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SwissFEL-Laser Heater Requirement Specification (Lastenheft)

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Zusammmenfassung/*Summary*

This document describes basic specification requirements for the SwissFEL laser heater.

Scope of the document:

- Baseline for the survey of the project
- Summary of the laser heater specification
- Description of concepts and designs as analyzed so far
- Definition and verification of the interfacing between involved groups
- Verification of the civil engineering, environmental and mechanical constraints
- The document will be maintained and updated according to the discussion/design progress

Remarks:

- The components and their positions described in this document are not yet reflected by the latest release of the “Heilige Liste”. Therefore, this document is based on the “proto Heilige Liste”. The specifications within this document are valid till the end of the evaluation phase.
- Fields marked in yellow must be clarified

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5	24.04.2013	M. Pedrozzi	Added figure for the optics, added figure and note concerning the undulator tenability versus laser wave length.
4	14.04.2013	M. Pedrozzi	Figure 2 corrected, Added comment x diagnostics
3	13.04.2013	M. Pedrozzi	Added laser systems, Building + environmental conditions
2	10.04.2013	M. Pedrozzi	Update specification – preparation of kick off meeting
1	14.11.2012	M. Pedrozzi	Started

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1 Introduction

The SwissFEL laser heater (LH) system allows a controlled heating of the elctron beam in order to minimize microbunching instabilities that could develop during the bunch compression stages.

The active manipulation of the beam occurs in a short undulator modulator sitting in the middle of a small magnetic chicane. Here an ifrared laser impulse resonantly interact with the electron beam modulating the energy of the elctrons along the buch. The sligth dispersion experienced by the electrons leaving the chicane smeares out longitudinally the electrons generating a net increase of the uncorrelated energy spread.

The laser heater section starts at at ~13 m from the photo-injector cathode after the first acceleration stage (SINSB01-SINSB02). The nominal energy of the beam is 130 meV. In the first 13 m of the injector the lattice design preserves the cylindrical symmetry for optimal emittance compensation, while in the laser heater section a set of quadrupoles ensure the matching. Five quadrupoles preceed the laser heater chicane and again a set of five quadrupoles are usde to match the beam in the accelerating booster section of the injector (SINSB03 amd SINSB04).

To guarantee a stable and efficiend operation of the LH, we have to ensure an optimal interfacing between all the LH componets and supprts. In particular critical the components used to manipulate and measure the electron beam and the laser impulse. To achieve and maintain an optimum overlap between laser and electrons in the unulator both photon and electron diagnostics of this section must operate synchronously.

LCLS integrates a LH system which experimentally confirmed an improvement of the FEL performances. For more detail see in particular [1,2]. A similar system is operated at FERMI [3,4] and foreseen for the European XFEL [5,6].

Important elements developed in this document:

1) The LH section consists in three functional sections, each supported by an independent girder. The central girder is hosting the magnetic chicane and the undulator modulator. A priori, the girder could include the optical table for the laser optics and photon diagnostics, but a solution with separate optical tables and girder support is preferred.
2) The nominal vacuum chamber diameter along the LH section is 16 mm. The chamber of the magnetic chicane has a special design including the laser in and out-coupling ports.
3) With LH ON, the beam orbit in the chicane center is 20 mm off axis with respect to the accelerator axis. Since the central part of the vacuum chamber has a diameter of 16 mm to match the SwissFEL electron diagnostic components, the chamber must be motorized to allow operation with straight orbit (chicane OFF)
4) The undulator must be transversally retractable via a remote controlled motorized system. In the retracted position, the distance between undulator magnets and accelerator axis is enough to have a negligible effect of the magnetic structure to the electron beam orbit.
5) Two transverse profile monitors capable of detecting electrons and photons are foreseen upstream and downstream the undulator. This instrumentation is essential to adjust the transverse overlap of the beam and requires close collaboration between the electron diagnostic, photon diagnostics and laser group. Two electron BPM and a laser pointing survey system are necessary to maintain the transverse overlap during the user operation.
6) For the longitudinal overlap, we have as well a close correlation between electron and beam diagnostics. The longitudinal overlap could require different system for setting adjustment and operation survey.
7) As far as possible components of SITF and/or SwissFEL standards will be used for the transmission and matching line of the Laser heater.

1.1 Goal

Design, realize, and integrate a safely functioning and reliable Laser Heater System into the SwissFEL facility that fulfills the user requirements by respecting the given SwissFEL Master Milestone timetable and cost-framework.

1.2 Boundary conditions

Following issues must be understood as a fact:

- For the work package, physical boundaries refer to Figure 1 and
- Tests / inspections to be performed (see paragraph 5)
- For SwissFEL LH we foresee two mode of operation: LH ON & LH OFF (undulator retracted and chicane off)
- The vacuum chamber design and related beam line components matches the SwissFEL standard with 16 mm inner diameter as specified in the DCR-32 [7]..
- The quadrupoles used in the LH section are of the QFD type

1.3 Open or unclear issues

Following issues later discussed in this document are open or must be investigated:

- The laser transfer line (TL) from the laser room to the optical table of the laser heater is responsible of PSI and will be coordinated by the SwissFEl laser group. The realization of the laser optics, laser coupling, laser diagnostics vacuum chamber, and girder system of the LH central section could be realized within a Sweede-Switzerland collaboration by the Upsala University. The final proposal for the founding request has been submitted to the Swedish governemnt by mid of March 2013.
- The preferred laser wavelength is 1040 nm. The decision depends on the final specification of the photocathode laser system from which we will derive the laser heater impulse.

1.4 Technical project boundaries

1.4.1 Realization concept of the SwissFEL- LH

Two collaboration agreements are under discussion within the framework of the laser heater Project.

- STFC in Daresbury (UK) already designed and started the engineering of the undulator modulator. This task has been discussed during a bilateral meeting at PSI May 8, 2012 [8], and a first design was presented at the SwissFEL advisory committee in May 2012. The documents are available in alfresco. The second version of the mechanical design was sent by STFC January 30, 2013 and is as well available in alfresco. The details concerning the realization of the undulator modulator are under discussion. Most likely STFC will take over the procurement and assembly.
- Within the framework of potential, in kind contribution of Swedish universities to SwissFEL, Upsala University (UU) submitted a proposal for founding to the Swedish government. The proposal focalizes on the design and procurement of the infrared laser transfer line, including all the laser optics and photon-beam overlap instrumentation (transverse and longitudinal). The design and procurement of the vacuum chamber and girder were also part of this package as well as the assembly, commissioning and early operation of the system during the SwissFEL user-friendly period. The Swedish authorities should state on the proposal until end 2013 (unfortunatel we do not have any guaranty). Since it is essential to progress with the overall injector design, we suggest PSI

taking over as "subcontractor" the design and realization of the following packages, regardless of the final decision of the Swedish authorities:

1. Girder system.
2. Optical table
3. vacuum chamber system and laser coupling ports

In case of positive decision PSI will charge UU for the procurement costs. This aspect will be discussed bilaterally between UU and the project management.

The strategy concerning the design and task distribution of laser optics, photon diagnostic and overlap monitors requires a discussion between UU and the PSI groups involved at the Kickoff meeting April 26, 2013..

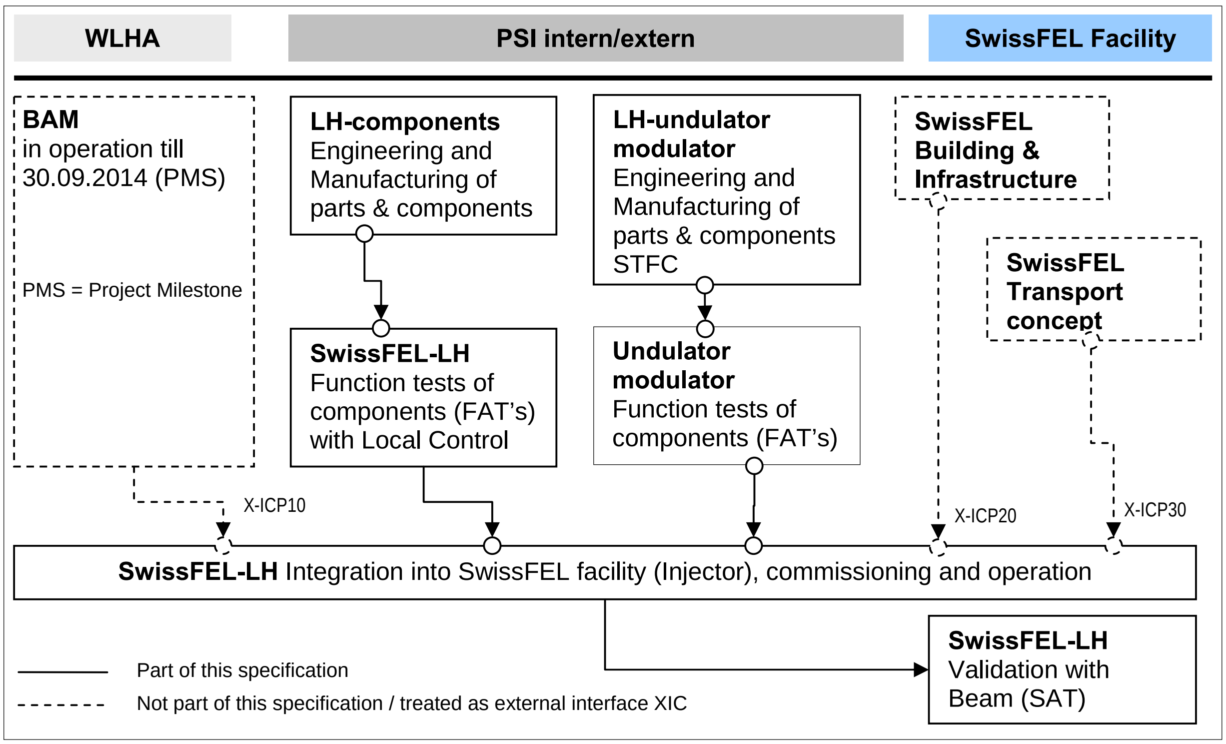

Figure 1 - Main tasks for the SwissFEL LH system.

1.4.2 External Interfaces

The external interfaces control points are shown in …

ID	Ext. System / Responsible	Int. System / Responsible	Remarks
X-ICP10		BAM / V. Arsov	Electronics in operation at SITF until October 2014 (could require an upgrade)
X-ICP20		SwissFEL building /G. Janzi	Space availability in tunnel for components, contact with general contractor
X-ICP30		Transport concept/ J. Wickström	Space availability. Transport of LH girders.

Table 1: external interfaces not described in this document

1.5 Risks

ID	Risks known / may be happen	Measures to prevent	Consequences if not realized
1.	Interfacing with STFC	Review meetings /STFC-PSI	Mechanical conflicts, specs not reached, inadequate control interfaces
2.	Collaboration with UU refused	Final proposal for the Swedish government submitted / UU. Strategy and resource definition if the proposal is refused	PSI realizes the project internally. Dedictated resources required. Risk of delays.
3.	Collaboration with UU interfacing	Review meetings	Mechanical conflicts, spec. not reached, inadequate control interface
4.	Injury caused by laser class 4	In-vacuum transfer line Protection box on the optical table	Eye injuries
5.	Vibration of optical components	Avoid mechanical pump on the in-vacuum transfer lines. Adeguate design of support systems (FE analysis) Verification of cooling scheme of the AFL dipoles Water cooled QFA quads replaced by air cooled QFD quads	Insufficient transverse overlap stability. Fluctuation of FEL emission
6.			

Table 2: List of known risks

2 System description

2.1 Lattice

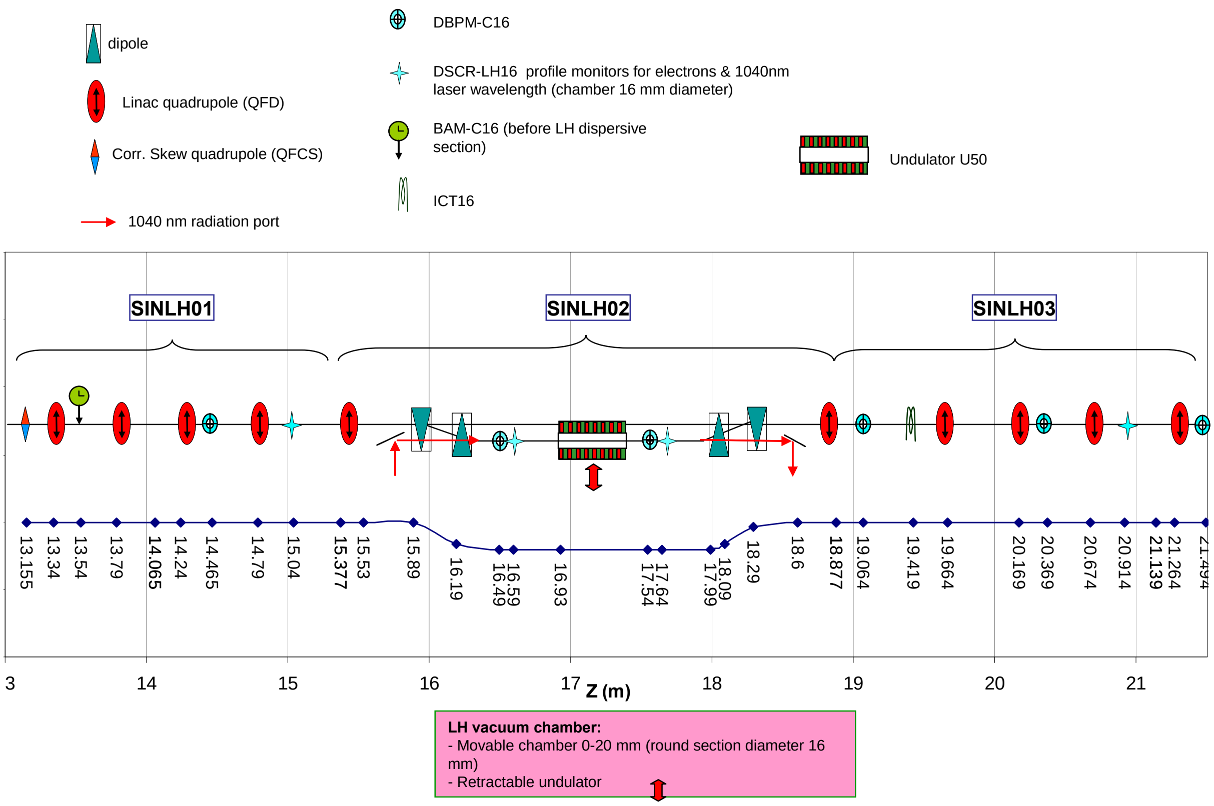

Figure 2: Schematic layout of the laser heater system

The SwissFEL LH consists in three functional sections defining the physical boundaries of this project and namely a matching section (SINLH1), the interaction region wit the magnetic chicane (SINLH2) and a matching section for the S-band booster linac (SINLH3). The lattice version 11 (proto “heilige Liste” version 11), presently being revised, is the source for the schematic layout on figure 2. In this figure, we anticipated the use of QFD quadrupoles instead of QFA and we removed the four stand alone SFC steerer magnets since replaced by four sets of steerer coils implemented in the QFD quadrupoles. In the next lattice version, the final position of the components will be updated. The position of the “connected” QFD steerers is not yet defined. Figure 3 represents a draft 2D model of the laser heater section. The quadrupoles are QFD magnets. The BPM and screen are already the 16 mm version (DSCR-LH16 and DBPM-C16).

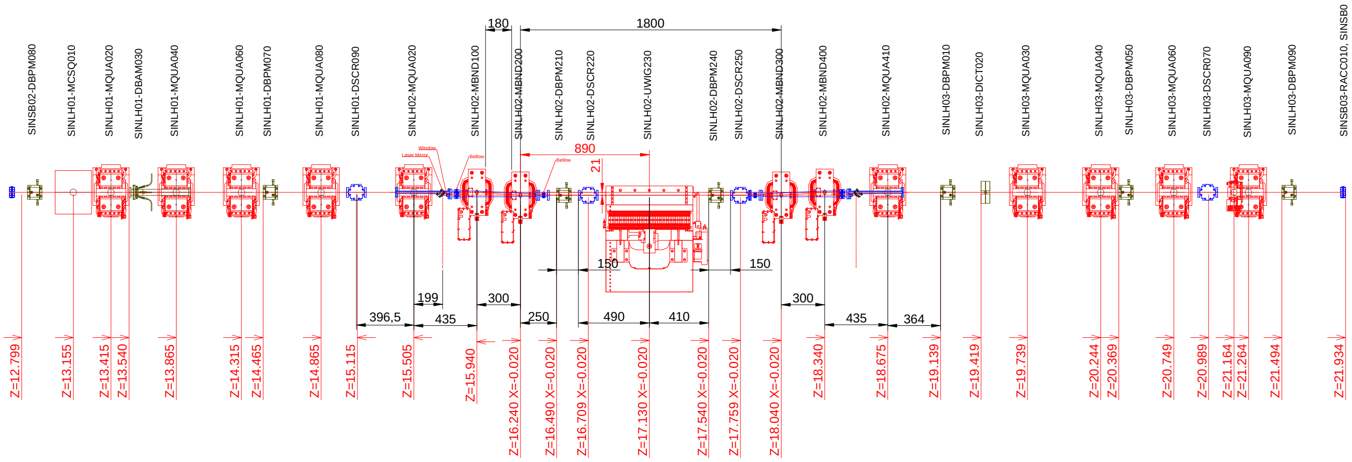

Figure 3: 2D draft layout of the laser heater section

Table 3 gives an overview of the component list for the LH section. The table shows the components as listed in the proto “heilige Liste” version 11 with some field marked in read anticipating corrections mentioned here above for the new version. The major modification in the next release will be the reduction of the vacuum chamber diameter from 38 mm to 16 mm all along the injector, beside for the first few meters after the RF-gun and the bunch compressor region (refer to the DCR-32 [7]). In particular the QFD quadrupoles replace the QFA ones and the 16 mm standard of the diagnostic components replaces the 38 mm standard. The position of the elements in the table is only indicative and subject to modifications.

Section	s [m]	z [m]	L [m]	Group	Type	Tag	Baugruppe
SINLH01	13.34	13.34	0.15	Magnets	Quadrupole	MQUA	QFD
SINLH01	13.54	13.54	0.2	Diagnostic	Beam Arrival Monitor	DBAM	DBAM-PS16
SINLH01	13.79	13.79	0.15	Magnets	Quadrupole	MQUA	QFD
~~SINLH01~~	~~14.065~~	~~14.065~~	~~0.05~~	~~Magnets~~	~~Hor. Corrector~~	~~MCRX~~	~~SFC~~
~~SINLH01~~	~~14.065~~	~~14.065~~	~~0.05~~	~~Magnets~~	~~Ver. Corrector~~	~~MCRY~~	~~SFC~~
SINLH01	14.24	14.24	0.15	Magnets	Quadrupole	MQUA	QFD
SINLH01	14.465	14.465	0.255	Diagnostic	BPM	DBPM	DBPM-C16
SINLH01	14.79	14.79	0.15	Magnets	Quadrupole	MQUA	QFD
SINLH01	15.04	15.04	0.15	Diagnostic	Profile Monitor	DSCR	DSCR-LH16
~~SINLH02~~	~~15.365~~	~~15.365~~	~~0.074~~	~~Magnets~~	~~Hor. Corrector~~	~~MCRX~~	~~SFC~~
~~SINLH02~~	~~15.365~~	~~15.365~~	~~0.074~~	~~Magnets~~	~~Ver. Corrector~~	~~MCRY~~	~~SFC~~
SINLH02	15.53	15.53	0.15	Magnets	Quadrupole	MQUA	QFD
SINLH02	15.89	15.89	0.1	Magnets	Dipole	MBND	AFL
SINLH02	16.190519	16.19	0.1	Magnets	Dipole	MBND	AFL
SINLH02	16.440594	16.44	0.15	Diagnostic	BPM	DBPM	DBPM-C16
SINLH02	16.590594	16.59	0.15	Diagnostic	Profile Monitor	DSCR	DSCR-LH16
SINLH02	16.930594	16.93	0.4	ID	Undulator	UWIG	U50
SINLH02	17.540594	17.54	0.15	Diagnostic	BPM	DBPM	DBPM-C16
SINLH02	17.690594	17.69	0.15	Diagnostic	Profile Monitor	DSCR	DSCR-LH16
SINLH02	17.990594	17.99	0.1	Magnets	Dipole	MBND	AFL
SINLH02	18.090668	18.09	0.1	Diagnostic	Synch. Radiation Port	DSRP	LSRM
SINLH02	18.291113	18.29	0.1	Magnets	Dipole	MBND	AFL
SINLH02	18.601187	18.6	0.15	Magnets	Quadrupole	MQUA	QFD
~~SINLH02~~	~~18.866187~~	~~18.865~~	~~0.074~~	~~Magnets~~	~~Hor. Corrector~~	~~MCRX~~	~~SFC~~
~~SINLH02~~	~~18.866187~~	~~18.865~~	~~0.074~~	~~Magnets~~	~~Ver. Corrector~~	~~MCRY~~	~~SFC~~
SINLH03	19.065187	19.064	0.255	Diagnostic	BPM	DBPM	DBPM-C16
SINLH03	19.420187	19.419	0.04	Diagnostic	ICT	DICT	DICT-16
SINLH03	19.665187	19.664	0.15	Magnets	Quadrupole	MQUA	QFD
SINLH03	20.170187	20.169	0.15	Magnets	Quadrupole	MQUA	QFD
SINLH03	20.370187	20.369	0.255	Diagnostic	BPM	DBPM	DBPM-C16
SINLH03	20.675187	20.674	0.15	Magnets	Quadrupole	MQUA	QFD
SINLH03	20.915187	20.914	0.15	Diagnostic	Profile Monitor	DSCR	DSCR-LH16
~~SINLH03~~	~~21.140187~~	~~21.139~~	~~0.05~~	~~Magnets~~	~~Hor. Corrector~~	~~MCRX~~	~~SFC~~
~~SINLH03~~	~~21.140187~~	~~21.139~~	~~0.05~~	~~Magnets~~	~~Ver. Corrector~~	~~MCRY~~	~~SFC~~
SINLH03	21.265187	21.264	0.15	Magnets	Quadrupole	MQUA	QFD

Table 3: Laser heater component list extracted from the proto heilige Liste version 11. This list is presently in the revision phase. In read already some correction with respect to version 11.

Table 4 describes the technical requirements for the LH chicane. For this section, we do not expect significant changes after completing the revision of the accelerator lattice.

AFL Dipole joke length L1 (coils excluded)	120 mm
Dipole 1-2 & 3-4 z separation L2 (exit-entrance)	180 mm
Dipole 2-3 separation L3 (exit-entrance)	1680 mm
Nominal bending angle θ	**3.82 deg**
Nominal transverse offset of central dipoles	**20 mm**
Nominal Beam Energy	**130 MeV**
Nominal R_{56}	**xx mm**
Minimum / Maximum Beam energy (reserve)	**120 / 140 MeV**
Chicane required bending angle range (with mechanical margin)	**-0.2 ↔ 4 deg**
Chicane required range for transverse off axis movement	**-1 ↔ 21 mm**
Required integrated B field AFL dipoles (max. angle & max. energy)	**0.033 T/m**
Required current AFL dipoles (max. angle & max. energy)	**38 A**

Table 4: Technical requirements of the Laser Heater chicane.

2.2 Laser & electron beam – summary basic specifications

Table 5 summarizes the main specification of electron beam and laser at the interaction point, namely the center of the undulator. This paragraph is particularly important because giving the essential parameters for the design of the undulator modulator, the laser optics and the photon & electron diagnostics. The laser heater is compatible with both high and low charge operation modes of SwissFEL. To allow some flexibility for the overall optimization the LH system must be compatible with a 20 MeV operational window around the nominal energy of the electron beam.

Electron beam		
Charge operation mode	10 pC	200 pC
Beta function at undulator center X / Y	40 / 35 m	40 / 35 m
Beam size rms X/Y	285 µm (0.5 mm.mrad)	156 µm (0.15 mm.mrad)
Pulse length (flat top/rms)	10 / 3 ps	3.4 / 1 ps
Chicane dispersion	20 mm?	
Nominal energy	130 MeV	
Energy range Min / Max	120 /140 MeV (115/135 MeV?)	
Energy for velocity bunching option (LH off)	*80 / 100 MeV*	
Arrival time jitter at U50 (if gun laser synchro. OK)	< 40-50 fs	
Laser		
# of pulses per cycle	2	
Pulse separation	28 ns	
Wavelength	1040 nm (260 nm UV)?	

Min. Energy at LH	100 μJ/pulse
Laser amplitude jitter	<5%
Pulse length FWHM (Gaussian)	50 ps
Waist at Focus	400 μm
Laser power at waist (overlap power)	20 kW
Range coarse longitudinal adjustment	1 ns
Range longitudinal adjustment for fine regulation	+/- 100 ps
Range transverse adjustment	+/- 2 mm
Overlap tolerable jitter	
Laser pointing jitter @ undulator center X/Y	+/- 10 μm (worse case)
Laser longitudinal @ undulator center jitter	+/- 2 ps

Table 5: Main parameter of the electron and laser system at the interaction point

2.3 Building and environmental conditions

The undulator of the laser heater stands in the initial section of the SwissFEL tunnel, approximately 17 m away from the RF photo-injector. Figure 4 shows the architecture of the SwisFEL tunnel in the injector section. The laser source for the gun and the laser heater sits in a dedicated room beside the tunnel and adjacent to the Timing & Synchronization room. An independent air-conditioning system, specified for clean room class ISO 7 and deserving both rooms, sits in a technical room together with some infrastructure for timing and synchronization. The control racks and the infrastructure dedicated to the laser systems have as well a dedicated room. A system of floor channels, 600 mm wide and 200 mm deep, allows the cabling between and within the different rooms.

The air conditioning of the accelerator tunnel starts in the experimental hall where the fresh air circulates before injection in the tunnel. A series of re-circulating stations, distributed all along the tunnel, guarantee the temperature stabilization and a global flow from the experimental hall down to the injector where the exhaust air is balanced. It is not foreseen to have an active control of the absolute air pressure and humidity along the SwissFEL tunnel. Table 6 summarizes the environmental conditions.

Laser + T&S room – Air temperature	21 °C	+/- 0.1 °C
Laser + T&S room – Air pressure	-	Follows external conditions
Laser + T&S room – Air humidity	40-45%	+/- 0.2 %
Tunnel - Air Temperature	24 °C	+/- 0.1 °C
Tunnel - Air pressure (not controlled)	-	Follows external conditions
Tunnel - Air humidity (not controlled)	30-60%	Follows external conditions

Table 6: Expected environmental conditions in the laser room and in the accelerator tunnel

The laser components in the tunnel will be mounted on optical table and protected via closed boxes (see paragraph 4.1). The stability of the environmental parameters around the laser lines is extremely important for minimizing drifts of the photo-cathode laser. For this reason, we foresee using the air conditioning system of the laser room to stabilize the atmosphere of the laser protection box. Although less sensitive to thermal drifts, one could foresee a similar air circulation scheme for the LH protection boxes.

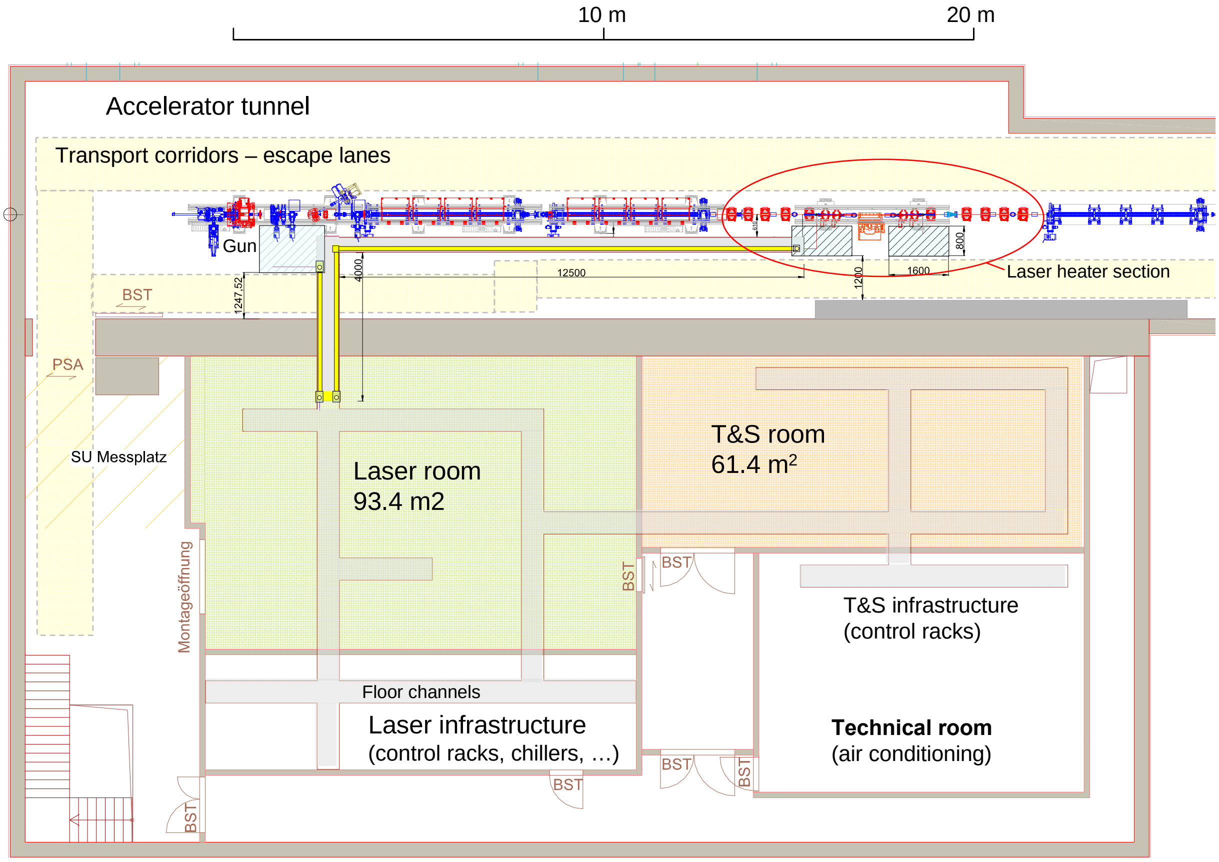

Figure 4: Underground tunnel situation in the first 25 m of the SwissFEL injector

Specifying the optical table for the laser components in the tunnel we must consider the constraints imposed by the transport and escape lines. On the left hand of the accelerator sits the main transport corridor used for the installation of the pre-assembled girders. Here we have to guarantee at least a 1.4 m wide corridor. Most of the infrastructure for the laser heater sits on the right of the accelerator line. In this area, the corridor is minimum 1.2 m wide. Since the injector tunnel has a comfortable cross section, we do not expect major constraints for the dimensioning and positioning of the optical tables. The main constrains come from a space reservation for a 500 mm thick reinforcement of the radiation shielding toward the T&S room near the LH section. If required, this shield will be realized with movable stones.

3 Beam dynamics of LH

3.1 Optics

The beam parameters in BC1 reported here below corresponds to the optic design in the SwissFEL DCR.

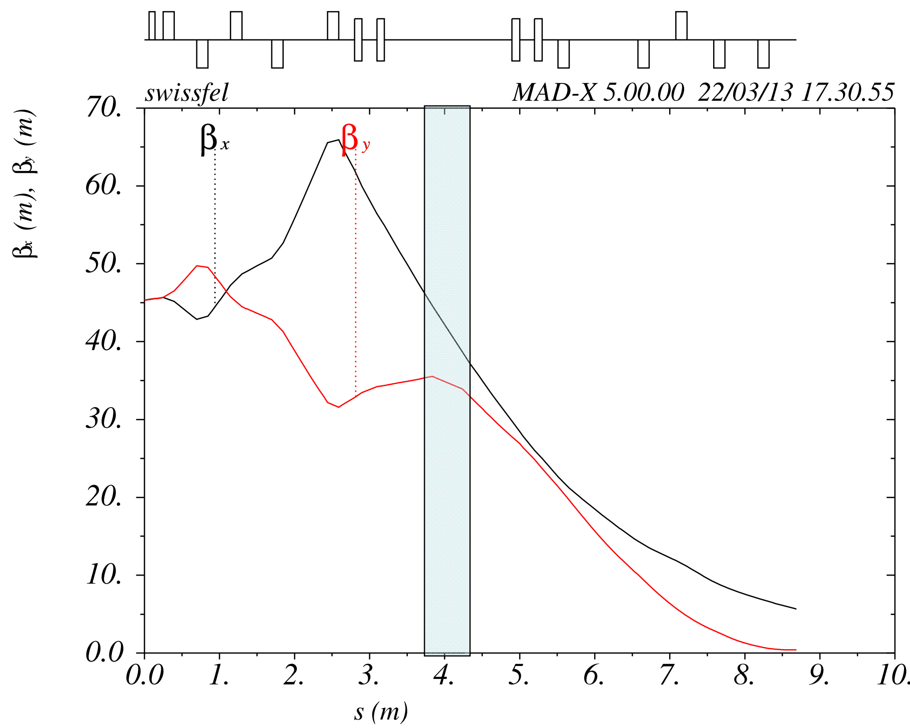

Figure 5: Optical functions and rms beam size along the bunch compressor in SwissFEL (normalized emittance 0.5, beam energy 330 MeV, energy chirp 1.4 %). Z=0 correspond to the beginning of the first dipole. Beam size from the optic functions simulated with elegant according to $\sigma_{x,y} = \sqrt{\varepsilon_{x,y}\beta_{x,y} + (D_{x,y}\sigma_E)^2}$

3.2 LH Components tolerances

The tolerances summarized in Table 7 are exctracted from the reference where the basic guideline criteria driving the tolerances are briefly described. Some parameters are uncritical and can be easily fulfilled (e.g. alignment of dipoles). For these parameters a reasonable upper limit has been imposed. The tolerances of BC2 are here reported as complement of information.

Parameter	Unit	static	Dynamic
Dipole Current Stability (rms)	ΔI/I		5e-5
Dipole to Dipole Field Deviation (rms)	ΔB/B	1e-4	
Dipole Good Field Region (FW)	mm	>5 mm	-
Dipole Multipole – Quad k_1 (max.)	1/m^2	X20 BC1	
Dipole Multipole – Sextupole k_2 (max.)	1/m^3		
Dipole Multipole – Dekapol k_4 (max.)	1/m^5		
Dipole Alignment in x and y (rms)	micron	500*	
Dipole Alignment in z (rms)	micron	500*	
Dipole Roll Angle (rms)	mrad	0.05*	
Dipole Yaw Angle (rms)	mrad	1*	

Dipole Pitch Angle (rms)	mrad	0.2*	
Quadrupole QFD Strength (130 MeV)	k_1L (1/m)		
Corr. Quad. Max. Strength (130 MeV)	k_1L (1/m)		
Corr. Quad trans. Alignment (rms)	micron	50*	0.2
Corr. Quad long. Alignment (rms)	micron	1000*	0.2
Corr. Quad Roll Angle (rms)	mrad		
Corr. Quad Yaw + Pitch Angl (rms)	mrad		
BPM transverse alignment (rms)	micron	12	0.3
BPM longitudinal alignment (rms)	micron	1000	0.3
BPM Resolution minimum requirements (rms)	micron	3	
BPM energy resolution @ nominal angle (rms)	relative	<0.0001	
BPM Re-Positioning Tolerance	micron	2*	
BPM transverse position jitter (rms)	micron	0.5*	
Undulator horiz. alignment (operating position)	micron	<100	5
Undulator vert. alignment (operating position)	micron	<10	1
Undulator gap opening precision	micron	<10	1
Undulator magnet arrays parallelism			
Undulator longitudinal alignment	micron	1000	10

Table 7: Tolerance table for the LH components. *Please refer to [9] for actual values.

3.3 Axis definitions

The axes illustrate in Figure 6 are defined according to the SwissFEL conventions. For more details see the reference [10].

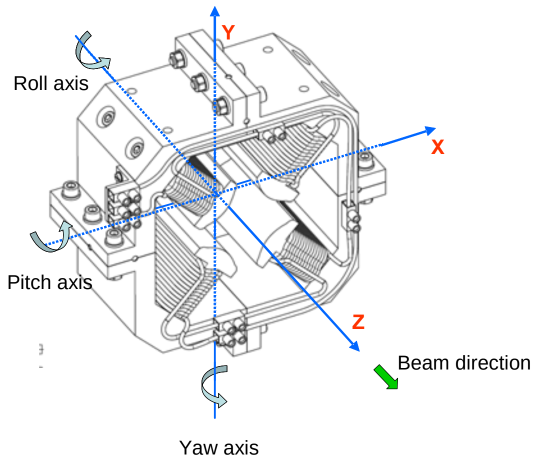

Figure 6: Axis and angle definitions

4 Design guide lines

4.1 Laser systems

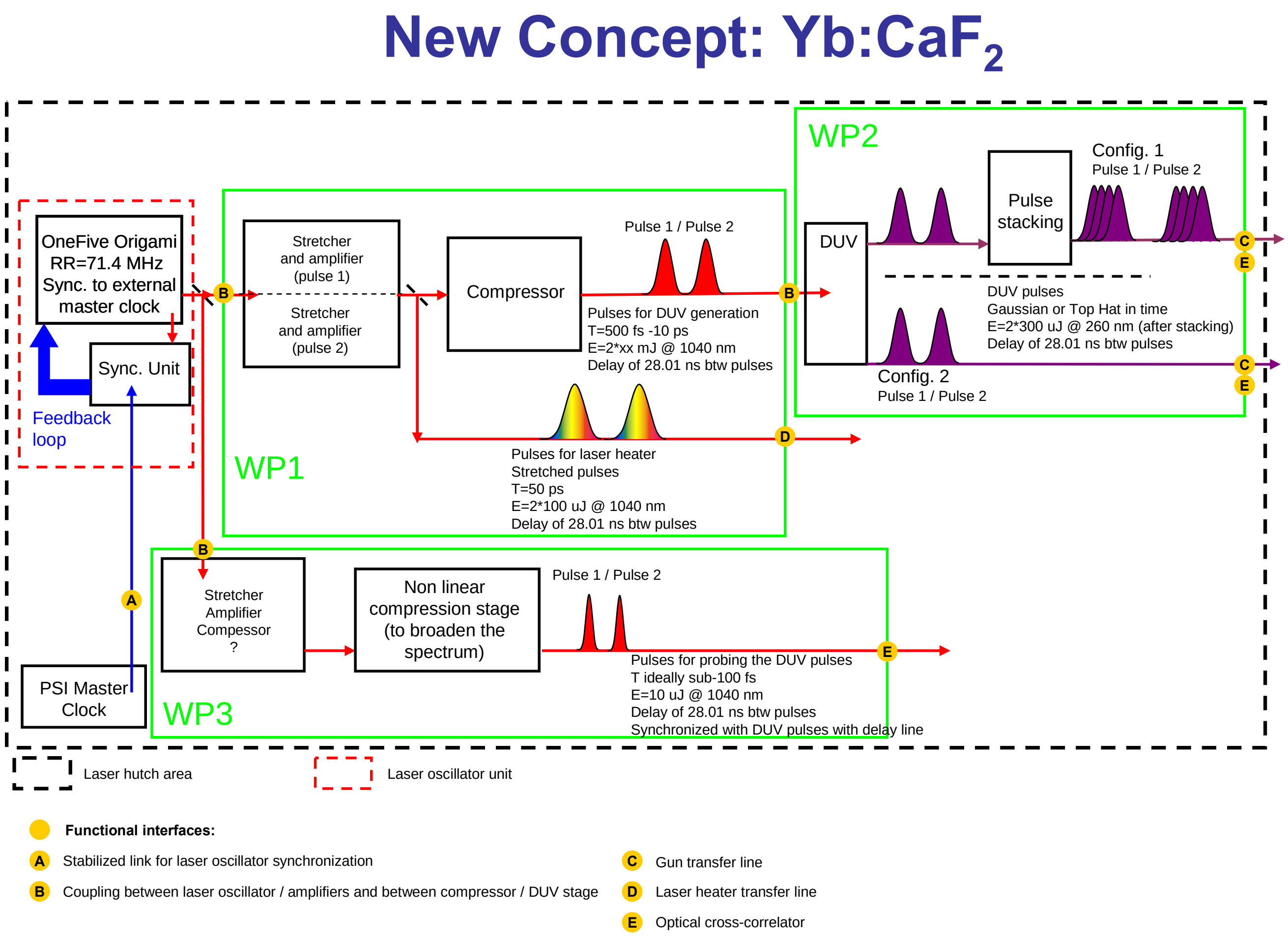

Figure 7: One concept for the new SwissFEL gun laser system, alternative to a Ti-Saph system (courtesy A. Trisorio)

The Infrared impulses for the laser heater system derive from the main laser system of the gun laser. Reference [11] describes the “to-date” specification for this system, the final parameters are still under discussion. Extracted from this document, Figure 7 shows a laser concept presently under investigation as alternative to a Ti-Saph system. The advantage of the proposed approach, with respect to two independent laser sources for photo-cathode and LH, is the easier phase locking between laser impulses for gun and LH.

The detailed amplification scheme for the LH impulses must be adapted to the requirements described in Table 5. In particular, the stability of transverse and longitudinal overlap requires enough energy reserve (laser waist versus electron beam size and laser pulse length).

Figure 8 shows the preliminary integration concept for the laser transfer lines (TL) and optical tables in the tunnel. The preferred scheme foresees two independent in-vacuum TL for UV (gun) and IR (LH). The TL between laser room and LH will be approximately 20 m long. To avoid interference with transport and escape lanes, both transfer line will sit in floor channels. The first floor channel section perpendicular to the accelerator axis has the standard cross section: 600 mm wide x 200 mm deep. The section parallel to the beam line has a smaller cross section: 400 mm wide x 200 mm deep. The design of the LH transfer line requires a minimum of 5 mirrors and probably half way to the LH a refocusing optic.

To avoid vibration issues we recommend using for both transfer lines UHV CF standards without rotating pumps (primary + turbo pumps).

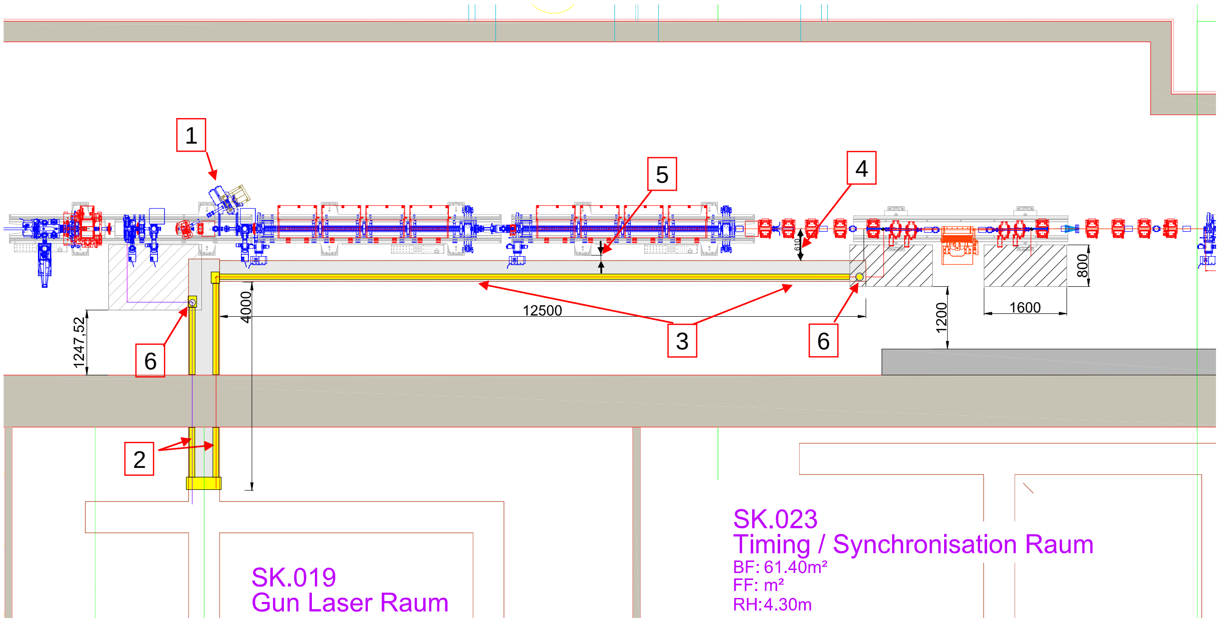

Figure 8: Concept for laser transfer line and optical table in the tunnel. See Table 8 for figure legend.

1	Beam dump relocated to the right side of the beam line
2	Two independent transfer line for UV (gun) and IR (LH) laser. Both line are in vacuum. Recommended standard UHV CF components without rotating pumps.
3	IR TL in a floor channel parallel to the accelerator line (400 mm wide, 200 mm deep and ~12.5 m long).
4	Minimum horizontal distance between floor channel from beam axis 610 mm
5	Minimum distance girder Jacks from floor channel 100 mm
6	Hole in the optical table for the transfer line to be evaluated

Table 8: Legend for Figure 8

The favorite support concept consists in three independent girders, one for each functional section, supporting the accelerator components. Two independent optical tables host the laser optics and photon diagnostics. The size of the optical table compatible with the geometrical constraints is ~1600 mm x 800 mm. A short corridor between the tables, ~1000 mm wide, allows accessing the Undulator modulator for maintenance.

Figure 9 shows schematically the LH interaction region and main diagnose functionalities. A draft 2D model of the chamber and surrounding components is available in Figure 10.

The out-coupling port sits symmetrically downstream the undulator at the same distance. Refer to Table 5 for the electron and laser parameters. The focusing optics and the photon diagnostics will sit on optical tables.

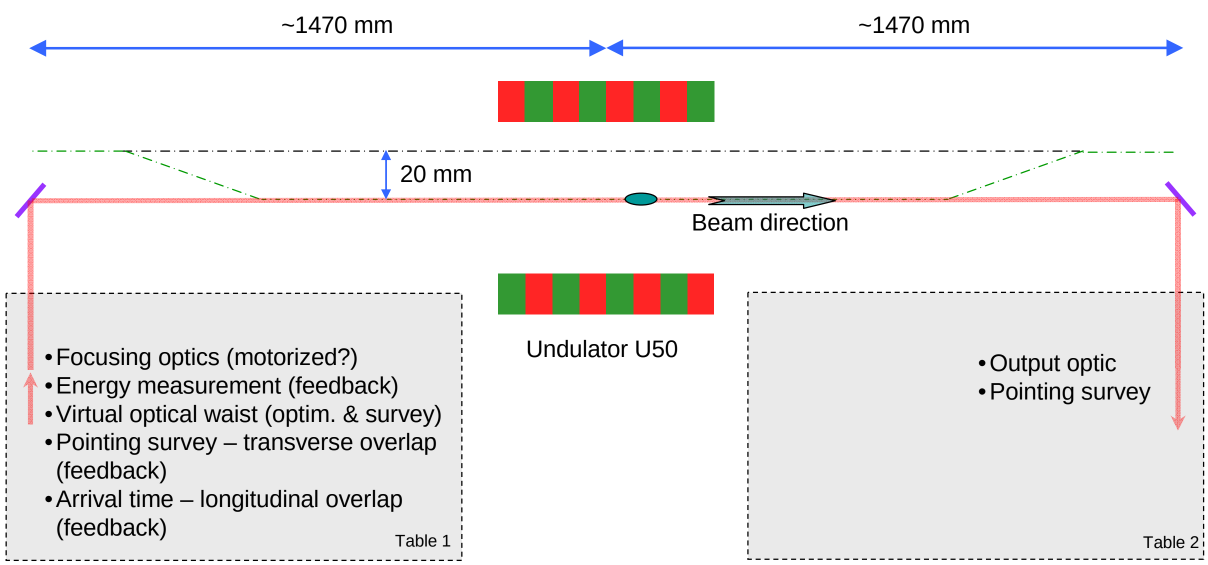

Figure 9: Schematic representation of the LH interaction region and main functionalities.

The photon diagnostics and especially the systems required for setting and maintaining an optimal electron-laser overlap, have a strong correlation with electron diagnostics and the global feedback system of SwissFEL. It is required to measure the laser energy after the transfer line and to provide a signal compatible with the SwissFEL global feed back system. A virtual optical waist must allow optimizing and maintaining the optimal focusing setting.

Table 9 summarizes possible schemes for the overlap diagnostics. The purpose of this table is to start the discussion without excluding alternative methods. Go to Table 5 for jitter requirements on transverse and longitudinal overlap.

Function	**Possible sensors**	**Method, expected resolution**
Longitudinal overlap rough setting	Photo-diode & beam signal (BPM?)	Overlap signals on Fast oscilloscope – resolution ~100 ps
Longitudinal overlap fine	Spectrometer system	Increases of uncorrelated energy dispersion. Resolution <10 ps, (<10 keV)
Longitudinal overlap survey for feedback	BAM + LAM systems	Correlate Beam arrival monitor with laser arrival monitor
Longitudinal overlap rough & fine	EOS	Electro optical sampling with LH laser as sampling reference. Direct measurement. Resolution <10ps
Longitudinal overlap survey for feedback	EOS (+ BAM if needed)	EOS alone should be sufficient. Resolution <<1ps
Transverse overlap settings	Screen monitor	Overlap of laser and electron beam on scintillating crystal. Resolution <10 µm
Transverse overlap survey for feed back	BPM + two camera system	BPM (resolution 3 µm) + inlet and outlet virtual waist monitoring (<10 µm)
Transverse overlap survey for feed back	BPM + 2 “four quadrant” photo-diodes	BPM (resolution 3 µm) + inlet and outlet photon orbit (resolution xx µm)

Table 9: possible schemes for transverse and longitudinal overlap diagnostics

Beam dynamic simulations are required to evaluate precisely the longitudinal bunching process and subsequent smearing out of the charge modulation. If enough modulation is preserved along the third dipole, detection of the coherent synchrotron radiation could be an option for the fine adjustment of the longitudinal overlap. Proposed for FERMI [12] this scheme is not operational, in use for setting the fine longitudinal overlap is the energy spectrometer method.

4.2 Vacuum systems

The PSI vacuum group is in charge and responsible for the concepts, design and procurement of all vacuum components – contact L.Schulz

Beside the chicane chamber, all other vacuum components will be SwissFEL standards.

The vacuum chamber of the LH chicane with the laser in and out-coupling is part of the deliverable within the collaboration framework defined with Uppsala University in Sweden. If the collaboration agreement becomes concrete, we suggest PSI designing and procuring this component as subcontractor of UU. This allowsstarting the design before finalizing the collaboration agreement.

Figure 10 shows the preliminary concept of the chicane chamber (left side of the chicane only).

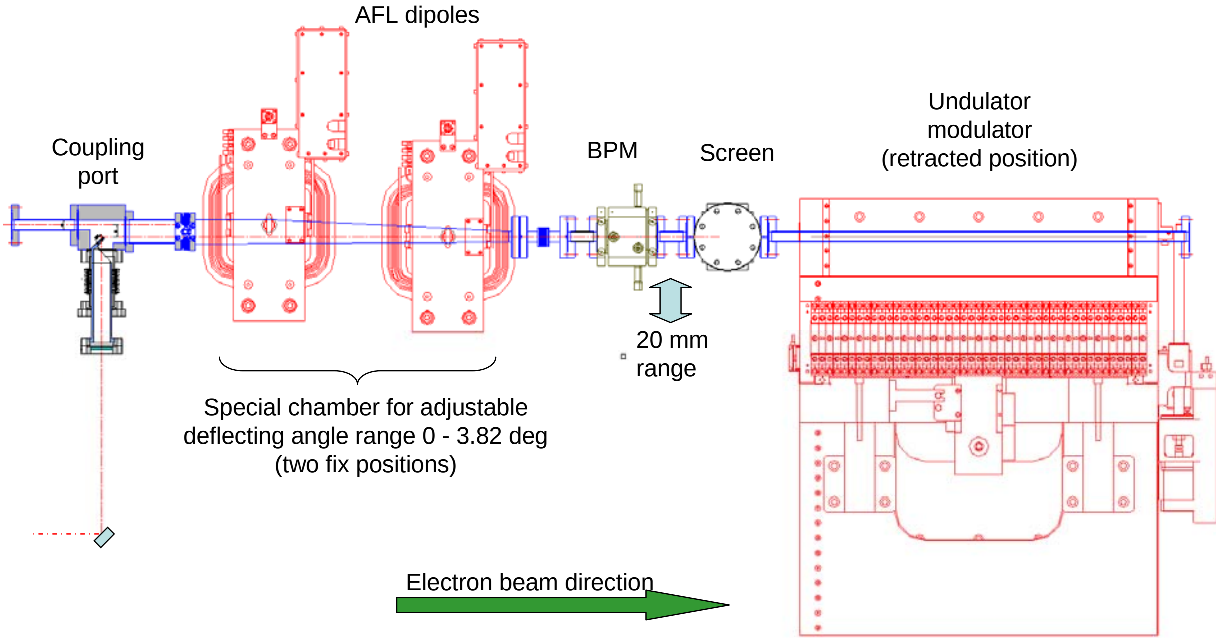

Figure 10: Preliminary concept of the LH chicane vacuum chamber

The chicane must allow operation with straight orbit and 3.82 deg bend angle with off-axis position of 20 mm. Within the chicane, two DBPM-C16 and two standard screens ensure respectively the electron beam orbit survey and the adjustment of the transverse overlap of laser and electrons. Since the central part of vacuum chamber has a diameter of 16 mm to match the diagnostic components, the central part of the chicane chamber has to be movable between two positions: 0 and 3.82 deg.

The space left for the laser in-coupling mirror is limited. Figure 11 shows a possible concept for the laser coupling system. In this proposal, an in-vacuum mirror with 45 deg incidence allows a 90 deg coupling. The geometry and setting of the coupling system are fixe and optimized for the nominal bending angle of 3.82 deg (20 mm off axis orbit).

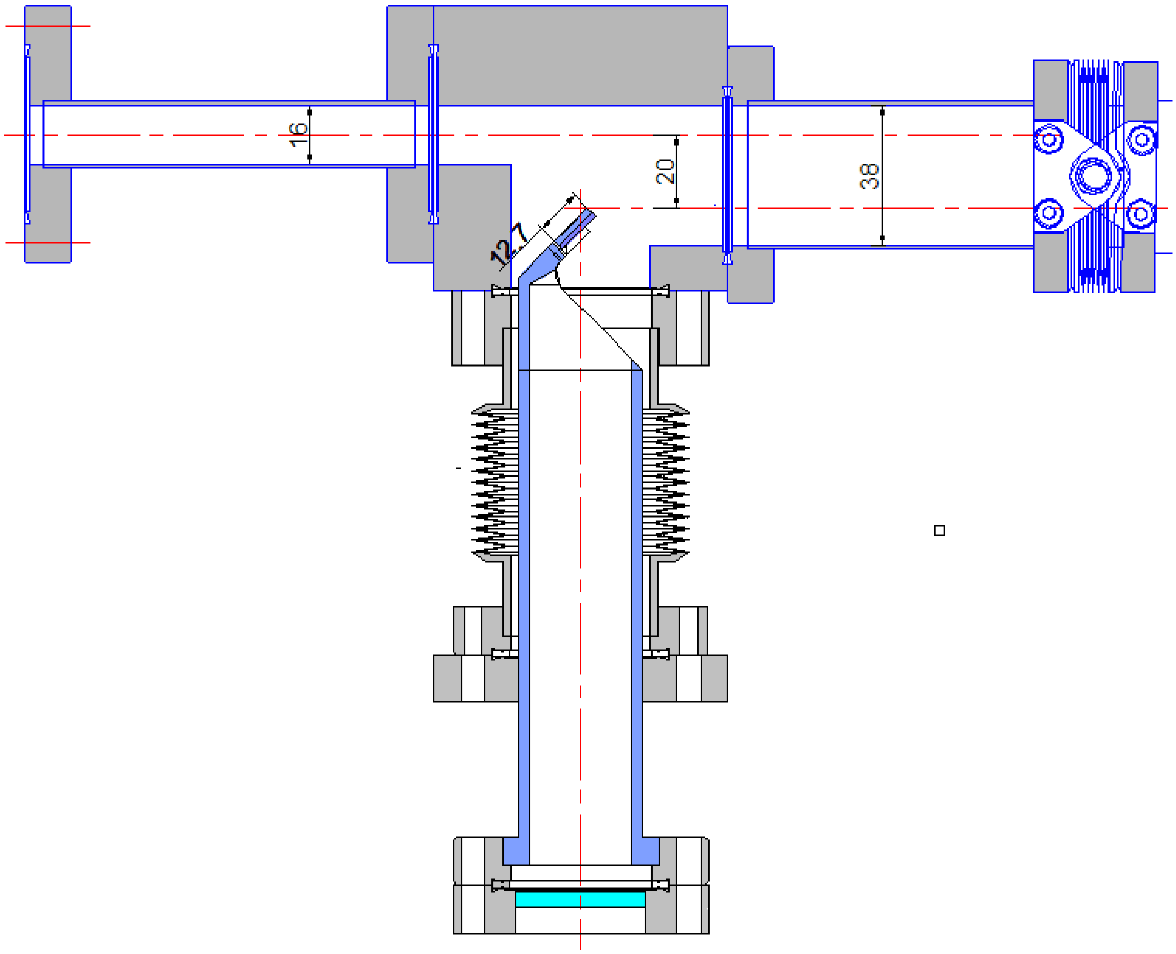

Figure 11: Draft concept for the laser in-coupling mirror. Proposal based on the gun laser coupling system. On this picture, the mirror sits slightly retracted.

4.3 Diagnostics

The detailed concept of the electron diagnostics systems is in the responsibility of the diagnostic section – contact V. Schlott, R. Ischebeck.

To be clarified the concept, interfacing and task distribution for the overlap monitors

4.3.1 BPM

Globally 6 cavity BPM monitors survey the electron beam orbit along the LH section (Figure 3). One BPM station, still in the SINSB02 functional section, sits at the entrance of the LH section. The BPM used in this section are of the type DBPM-C16 with a flange-to-flange length of 150 mm and inner diameter of 16 mm..

Two BMPs, sitting within the LH chicane respectively in front and after the undulator, can additionally allow monitoring the electron beam energy. Those are the relevant monitors, in conjunction with the laser pointing survey, for maintaining the transverse electron-laser overlap. The absolute calibration of the energy can be performed using the energy spectrometer sitting at the end of the injector after the first two accelerating modules of Linac 1 relaxing the requirements on the position reproducibility of the BPMs. The energy resolution depends on the dispersion at the BPM and on the orbit resolution of this component. Table 10 shows the energy resolution of the BPM Assuming the dispersion of the nominal optics (Figure 5).

BPM expected center of mass resolution	Nominal dispersion	Energy resolution
3 μm	20 mm	11.5e-4 (~20 keV)

Table 10: Energy resolution DBPM-C16

To be noted that the BMP stations allow a very precise relative survey of the bunch charges (<0.1% resolution) and therefore are well suited for surveying the global transmission along the chicane.

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BPM station name	Indicative position (m)	Function
SINSB02-DBPM080	*12.8*	*Orbit (feed-back), transmission*
SINLH01-DBPM070	14.5	Orbit (feed-back), transmission
SINLH02-DBPM210	**16.5**	**Energy & Orbit (feed-back), transmission**
SINLH02-DBPM240	**17.5**	**Energy & Orbit (feed-back), transmission**
SINLH03-DBPM010	19.1	Orbit (feed-back), transmission
SINLH03-DBPM050	20.4	Orbit (feed-back), transmission
SINLH03-DBPM090	21.5	Orbit (feed-back), transmission

Table 11: Overview of the BPM functions. In bold the system strongly correlating with the electron-laser overlap survey

4.3.2 Transverse screen monitors

The transverse monitor systems of the laser heater section consist in fours stations primarily equipped with fluorescent screens (type of crystals) or the visualization of the transverse profile and position of the electron beam. The monitors are of the DSCR-LH16 type with a flange-to-flange length of 150 mm and inner chamber diameter of 16 mm. In normal operation mode, the scintillating screens are retracted and an RF shield mitigates the impedance discontinuity due to sudden chamber diameter variations.

One station precedes the LH chicane and allows the adjustment of the optic matching in the chicane section. Two monitors sit within the LH chicane, respectively in front and after the undulator; those play a fundamental role for adjusting the electron-laser transverse overlap. The interface with laser diagnostics is here evident, the detection scheme and measurement procedure must carefully match electron and laser parameters for the overall operating range of the LH.

The last camera sits in front of the S-band booster linac for optic matching purposes.

BPM station name	Indicative position (m)	Function
SINLH01-DSCR090	15	LH optic matching
SINLH02-DSCR220	**16.7**	**Electrons-laser transverse overlap**
SINLH02-DSCR250	**17.7**	**Electrons-laser transverse overlap**
SINLH03-DSCR070	20	SINSB03-SINSB04 optic matching

Table 12: Overview of the screen functions. In bold the system strongly correlating with the electron-laser overlap adjustment procedure.

4.3.3 Beam Arrival Monitor

The high BW RF pickup of the Beam Arrival Monitor (BAM) provides very fast transient signal when excited by the electron bunch. Within an electro optical modulator, this signal mixes with the pulsed optical reference signal of the SwissFEL synchronization system. The intensity of the Reference signal modulate depending on the overlap with the reference signal, allowing measuring the relative arrival time beam-reference with a resolution <10 fs [13].

In the SwissFEL baseline design the first BAM sits in front of the LH section. Once the longitudinal overlap electron-laser in the LH has been achieved, the BAM gives useful information for the overlap survey. To be clarified the final implementation in the overlap feedback system and setting procedures.

4.3.4 Integrated Current Transformer

An integrate Current Transformer (ICT) follows the dispersive section of the LH and provides an absolute measurement of the beam current. The expected absolute precision of the monitor is ~1%.and his functionality, besides monitoring the charge transmission, is to provide a reference for the cross calibration of the charge measurements performed with the BPMs. The flange-to-flange length of this monitor is 100 mm.

4.3.5 Synchrotron radiation monitor

Installing a synchrotron radiation monitor after the third dipole is an open option, although the functionality of such a system is questionable. As mentioned here above, since the energy modulation rapidly smears out longitudinally it is not yet demonstrated if enough charge modulation at the third dipole would allows using synchrotron radiation as overlap monitor. Beam dynamic simulations are ongoing to clarify this aspect.

4.3.6 Electro Optical Sampling

In the SwissFEL Injector Test Facility, the R&D program on Electro Optical Sampling (EOS) aims demonstrating the feasibility and reliability of such a system as pulse length monitor [14]. In the phase 1 of SwisFEL no EOS monitors are foreseen for the moment. Nevertheless, an EOS system using as sampling optical impulse the IR laser used for the laser heater could give a conceptually natural measurement and survey of the electron-laser overlap.

This approach presents a very close interfacing between laser and electron diagnostic experts, who should evaluate together this option.

4.4 Undulator system

STFC in Daresbury is in charge of the design and the procurement of the U50 undulator modulator. The magnetic design and mechanical engineering of the U50 undulator modulator is in an advanced phase and the documents relevant for reviewing the concept (magnetic design and engineering description, construction drawings) are available in the PSI documentation system alfresco:

\\ecm\Alfresco\Projects\SwissFEL\Facility\TP Injector\SwissFEL 6 GeV\2-Laser heater\Undulator U50\2013.01.31-Design_review

The concept matches the specifications discussed at the PSI-STFC bilateral meeting in May 2012 [8] and the additional documentation provided by mail exchanges (girder, magnet keepers, alignment marks, operational range). The magnetic design allows the tunability specifications of Table 5 and already includes the interfacing to the standard SwissFEL girder via a motorized system and alignment concept.

Our colleagues of STFC will present the engineered model at the Kick off meeting, April 26, 2013. A verification of the specifications and interfaces will follow the design presentation.

Some point to be verified:

- Undulator design and tenability with respect to laser wave length (still in discussion) and electron beam energy. In particular, the option of choosing longer wavelength for the photo-cathode could influence the undulator optimization.

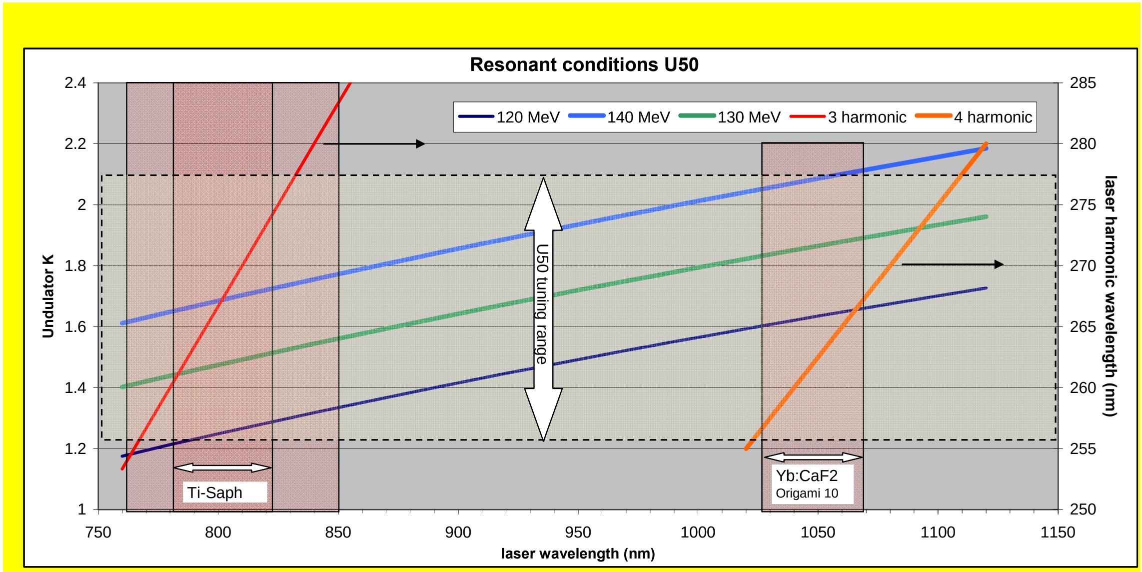
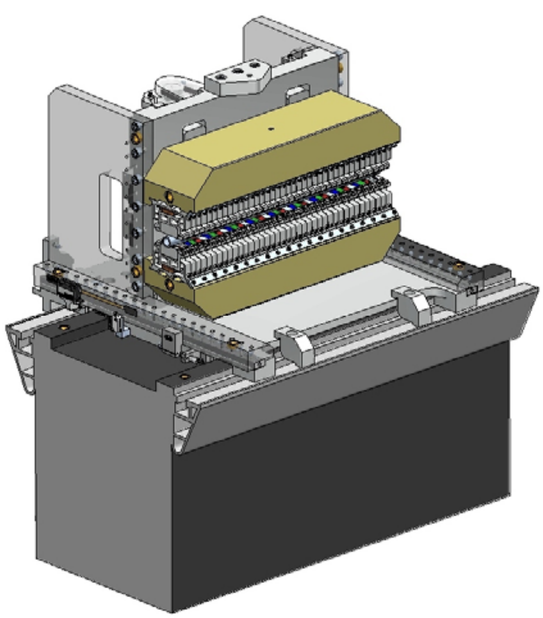


Figure 12: U50 resonant conditions, undulator parameter K versus laser wavelength for 3 different electron beam energies

- Orientation of the undulator on the girder (ideally parking position in same direction as chicane for maximizing the distance magnets-beam axis when U50 parked)
- 5 phase motor system: so far not supported from PSI control group
- Encoder “Renishaw RGH 41” for gap position: interfacing OK since using RS-422. Magnetic actuators as reference mark and radiation compatibility? Absolute encoder strongly preferred.
- Magnet keeper: wedge system for magnet block adjustment grips when not enough greased (U15 experience PSI ID group)
- Possible interference between U50 fixation and movable chicane system.
- Materials: magnetic permeability of support structures
- Functional test of movable parts (where, who?)
- Magnetic measurements and tuning (where, who)



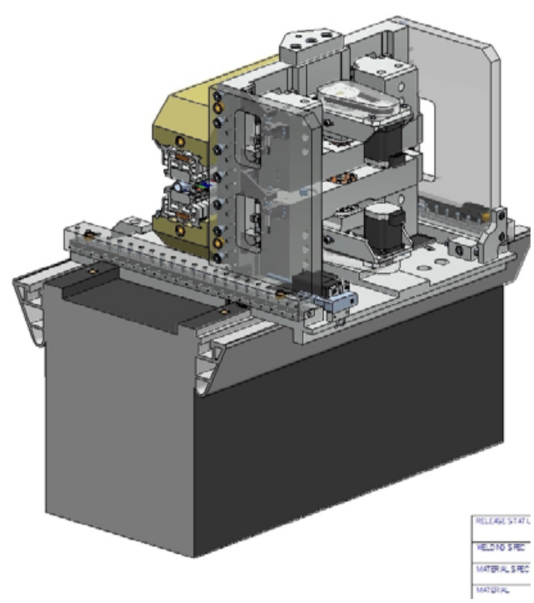


Figure 13: 3D model of the U50 undulator modulator mounted on a standard SwissFEL girder (courtesy Barry Fell, STFC) .

Contac persons at STFC:

Neil Thompson (neil.thompson@stfc.ac.uk): Coordination, magnetic design

Berry Fell (barry.fell@stfc.ac.uk): Mechanical engineering

4.5 Support system

The detailed concept and design is in the responsible of the construction section from AMI – contact H. Joehri.

4.5.1 Girders

As shown on Figure 8, the preferred approach for the support system of the LH section consists on three separate granite girders for the accelerator components and two optical tables for laser components and diagnostics.

For the three granite girders, it is recommended keeping the SwissFEL standard while adjusting the length of each unit. Figure 14 shows the typical girder concept of SwissFEL. The beam line components sit on precise reference surfaces (rails) with specified positioning accuracy over the entire length of 50 μm. Two aluminum rails allow fixing the beam line components to the girder after completing by shimming the alignment process. For SwissFEL the girders are pre-assembled and pre-aligned before being transported to the tunnel.

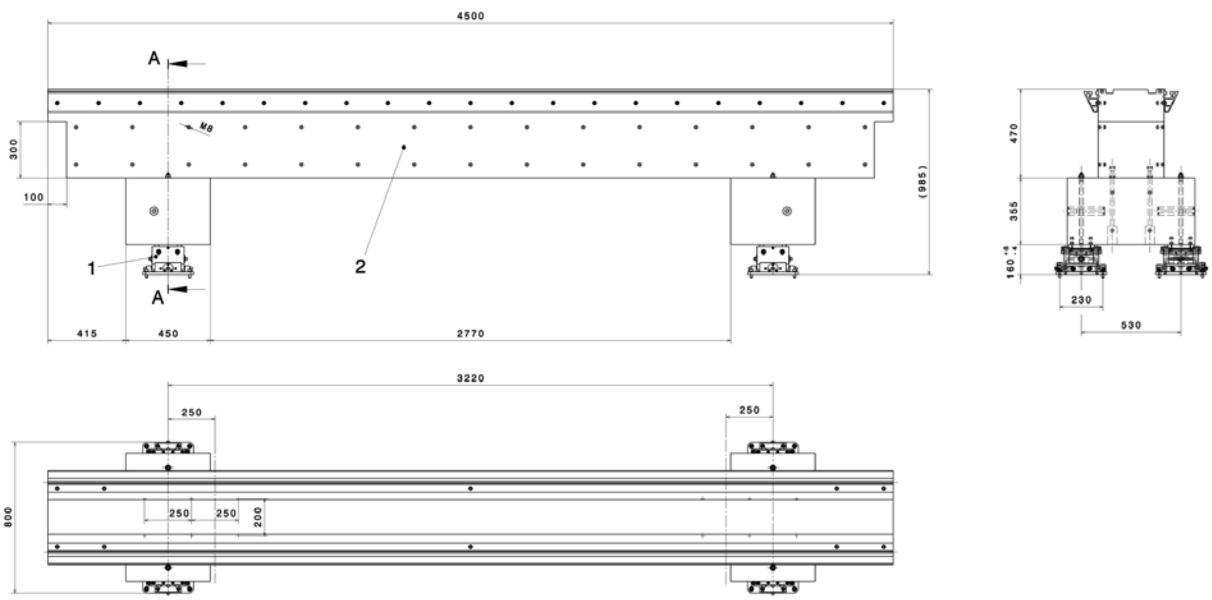


Figure 14: Granite Girder assembly in SITF (extracted from drawing 50023.21.008A)

All Girders stand centered with respect to the accelerator axis. This means that most of the LH chicane components and in particular the undulator do not sit in the center of the girder during nominal operation. The parking (retracted) position of the undulator is the extreme case requiring a verification of the stability criteria.

4.5.2 Component supports

The standard components of the beam line will sit on the respective standard supports.

The support for the AFL dipoles must allow assembling the magnets on axis and 20 mm out of axis. The position of the **dipole is not** motorized.

Beside the undulator system, the chicane chamber with the relative diagnostic elements sits on a movable support system allowing a straight orbit of the electrons and with 20 mm of axis. The positioning tolerances (Table 7) are defined for two operational points and namely for a bending angle of 0 and 3.82 deg.

The mover systems must guaranteed a precise repositioning of the BPM after each movement in order to preserve the transverse overlap calibration. The tolerance for the re-positioning reproducibility of the BPM after a movement of the support is **<10 μm.**

The fixation of the in and out-coupling mirrors with the respective chambers must be rigid enough to avoid drift and/or tilt of the in-vacuum mirror, due to the transverse movement of the chamber, which could deteriorate the transverse overlap conditions.

The BAM electronics is sensitive to radiation damages and require sufficient shielding. The idea is integrate the shielding concept within the support design knowing that the tolerable maximum cable length between pickup and electronic is ~30 cm.

4.5.3 Motor and Encoder systems of the chicane components

The motor(s) specifications meet the system load and the requirements for the positioning tolerances. A functional test and verification of the system performance are required before installation in the SwissFEL tunnel.

At the location of both BPMs a linear absolute encoder will be used to determine the absolute of the BPM allowing a repositioning tolerance within <10μm.

Pierfranco Valitutti centralizes and coordinates the SwissFEL design requirements for motor and encoder systems. During the design phase, he delivers indications on control interfacing requirements of supported systems fulfilling the specifications and/or suggestions on best alternative. The list of recommended and supported systems can be found in [15].

4.6 Magnets

The magnet design, procurement and characterization are in the responsibility of the magnet section. For dipoles, quadrupoles, skew-quadrupoles and sextupoles field maps must be experimentally measured and a cycling procedure defined. – contact M. Negrazus

4.6.1 Quadrupoles

The QFD quadrupole magnet used in the LH sections are standard components used all along the SwissFEL accelerator facility (drawing 50023.41.001). The skew quadrupole is a component presently in operation at the SwissFEL injector Test Facility. Table 13 describe the parameters of both QFD and QFCs (drawing 50022.41.152 XX) magnets.

Parameter	**QFD**	**QFCS**
Max current in (A)	10	10
Max Gradient (T/m)	21	0.5
~effective length (mm)	163	80
~strength steerer magnet (Tm)	xx	-
~effective length steerer (mm)	190	-
Length Joke (mm)	150	80

Max K_1 at 120 MeV (m^-2)	53.9	1.23
Max K_1 at 130 MeV (m^-2)	49.7	1.14
Max K_1 at 140 MeV (m^-2)	42.6	1.06

Table 13: Quadrupole and skew quadrupole parameters

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4.6.2 AFL Dipoles

Table 14 summarize the main parameters of the AFL dipoles. The reference drawing for this magnet is 50023.41.177B.

Parameter	**AFL**
Max current in (A)	75
Max current at LH, pws limited (A)	50
Required current @140 MeV, 3.82 deg bending (A)	36.2 A
Integrated field @ 50 A (Tm)	0.043
Gap aperture (mm)	20
Joke length (mm)	120

Table 14: AFL dipole parameters

4.7 Controls

A Synoptic view of the laser heater section including all three functional sections must be created. The panel will be used as graphical description of the hardware and for visualizing the system status (magnet currents, chicane angle, position of movable parts, vacuum, BPM read back and laser parameters). The display shows as well the status of transverse and longitudinal overlap. A shortcut redirect the user to the laser control panel and to the LH and chicane setting controls.

Controllable from the chicane panel the positioning of the chicane and of the modulator as well as the magnet settings.

Systems	Object	Controling	Monitoring & displaying	100 Hz synchr.	# of elements
Magnets	Dipole current/voltage	yes	yes	-	1
Magnets	Dipole correctors current/voltage	yes	yes	-s	4
Magnets	Corrector Quadrupole current/voltage	yes	yes	-	4
Magnets	Skew Quadrupole current/voltage	yes	yes	-	1

Mechanics	Chamber motor	yes	yes	-	1
Mechanics	Chamber linear encoder	-	yes	-	2
ID	Undulator translation motor system	-	yes	-	2
ID	Undulator translation linear encoders	yes	yes	-	2
ID	Undulator gap motor system	-	yes	-	2
ID	Undulator gap linear encoders				2
Diagnostics	Screen monitors camera and motor systems	yes	yes	-	4
Diagnostics	Synchrotron Radiation Monitor	yes	yes	Yes	1?
Diagnostics	Alignment laser for SRM			-	?
Diagnostics	BPM read out	-	yes	Yes	6
Diagnostics	BAM read back		Yes	Yes	1
Laser	Motorized coupling laser port	yes	Yes	-	1
Laser	Motorized mirrors	Yes	yes	-	??
Laser	Shutter system	yes	yes	-	??
Laser	Pointing read back system (photo diode/cameras?)				
Laser	Energy measurement read back				
Laser	Virtual cathode read back (same as pointing?)				1
Laser	LAM read back				1

Table 15: list of (possible) interfacing to control system,

4.8 Shielding

Radiation protection contact: A. Fuchs

In the laser heater chicane, the vacuum chamber walls will intercepts a small fraction of the dark current transported from the gun trough the first accelerating stage of the injector (energy acceptance ~30%). The resulting neutron and gamma shower could reduce the lifetime of electronic components installed in the surrounding area (cameras, vacuum gauges, BAM electronics).

The evaluation of dark current transport with the 16 mm chamber and losses is not yet complete.

4.9 Alignment

Alignment group contact: K. Dreyer

Allignment marks according to the SwissFEL specifications [16] must be foreseen on all beam line components and support systems. The exact location must be agreed with the alignment group.

5 Projectmanagement

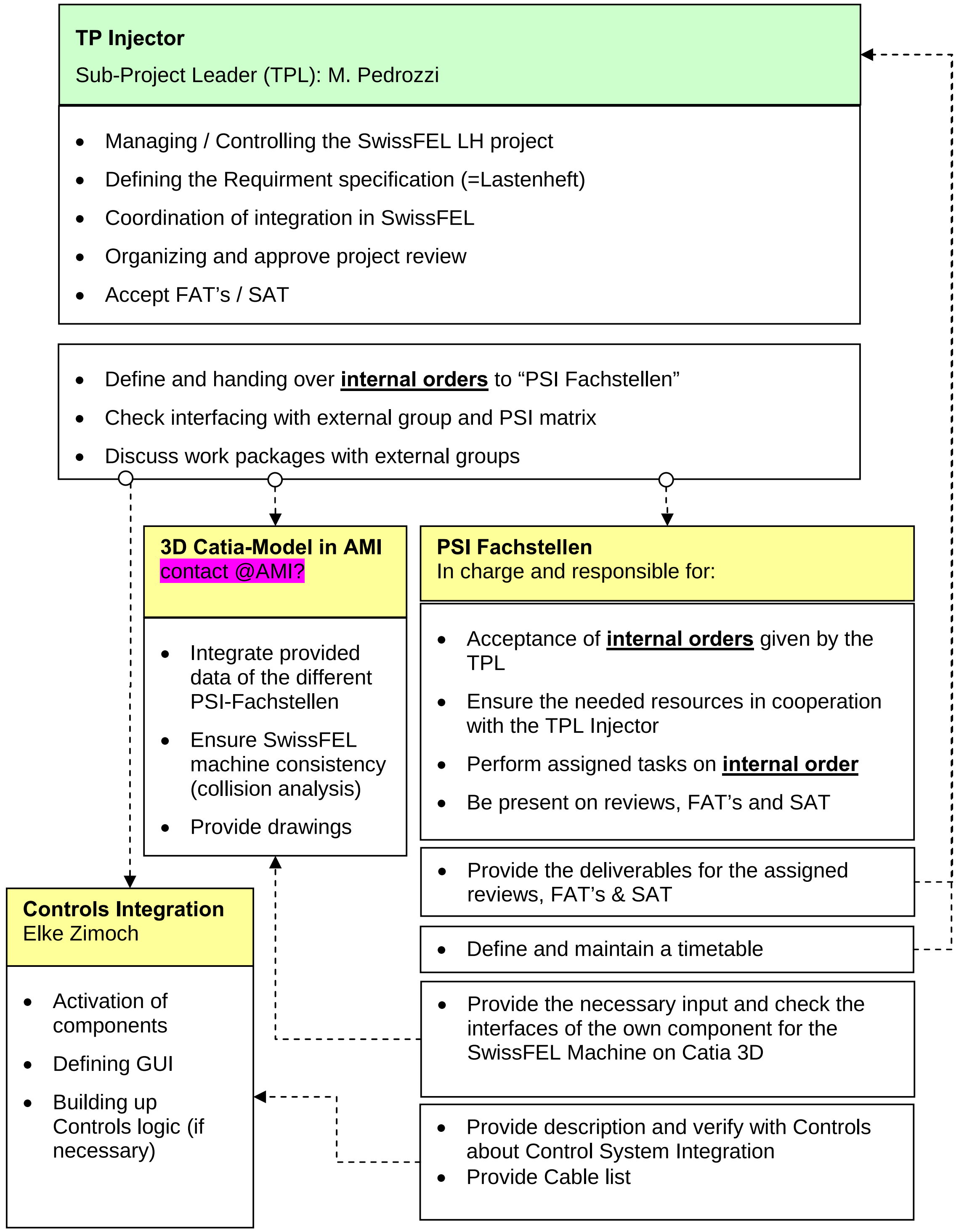
5.1 Projectphases and Milestones

The LH system is handled as a project. The project starts with the collecting of the requirements and is finished with the achieved Milestone Ready for Beam Commissioning in SwissFEL. It consists of the following phases and milestones:

Name of phase	Phase action	Milestone reviews & deliverables
00-Initialization	Determination of requirements: • Function & Technique • Projectmanagement • Risks named	**MS00 - Kickoff-Meeting** • Requirement Specification (Lastenheft)
10-Evaluation	Investigation of solutions • Feasibility study / simulation • Selection of solution • Needed infrastructure for realisation, tests, acceptance • Interfaces defined • Rough planning (Workpackage/Responsability) & Milestones & Budget	MS10 – Evaluation Review • Revised Requirement Specification (Lastenheft)
20-Concept	• Define System specification • 3D Layout & materials • Define realization concept • Detailed task list with milestones • Risk-Anylsis	**MS20 – Concept Review** • System specifications (MUST/WISH) • List of needed infrastructure • Schedule with assigned resources • Long term delivey items defined • Measures to reduce Risks
30-Design	• Manufacturing drawings • Define purchase orders • Define test specifications	**MS30 – Design Review** • Released manufacturing drawings • Released purchase order • Cable list • Manufacturing and Inspection Plan • Assembly and Testspecification (FAT) • Integration concept into SwissFEL • Draft of SAT Spec
40-Realisation	• Manufacure and test the parts • Purchase parts/components • Pre-Assemble parts	**MS41 - Ready for Assembly Review** • Product items, components for BC1 • Released Assembly and Testspec (FAT) • Draft Integration spec into SwissFEL •
	•	**MS42 - SAT of components**
50-Integration	Integrate the BC1 into SwissFEL	MS51 - Ready for Integration into SwissFEL • pre-assembled BC1 components • Released Integration specification
		MS52 - Ready for Acceptance Review (SAT) • Released SAT specification

Name of phase	Phase action	Milestone reviews & deliverables
		• Draft of Commissioning script
60-Operation	Commissioning of BC1	**MS60 - Ready for commissioning with beam** • Achieved SAT • Released Commissioning script

5.2 Intern project organization and responsibilities



5.3 Organization extern collaborations

5.4 Time table BC1

To be done

Table 16: Draft time schedule for the SwissFEL-BC1

5.5 Foreseen SwissFEL resources

5.5.1 Budget Money

The figures are taken from link

No.	Organisation unit	System / tasks	Money [kFr.]	Time period	Status
7.	TP Injector	PM-Tasks, System compatibility & Interface control			included
8.	Beam dynamics	Specification optics and component requirements. HL			excluded
9.	Transport Logistics	Transport and Installation of LH into SwissFEL			partly incl.
10.	SU	Shielding concept			
11.	Vacuum	Vacuum components and local control			
12.	Engineering (AMI)	Design and FEA verifications			
13.	Diagnostic				
14.	Magnet				
15.	Alignment				
16.	Controls		2		
17.	STFC				
18.	UU				

5.5.2 Budget Manpower

No.	Organisation unit	System / tasks	Manpower [Days]	Time period	Status
19.	TP Injector	PM-Tasks, System compatibility & Interface control			included
20.	Beam dynamics	Simulation, proto HL			excluded
21.	Transport Logistics	Transport and Installation of LH into SwissFEL			partly incl.
22.	SU	Shielding concept			
23.	Vacuum	Vacuum components and local control			

24.	Engineering (AMI)	Design and calculation			
25.	Diagnostic	Measurment system and control			
26.	Magnet				
27.	Alignment				
28.	Controls				
29.	STFC				
30.	UU				

6 Annex

6.1 Tests

To be defined here which type of test we requires for components or systems before integration or during pre-assembly. For example for

Motorized systems

Magnetic measurements

Vacuum tests

Component related tests…

6.2 Contact persons

Function	Name	Email
LH project coordination (PSI)	Marco Pedrozzi	Marco.pedrozzi@psi.ch
Quality control	Peter Ming	Peter.ming@psi.ch
Beam dynamics	Sven Reiche	Sven.reiche@psi.ch
Support systems	Haimo Jöhri	Haimo.joehri@psi.ch
Insertion Devices	Thomas Schmidt	Thomas.schmidt@psi.ch
Magnets	Marco Negrazus	Marco.negrazus@psi.ch
Electron diagnostics	Rasmus Ischebeck	Rasmus.ischebeck@psi.ch
Vacuum systems	Lothar Schulz	Lothar.schulz@psi.ch
Control systems	Elke Zimoch	Elke.zimoch@psi.ch
Alignment	Kartsen Dreyer	Karsten.dreyer@psi.ch
Radiation protection	Albert Fuchs	Albert.fuchs@psi.ch
Laser systems (PSI)	Christoph Hauri	Christoph-hauri@psi.ch
Laser systems (UU)	Gergana Angelova Hamberg	gergana.angelova@physics.uu.se
Laser systems (UU)	Mathias Hamberg	mathias.hamberg@physics.uu.se
Laser systems (UU)	Volker Ziemann	volker.ziemann@physics.uu.se
U50 coordination (STFC)	Neil Thompson	neil.thompson@stfc.ac.uk
U50 mechanical engineering (STFC)	Barry Fell	Barry.fell@stfc.ac.uk

[1] R. Carr, et al, inverse free electron laser heater for LCLS, EPAC 2004, Lucerne, Switzerland

[2] Z. Huang,et al, Measurements of the LCLS laser heater and its impact on thex-ray FEL performance, SLAC-PUB-13854

[3] A. Zolenth, Design and commissioning Plan fort he Laser Heater for FERMI@elettra, http://www.escholarship.org/uc/item/57r2b90b

[4] S. Spampinati et al, Diagnostic of the laser heater induced beam heating in FERMI@ELETTRA, Proceedings FEL08

[5] G. Angelova, et al, The XFEL laser heater, Proceedings EPAC08, Genoa, Italy

[6] V. Goryashko, et al, Transverse alignment tolerances fort he EU XFEL Laser Heater, Proceedings IPAC2011, San Sebastián, Spain

[7] M. Pedrozzi, FEL-PM16-052-05

[8] M. Pedrozzi, et al, FEL-PM16-007-02

[9] P. Wiegand, FEL-WP06-010 SwissFEL stability criteria - P. Wiegand

[10] P. Ming, FEL-MP06-371-0_SwissFEL-Strahlhöhe_Koordinatensystem - P. Ming, (available in Alfresco)

[11] A. Trisorio et al, FEL-…

[12] S. Spampinati, et al, Proceedings of FEL08, Gyeongju, Korea

[13] F. Löhl et al, Phys. Rev. Lett. 104, 144801

[14] B. Steffen et al, Proceedings DIPAC09, Basel, Swirtzwerland.

[15] C. Pradervand et al, SwissFEL motor and encoder standards_rev1-1 (available in Alfresco)

[16] K. Dreyer, FEL-DA88-009-04 For more detail see for example (available in Alfresco)