THE ALIGNMENT OF THE SPARC FACILITY

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Abstract

The SPARC project [1] is a collaboration between ENEA, INFN, CNR and Rome "Tor Vergata" University on an R&D activity oriented to the development of a high-brightness photoinjector to drive SASE FEL experiments. Tolerances for the alignment of the accelerator components were very tight and it has been quite a challenge to obtain them using standard techniques and instruments such as optical levels, theodolites and laser trackers. A description of the alignment and fiducialization procedures of the accelerator components is presented.

INTRODUCTION

The SPARC machine has been realized in a 36m long and 14m wide rectangular hall, which was built about 20 years ago and is supposed to be stable.

The SPARC accelerator is mainly composed of an RF gun and 3 accelerating sections followed by a 6-module 12m long undulator. The layout also includes a dogleg line used for other experiments.

All the activity on the undulators and on the undulator line, installation and alignment included, is under the responsibility of ENEA and will not be described in this paper.

The alignment [2] of the whole accelerator is based on the use of a network of nodes as a reference frame. The first step of the alignment procedure was to accurately design, install and qualify a reference network. The second was the fiducialization of all components in order to determine their magnetic (or mechanical) geometry with respect to targetable markers. At last the alignment of all components was performed, with a first rough and quick positioning and a subsequent precision alignment using surveying instruments.

REFERENCE NETWORK

A network of reference nodes (Figure1) has been built inside the SPARC hall and it represents the reference frame for all alignment and surveying operations.

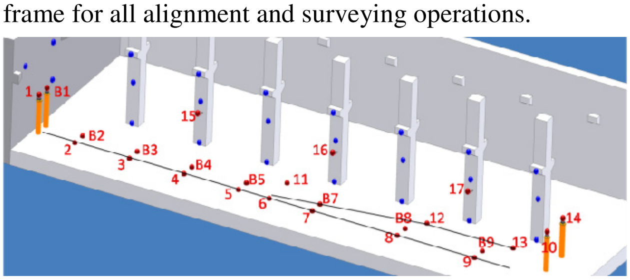

Figure 1: Layout of the reference network

The network was initially studied and designed for alignment and surveying activity performed by means of optical instruments (level, theodolite and total station). For this reason the network is made of a primary group of nodes which lie on two straight and parallel lines. This primary group of nodes is made of 4 pillar sockets and 17 ground sockets.

In standard LNF pillar sockets (Figure 2) it is possible to place either targets (3.5 inch Taylor Hobson spheres or 1.5 inch Corner Cube Reflectors) or optical instruments (theodolites, levels or total stations) by means of tribrachs which allow centering and repeatable positioning.

The ground sockets can house only targets. These are installed in the floor using supporting devices equipped with adjustment screws which can be removed after having blocked the sockets in position by means of a resin.

Three more sockets have been mounted on brackets (Figure 2) on a side of the accelerator hall. The latter provide comfortable fixed and qualified sites for optical instrument positioning and for triangulation checks of the network.

Figure 2: Pillar, Bracket and Ground Sockets

A first complete campaign of measurements has been performed by means of theodolites, total station and optical levels. The data have then been analyzed using STAR*NET software. A best-fitting solution of the network has been calculated and the error ellipses of measurements for each point have been evaluated exploiting the redundancy of measurements.

Subsequently some other "secondary" nodes, well distributed on the walls of the SPARC hall (blue dots in Fig. 1), have been added to the network and other accurate measuring campaigns have been carried out using a laser tracker. The addition of the secondary nodes, capable of housing only CCR targets (Figure 3) used for LT measurements, provided a cheap but efficient solution to have a denser network.

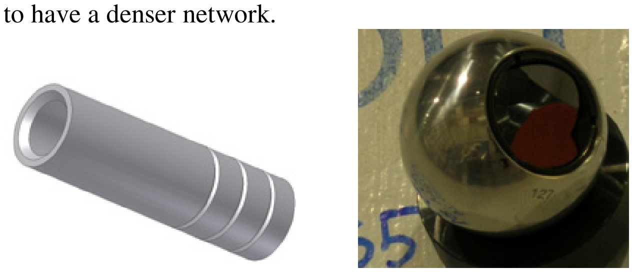

Figure 3: Secondary Socket and CCR placed in a Secondary Socket with a CCR holder

Three complete campaigns of laser tracker measurements of the network have been performed from July to November 2005.

Data have been analyzed and comparisons show that the differences never exceed 0.15mm and are mainly lower than 0.10mm.

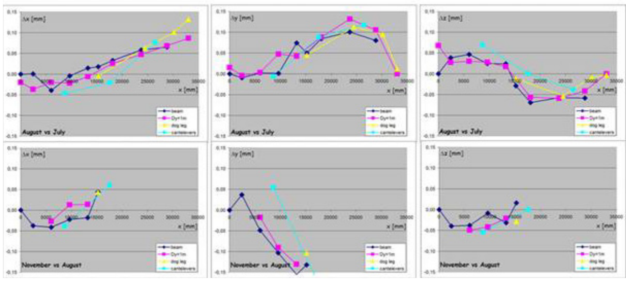

Figure 4: Comparisons of the different campaigns of LT measurements of the network nodes

Level measurements of the primary nodes have been repeated also by means of optical levels, independently by three different operators.

MACHINE LAYOUT

The SPARC machine is made of a 1.6 cells s-band RF gun driven by a Ti:Sa laser. The beam is then injected into three SLAC-type accelerating sections, the first two of which are embedded in 2 arrays of 13 solenoids each. Along the beam line, after the linac, there is an RF deflector necessary for the characterization of the longitudinal and transverse phase space of the beam and a seeding chamber, necessary to match the electron beam with a seeding laser, allowing the facility to generate seeded FEL emissions as well. The electron beam is at last driven through a 6-module 12m long undulator. The accelerator layout also includes a dogleg line used for beam compression studies and other experiments. The latter contains 2 dipole magnets, which produce the 2 14° bendings of the beam line, 8 quadrupoles and several other devices for diagnostics.

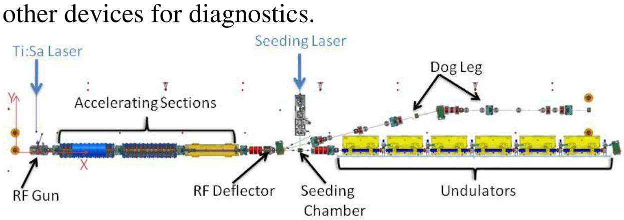

Figure 5: Machine Layout

FIDUCIALIZATION OF COMPONENTS

Great attention has been given to the fiducialization of components because indeed it is as important as their correct positioning, since an error in either task will affect the particles' trajectory and these errors cannot be distinguished.

Some of the SPARC components were pre-existing magnets or RF devices. Fiducialization data for these just had to be checked, and updated if necessary. For newly built components the reference markers have been specifically designed and realized trying to optimise their visibility and stability. In some cases we have realized and fiducialized some auxiliary alignment tools.

The referencing of fiducial markers with respect to the geometrical axis of components and the check of data for pre-existing components has been in most part performed by means of laser tracker measurements exploiting the tracking capabilities of this instrument and the versatility of Leica Axyz software [3] which offers tools for many types of geometrical analyses. For a part of the newly built components this operation has been accomplished by means of tactile probe 3D coordinate measuring machines in outsourcing.

Gun and Gun Solenoid

The gun and gun solenoid have been aligned on the basis of design data. Consistency of design data with LT measured reference marker coordinates has been verified.

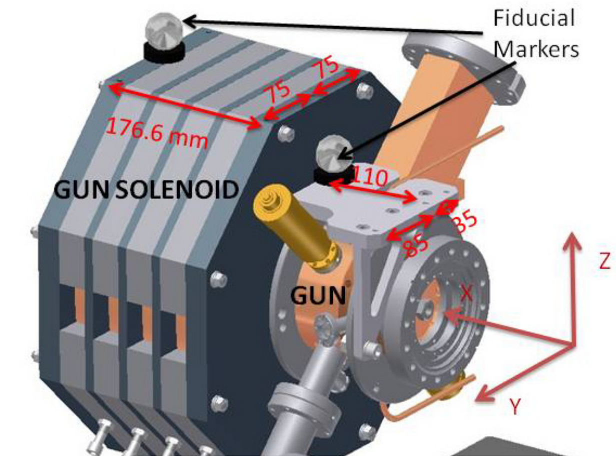

Figure 6: Gun and Gun Solenoid

Accelerating Sections

Two of the three accelerating sections of the SPARC linac have been delivered to LNF by Mitsubishi, while the third one comes from SLAC as part of a collaboration agreement. The two Mitsubishi sections have been fiducialized by LT measurements. A continuous mode acquisition of points on the cylindrical surface has allowed to determine the accelerating section axis. Some specific alignment tools (the plates shown in fig. 7) were designed and used, because reference markers on the section body would have been hardly visible after the installation.

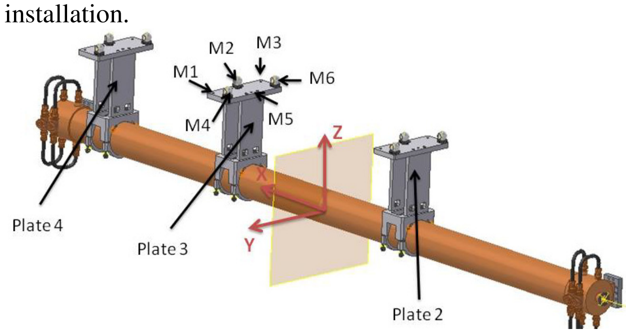

Figure 7: Accelerating Section with Alignment Plates

The SLAC accelerating section is clearly visible, and it has been aligned just by surveying the position of its external cylindrical surface.

Focusing Solenoids

The accelerating section focusing solenoids have all been measured by means of a laser tracker to determine their geometrical axes. Each one of them has then been measured by a Hall Probe machine (with a 3D precision movement device) to determine the magnetic axes with respect to the geometrical ones [4].

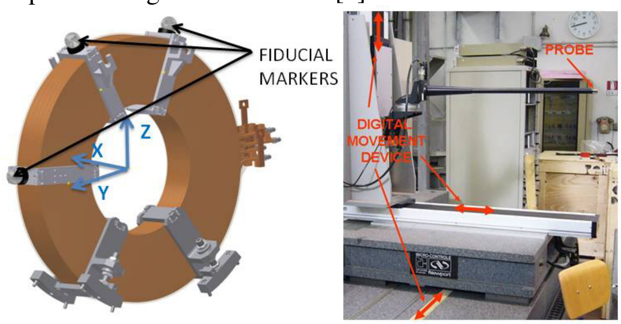

Figure 8: Focusing Solenoid (left) and Hall Probe Magnetic Meausuring Machine (right)

Dipole Magnets and Quadrupole Magnets

The SPARC dipoles were pre-existing magnets. The fiducialization data were retrieved from their datasheets and a check of the reference marker positions was performed by means of LT measurements.

The SPARC quadrupoles too were pre-existing components, but some new alignment tools have been added to them. A new fiducialization of all the quadrupole magnets has therefore been necessary. The latter has been carried out using the LT.

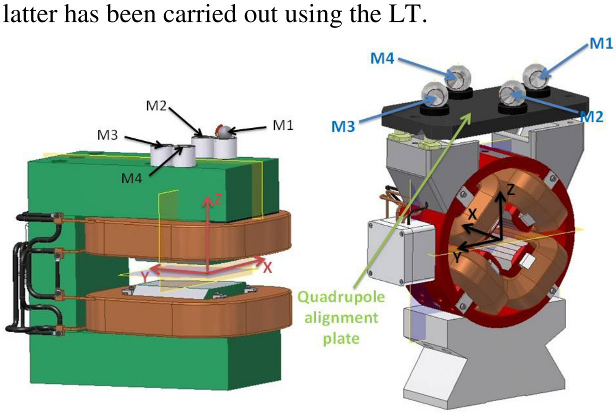

Figure 9: Dipole Magnets and Quadrupole Magnets

Seeding Chamber, RF Deflector and BPMs

The fiducialization of the seeding chamber, of the RF deflector and of the strip-line Beam Position Monitors has been realized by means of a tactile probe 3D measuring machine by an external firm. Complete datasheets for all these components have been provided.

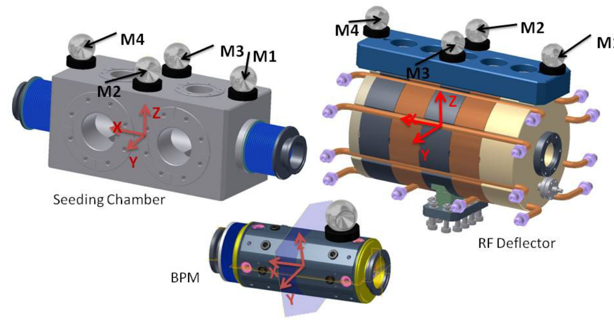

Figure 10: Seeding Chamber, RF Deflector and BPM

Steering Magnets

In the SPARC accelerator layout there is a total of 18 steering magnets. 12 of these are installed on the 3 accelerating sections (4 for each section). The section steering magnets (Figure 11 right) have only one couple of coils and can therefore correct the beam trajectory in only one direction. They are mounted rotated of a 90° angle one with respect to the other in order to correct alternatively the beam on the horizontal plane and on the vertical plane.

The remaining 6 steering magnets (Figure 11 left) are 2-layered magnets (i.e. they have two concentric couples of coils, tilted of 90° one with respect to the other) which allow correction of beam trajectory on both horizontal and vertical plane. 5 of these are positioned around the center of beam position monitors. The 6th one is on the 14° line of the dogleg

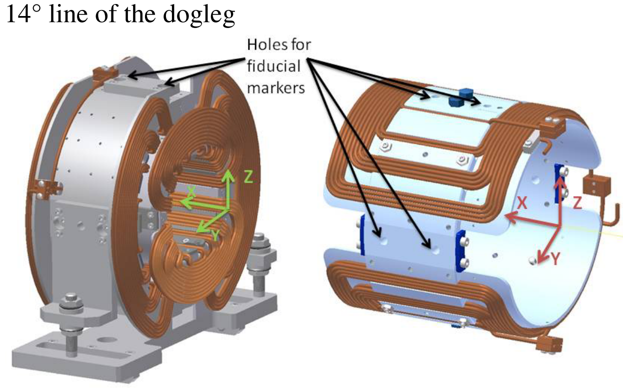

Figure 11: Steering Magnets for BPMs (left) and Sections (right)

REFERENCES

[1] Technical Design Report for the SPARC Advanced Photo-injector, www.lnf.infn.it

[2] F. Sgamma: "The SPARC Project Alignment Procedures", ME-04/001, 22/09/2004

[3] www.leica-geosystems.com

[4] B. Bolli et al. ”Mechanical and Magnetic Qualification of the Focusing Solenoids for SPARC”, SPARC-ME-07/001, 2 March 2007