SURVEY AND ALIGNMENT FOR THE NEW SWISSFEL ACCELERATOR

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Abstract

The new SwissFEL accelerator is a free electron laser which will be built at Paul Scherrer Institute (PSI) Villigen in Switzerland. The design of the 700m accelerator consists of the gun, injector, C-Band-LINAC and two undulator lines. Start of building civil construction is 2013, machine installation will start in January 2015. First beam is expected for the end of 2016. A dedicated 250MeV-Injector-Testfacility is operational since 2010.

LOCATIONS

The accelerator building for SwissFEL with the accelerator tunnel and experimental hall will be built up in a forest close to the east side of PSI. The decision of location was based on the demand of ground water for cooling. An existing bunker is already in use for gun and RF tests. For intermediate storage of accelerator modules and pre-assembly purposes, a big assembly hall in an industrial zone nearby was rented. Our 250MeV-Injector-Testfacility is operating since 2010 and is used as a test lab for the functionality, stability, interaction of the SwissFEL injector components (Gun, RF-Modules, bunch-compressor chicane, diagnostics) and for the study of prototypes (undulators, diagnostic elements).

SWISSFEL FACILITY

The SwissFEL-Facility has a total length of 720m including the experimental hall. Most parts of the building structures will be covered by top soil and plants after completion, so the disturbance of the natural landscape will be minimized and temperature stability inside the accelerator building will be improved.

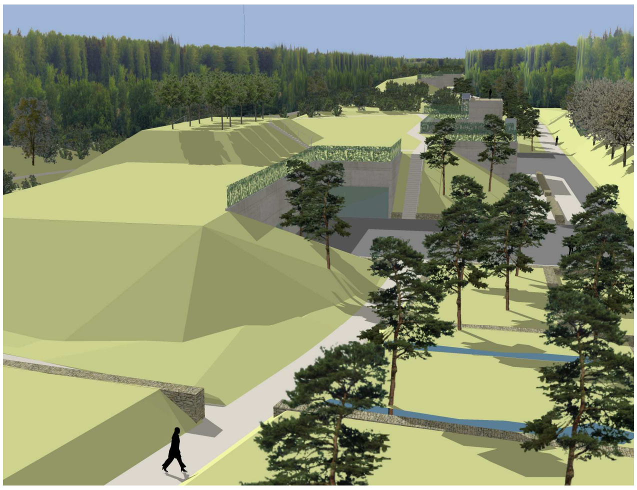

Figure 1: Impression of SwissFEL facility entrance[1]

Key Parameters

The following table gives a short overview of some key parameters for the machine design, features and operating modes.

Table 1: Key parameters and features[1]

Overall length (incl. experimental hall)	720 m
Total electrical power consumption	5.2 MW
Maximum electron beam energy	5.8 GeV
Height of beamline above tunnel floor	1.2 m
Electron gun	3 GHz RF gun with 2.5 cells
Cathode type	Cu photocathode driven by a frequency-tripled TiSa laser
Injector booster	Normal-conducting travelling wave structures (copper) with ν=3 GHz
RF source main linac	Klystron with solid-state modulator and RF pulse compression
Accelerating structures, main linac	Normal conducting travelling wave structures (copper) with ν=5.7 GHz and G=26 -28 MV/m
Linac repetition rate	100 Hz
Bunch compression	Two 4-magnet chicane bunch compressors at 0.35 GeV and 2.0 GeV, With X-band harmonic cavity at 1st bunch compressor
Number of FEL lines	2 (Aramis and Athos)
Undulator type, Aramis	In-vacuum permanent magnet with λ_U=15 mm
Wavelength range, Aramis FEL	1Å-7Å (SASE)
Undulator type, Athos	Apple II permanent magnet with λ_U=40 mm
Wavelength range, Athos FEL	7Å-70Å; seeded and SASE

CROSS SECTION (LINAC)

The technical gallery containing the klystron and modulator is on a level above the machine tunnel. Reference marks for the alignment network are mounted to the tunnel walls and into the concrete floor.

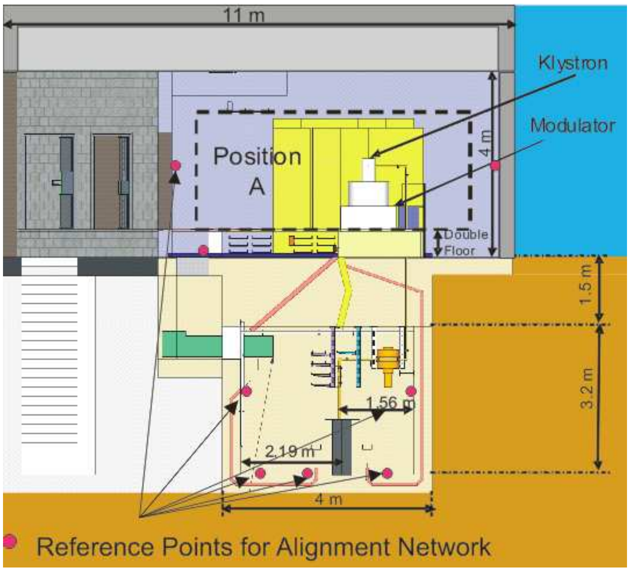

Figure 2: Cross section of SwissFEL building[1]

Project Schedule

- In a pre-phase the 250MeV-Injector-Testfacility has been built and is operational since 2010.
- After completion of the SwissFEL-Building in January 2014 the injector part of the testfacility will be moved to final location.
- Phase I of SwissFEL project includes the installation of the accelerator and initially one undulator line for hard X-rays called ARAMIS and about three associated optics beamlines. First beam on experiments will be expected for the end of 2016.
- In phase II until 2018 another undulator line ATHOS for soft X-rays and more optic beamlines will be installed, also seeding is foreseen for this soft X-ray beamline.

ALIGNMENT OF COMPONENTS

The alignment strategy for the accelerator modules is based on a girder and pre-assembly concept. Basically most of the individual components (except the vacuum connections and waveguides) should be installed and adjusted on the granite girders by a subcontractor which is in this case the manufacturer of RF-structures. Magnets and BPMs of other manufactures or PSI groups will be delivered to the subcontractor. The rigid granite girder structure ensures the save transportation of the delicate RF-structures to the PSI site. An alignment check for verification and optimization of the modules after delivery is implemented in the procedure for the girder alignment in the machine tunnel and will be carried out by the PSI alignment group.

INJECTOR MODULES

Most all injector components were already assembled and tested in our 250MeV-Injector-Testfacility. The test facility is subject of our separate poster presentation.

LINAC MODULES

RF-structures for the C-band LINAC are 2m long and will be mounted on 4.5m long granite girders. The girders have precise machined reference surfaces for vertical and horizontal alignment of the individual elements. Each LINAC-module consists of two girders with four RF-structures so one module is about 9m long. The associated klystron and modulator are located in the technical gallery one level above the accelerator tunnel.

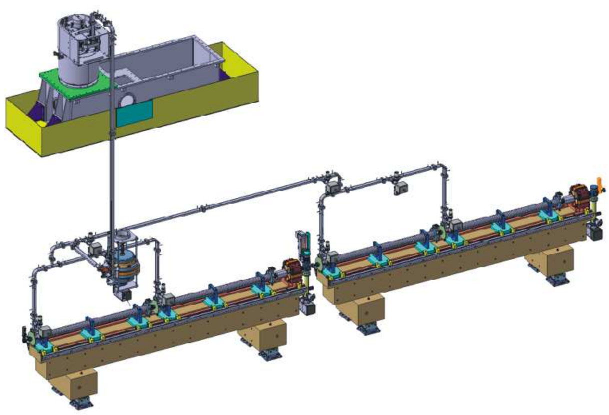

Figure 3: LINAC-Module[1]

The alignment of the girder modules will be done with the four girder feet.

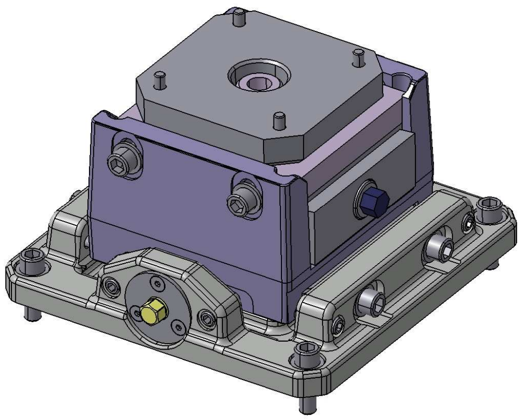

Figure 4: Girder foot with driving wedge[1]

We will use shimming blocks and metal foils to optimize the position of the individual components on the girder.

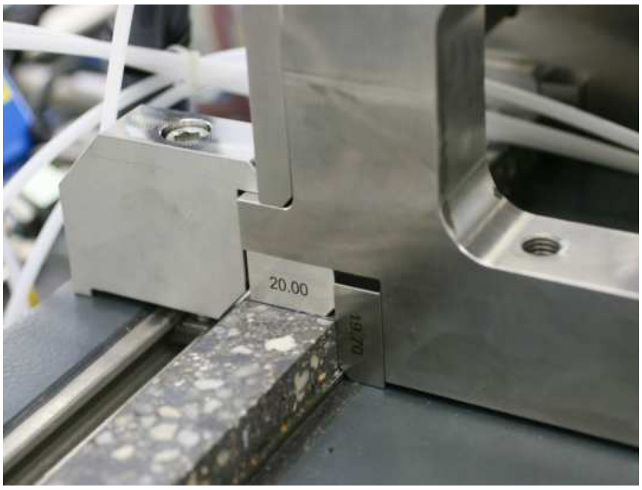

Figure 5: Reference surfaces and shimming blocks[1]

UNDULATORS

The undulator line ARAMIS consists of 12 in-vacuum undulators U15 with variable gap of 12mm to 20mm (nominal gap is 14mm) the undulator frames are made of mineral cast material. A mover system is foreseen to provide positioning accuracy in micron range for 20to undulator. The measurements for referencing of fiducials will be done directly after magnet measurement and tuning, which will be performed in an on-site lab in the undulator hall. An air cushion vehicle will be used for transportation to the defined undulator position. Two alignment quads (retractable permanent magnets) at the up- and down- stream end of the undulator frame are designated for the beam based alignment and position monitoring of the undulators.

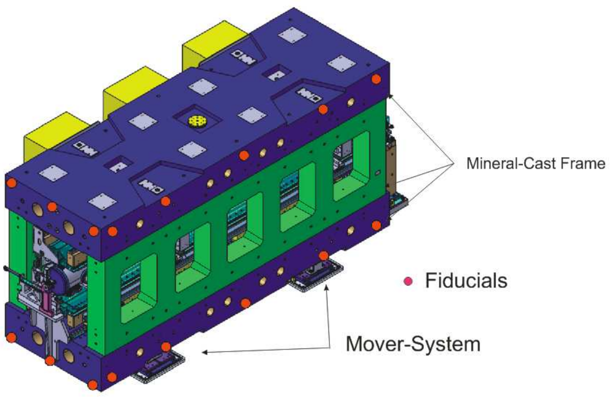

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Figure 6: U15 undulator, mover-System, fiducials[1]

Switchyard, Transferlines, Optic-Beamlines

At this moment the design of the components and support system for the switchyard, transfer lines and beam line optics are under development.

ALIGNMENT NETWORK

The coordinate reference is defined by the Machine Coordinate System (MCS) which is the reference for the planning, construction works and alignment. MCS is a local cartesian right handed coordinate system with it's fundamental point in the virtual center of the facility. The origin is set to the gun center.

TRANSFORMATIONS

All necessary transformations between MCS and the official coordinate system (LV03, LN02, BESSEL ellipsoid) are handled exclusively by PSI alignment group using the official computation service REFRAME provided by SWISSTOPO (Bundesamt fuer Landestopographie).

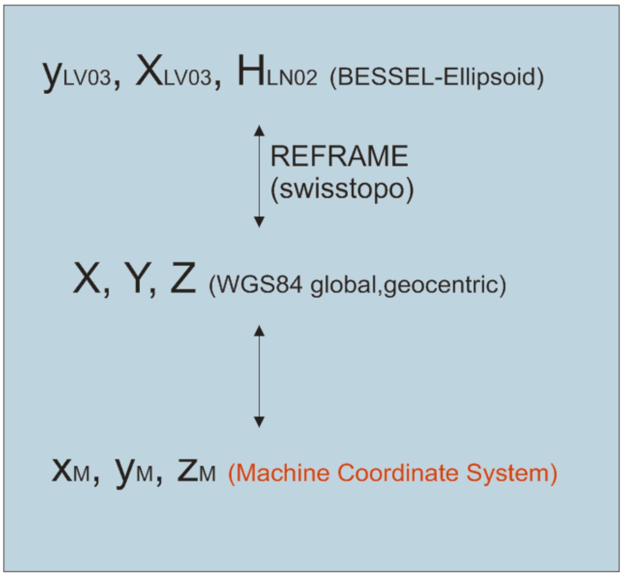

Figure 7: Coordinate Transformations

REFERENCE POINTS

The alignment network is represented by 200 floor- and 300 wall-reference points (cones for 1.5" CCR). We try to provide a full profile (4 to 5 reference points) every 7.5m in the tunnel, which is optimized to our typical range of lasertracker measurements (~10m), the network density and the accuracy in the technical gallery is less.

INSTRUMENTATION

We will use different instrument types for the network measurements. The observations of our lasertracker measurements (LEICA AT901-LR, LTD800+NIVEL20 and AT401) and a totalstation (LEICA TDA5005) will be combined with height observations of N3 leveling. We are aiming for an overlap of 80% (station to station) for the lasertracker measurements.

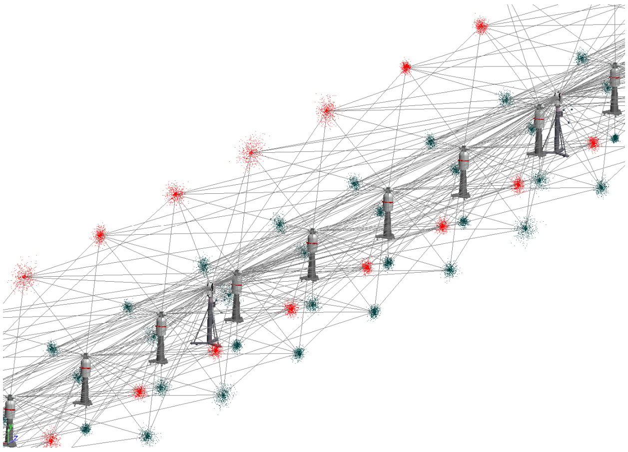

Figure 8: SwissFEL-Alignment-Network Simulation with Spatial Analyzer

Additionally we try to make use of our totalstation and a Taylor Hobson Alignment telescope to improve straightness of the network. The calculation and graduation of measurement data will be done with WinGeonet (SLAC) und Spatial Analyzer (New River Kinematics). The main part for the alignment work will be based on our laser tracker instruments and Spatial Analyzer software. Network simulations with WinGeonet and Spatial Analyzer have given confidence to our survey and alignment concept. The methods and instrumentation are capable of providing a high accuracy alignment network in the order of RMS < 0.05mm locally and enough global straightness for the requested accuracy of 0.1mm for the accelerator components. These results have already been confirmed by the results in our 250MeV-Injector-Testfacility.

Table 2: Accuracy requirements LINAC[1]

Alignment	
pre alignment	σ transvers ± 1 mm σ longitudinal ± 1 mm
final alignment	σ transvers ± 100µm σ longitudinal ± 100µm
beam-based alignment (BBA)	σ transvers ± 10µm

The tighter accuracy claims for the undulator lines will require additional beam based alignment methods (e.g. alignment quads).

Table 3: Accuracy requirements for undulators[1]

Device / Category	Item	Specification / Resolution
Survey alignment	Long range	< ±1 mm
	Short range	50 µm rms
Undulator	Girder mover	<10 µm
Alignment Q (BBA)		<10 µm
Quadrupole	Mover range	±1 mm
	Mover resolution	1 µm
BPM	Average	~0.3 µm rms

CONCLUSION

The presented SwissFEL facility is a challenging task for the coming years. The alignment concept, the methods and tools have been prepared. Simulations of our methods and the results of our 250MeV-Injector-Testfacility are promising for the successful completion of this demanding task.

REFERENCES

[1] C. SwissFEL Conceptual Design Report V20 (2012)