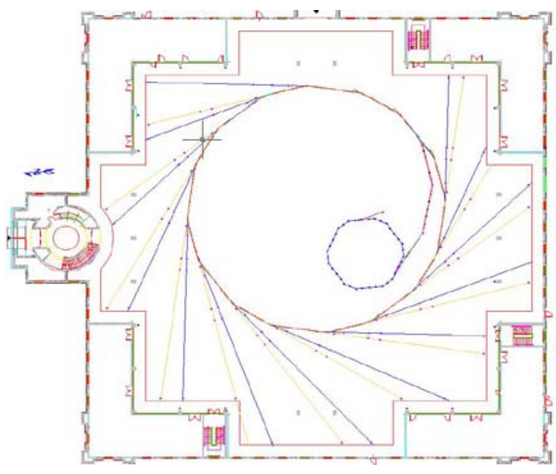

Figure 7: Brass Nails on Beam Path on the floor

Primary Leveling

Steel nails are installed on the floor as leveling Benchmarks, 3 in the Booster area and 8 in the Storage Ring tunnel (Fig. 8).

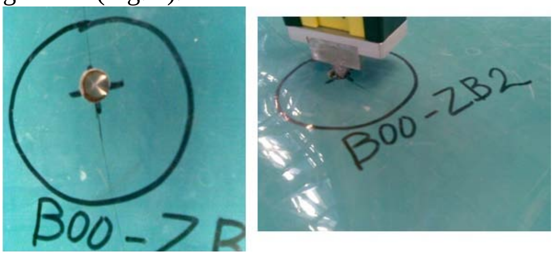

Figure 8: Steel nails as Leveling Benchmarks

BOOSTER ALIGNMENT

Booster Network

Four wall brackets have been installed in the BOO tunnel; where after the wall brackets installation a survey of the set WB-brass nails were done to do the calculation of the WB coordinates with respect to brass nails (Fig. 9).

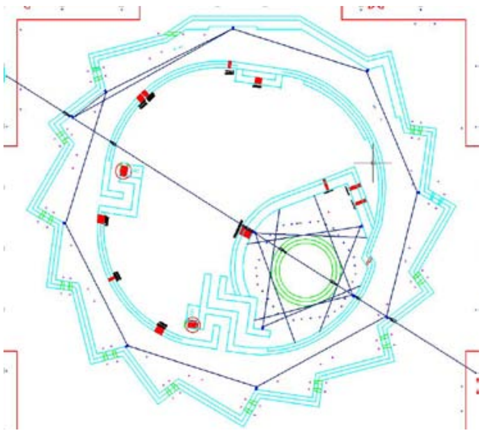

Figure 9: Booster wall brackets & floor nails network

Alignment Tolerances of the Booster

The following figures shown in Table 1 have to be applied for Booster magnets & girders in terms of positioning with respect to the nominal orbit. Fig. 10 shows the definition of reference axes where Longitudinal axe (along the propagation of the electrons) is named S axe, Transversal axe is named X axe and Vertical axe is named Z axe, this orthonormal system is then S, X, Z.

Table 1: Booster Tolerances

	Girder	**Dipole**	**Quadrupole**
S (mm)	±2	±0.5	±0.5
X (mm)	±2	±0.2	±0.2
Z (mm)	±2	±0.2	±0.2
θ_S (mrad)		±0.2	±0.2
θ_X (mrad)		±0.2	±0.2
θ_Z (mrad)		±1	±1

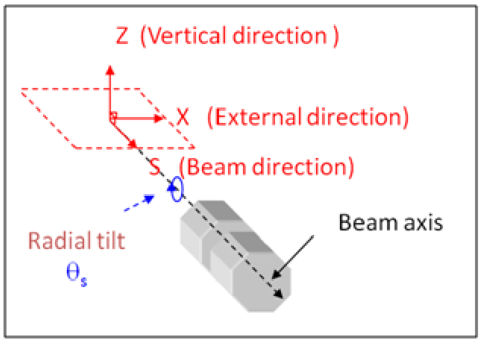

Figure 10: Definition of Reference Axes

Girder Installation

The screw holes of the six girders are not accurately machined; the distance between the holes can vary of about 5mm from a foot to another, which is challenging for the positioning of the drilling holes with respect to the girder; so each girder will be used as its own template for drilling the holes into the slab. The adjustment range of the magnets with respect to the girder is ±20mm in Planimetry; then the nail-template accuracy for the girder adjustment can be at level of few mm. The booster girders are fixed with chemical anchors directly on the slab (Fig. 11); these anchors are made of capsules of polyester resin inserted in the slab holes where a threaded rod with a sharp end is inserted in the hole by means of a drill at slow speed, the sharp end breaks the capsule and the resin components are mixed, the rod is then ready.

Figure 11: Chemical Anchor & Threaded Rod

Dipoles

Two fiducials (survey monuments) are on the top surface of the dipoles; no information from BESSY1 about their exact location with respect to the magnetic centre. The monuments location with respect to the magnetic definition of the dipole has been measured by mechanical measurements where finding the magnetic axes of the dipole is not necessary. Only the planimetry is concerned since the altimetry of these survey monuments is very easy to be determined.

Quadruples

A gauge have been designed and used for the alignment of the Qpoles (Fig. 12). The gauge is equipped with three contact points and a pair of small fiducials (ø24mm) and used in two reversed positions to define the Qpole axes. The gauge also is in contact with the laminas by means of three shoulders, one on a side and two on the other side. The elastic system is to ensure the good contact of the gauge with the opposite side of the yoke.

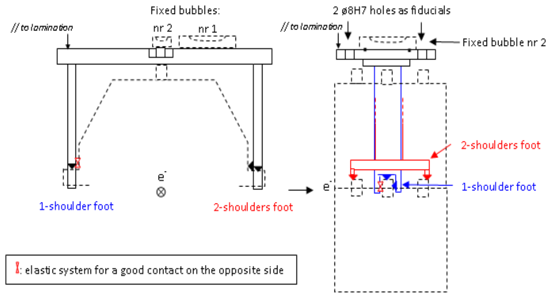

Figure 12: Quadrupole Gauge

Magnets Pre-alignment

After installing the girders, dipoles and quadrupoles are installed on the girders (Fig. 13). A pre-alignment in collaboration with Soleil's alignment group has been performed on all the Qpoles and dipoles in order to make an accurate survey, this operation allows to set the magnets close to their theoretical position (within ±1mm in S, X, Z and less than ± 0.5mrad). As it is needed to control the 6 DOF, the less movement we have to do on the magnets for the fine tuning, the better it is to keep the correct position. The pre-alignment has been done with the main measuring tools: NA2 level, TDA5005 and spirit levels for the Tilt. The Survey results after the pre-alignment are presented below (from Fig. 14 to Fig. 17).

Figure 13: Booster Girder with Magnets inside tunnel

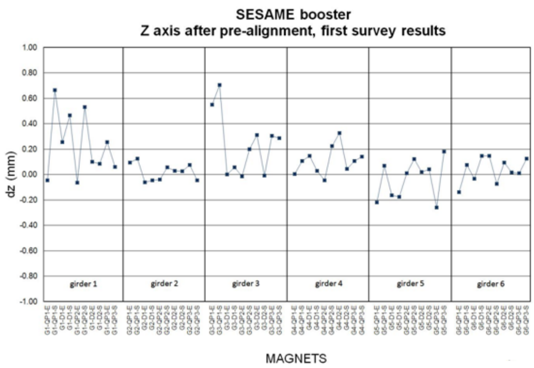

Figure 14: Z axis Pre-alignment Result

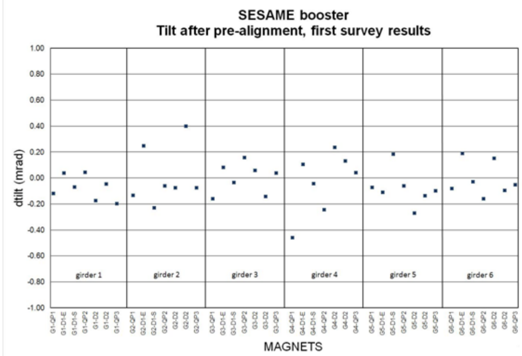

Figure 15: Tilt Pre-alignment Result

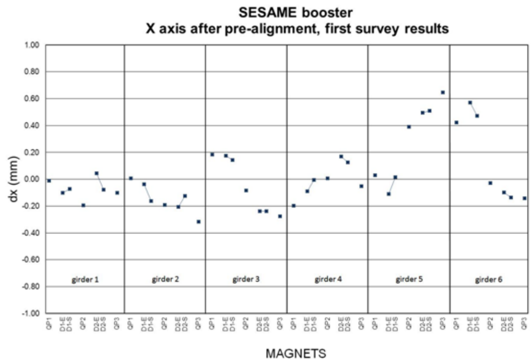

Figure 16: X axis Pre-alignment Result

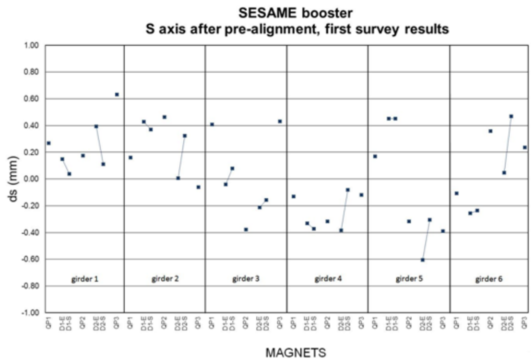

Figure 17: S axis Pre-alignment Result

The result of the survey shows that a fine tuning is requested for several magnets. The pre-alignment tilt has been done with spirit level, where it's very hard to reach the ± 0.2mrad requested because of the lack of numerical values. A fine tuning has been done using digital inclinometer and comparators.

Magnets Final Alignment

A second Survey has been done to check the position of all the magnets after the corrections that have been done, there were still some magnets out of range. This process has been repeated until all the magnets are in a correct position. The results of the final alignment for the dipoles and Qpoles are presented from Fig. 18 to Fig. 21.

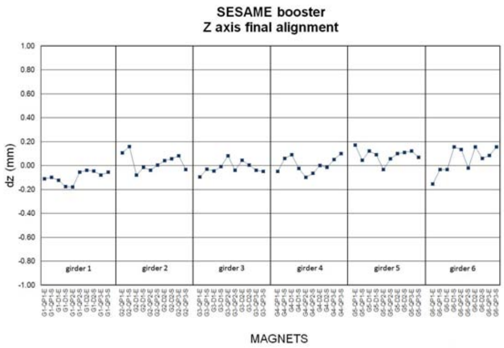

Figure 18: Z axis Final Alignment Result

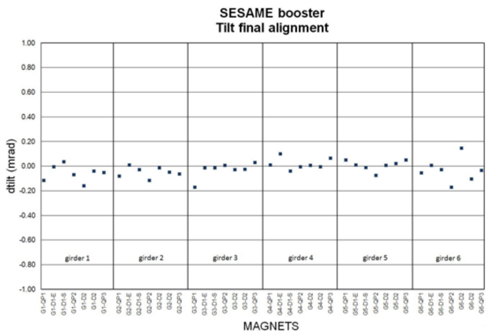

Figure 19: Tilt Final Alignment Result

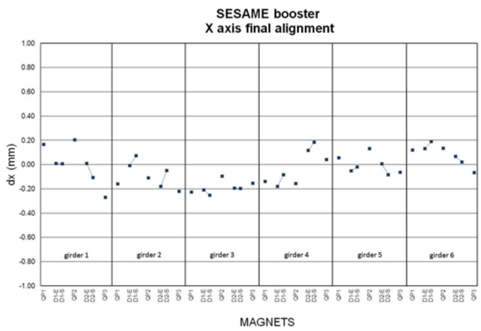

Figure 20: X axis Final Alignment Result

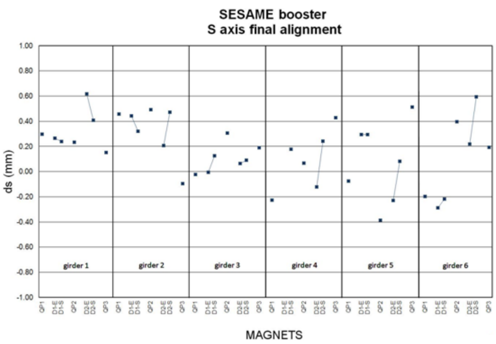

Figure 21: S axis Final Alignment Result

Note about S position for dipole magnets, that both fiducials have been measured but as shown on the charts (pre-alignment and final alignment) a small difference can exists between the entrance and the exit of the dipole, this is due to the uncertainty relative to their position respect to the dipole and from each other.

Measurement uncertainty: ±0.05mm, 1 sigma for X and Z axis, ±0.15mm, 1 sigma for S axis and ±0.05mrad 1 sigma for Tilt.

Using a digital inclinometer allows a good tilt management and a faster measuring method respect to spirit levels. The difference between tilt pre-alignment done with spirit level and final tilt done with digital inclinometer only comes from the measuring tool.

Transfer Line 1 (TL1)

TL1 is composed from two sets of two magnets embedded in metal flanges (Fig. 22). The TDA5005 has been placed exactly on the theoretical position of the beam and using Plexiglas targets, the magnets and girders have been set in place. As the vacuum chamber is cantered on the poles of the magnets and as it wasn't possible to measure the poles directly, the vacuum chamber has been used as the reference for centring these magnets.

Figure 22: Transfer Line 1

Microtron

The Microtron as shown in Fig. 23 has been set up to its theoretical position, using the free station technique by placing the TDA exactly on the theoretical axis of TL1.

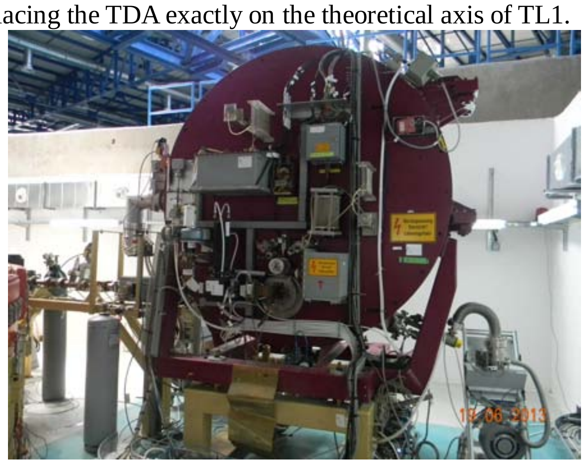

Figure 23: Microtron

ALIGNMENT SOFTWARE

Currently, SESAME uses three softwares from SOLEIL for the measurements and calculations: EXCEL sheet “Offset et Reglage”, Pilot-TDA.exe, and Reseau with MatLab. The problem existing with using these softwares is about the local referential definition; where the sense of SESAME beam direction is CCW opposite to SOLEIL beam direction which is CW, This problem occurs in the use of the Excel sheet “Offset et Reglage” and the use of the Access Database. Also, these softwares are in French language which is another problem in some cases.

Recently, SESAME has purchased Spatial Analyzer software and will start using it.

STATUS OF SESAME MACHINE

After the completion of the shielding walls (Fig. 24); SESAME’s Microtron became operational in 2012, installation of its Booster was completed in 2013, and on 3rd September, 2014 the SESAME team succeeded in accelerating the electrons in the Booster to their final energy of 800 MeV. Successfully having brought SESAME’s Booster to full operation is of particular significance since this is the first high-energy accelerator in the Middle East, and this achievement with the Booster is to be attributed to a team of young scientists and technicians from the region for whom accelerator technology is a new field. This success will open the path for the final goal, which is to make SESAME the first operational Synchrotron Light Source in the Middle East and to confirm its position as a truly international research centre.

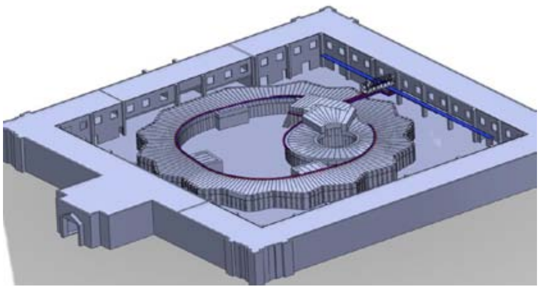

Figure 24: Shielding Walls

NEXT STEPS

Quadrupoles monuments

Designing, installing, and measuring new permanent fiducials (monuments) for booster quadrupoles to be used for the survey in the future instead of the long and hard process of using the quadrupole gauge.

Spatial Analyzer Software

Training on SA software is required. Once it is done; we are going to do a full survey (X, Y, Z, and tilt) of booster magnets to compare the MatLab results calculated by Alain Lestrade and SA results.

Laser Tracker

SESAME is in the process of purchasing a new Laser Tracker; this will enhance the capabilities of the alignment work at SESAME. Training on the Laser Tracker is required and will be planned to.

TL2 Installation and Alignment

Installing all the girders, magnets, and components of transfer line 2 (TL2) on their right positions, and making the fine alignment required to deliver the beam from the booster ring to the storage ring.

Storage Ring Alignment Network

Installing the wall brackets inside the storage ring tunnel (Fig. 25), surveying the set WB-brass nails in order to do the calculation of the WB co-ordinates with respect to the brass nails, then the absolute coordinates of new installed wall brackets are well known. Then, tracing the locations of storage ring girders and installing them, followed by the installation of storage ring magnets.

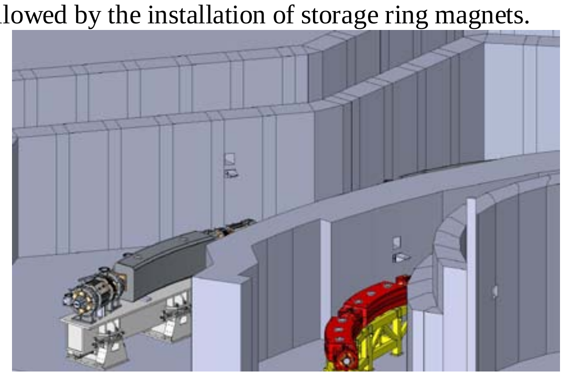

Figure 25: Booster and SR Wall Brackets

CONCLUSION

SESAME is now at a key transitional stage moving from construction activities through into machine installation and commissioning. The booster network is installed and qualified, and the storage ring network in the process. Future work activities include the installation and pre-alignment of storage ring components and the installation of phase 1 beamlines. The development of survey and metrology techniques during this next phase of the project provides exciting challenges for SESAME Survey Team.

ACKNOWLEDGMENT

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REFERENCES

[1] SESAME website: “www.sesame.org.jo”

[2] SESAME Green Book, October 1999.